University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2023

The Demon Within: A Case Study Analysis of Post-Concussion Syndrome and its Effects

Jessica Brock
Psychology & Neuroscience
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty advisors: Dr. Patrick Foo, Dr. Kedai Cheng

Abstract

This case study investigates post-concussion syndrome. Post-concussion syndrome (PCS) is defined as a continuation of behaviors and/or causal factors that persist after sustaining a traumatic brain injury for longer than six months. The subject is a 44-year-old female professional in the Southeastern United States who suffered a fall while hiking 2.5 years ago. The initial treatment was performed at a local emergency room where full concussion protocols were not conducted, although patient retrograde amnesia was present. The amnesia only spans the length of time directly after the fall up until a short time after patient analysis. Since diagnoses and prognoses are so individualized, careful case studies like this can serve as a model for improved patient outcomes and help further research on TBIs and their effects.

1. Introduction

A traumatic brain injury (TBI) is the result of trauma to the head, usually a violent force; most commonly, concussions. These are usually the circumstance of an accident caused by a sport or recreational activity[1]. According to the Brain Trauma Foundation, TBIs are a leading cause of death and disability in children and adults ages 1-44.

Additionally, 2.5 million suffer from TBIs each year and 68 million cases worldwide. Approximately 50000 of the 2.5 million cases result in death and 80000 result in disability.

Most of all TBI cases are classified as mild, due to the severity of symptoms. Post-concussion symptoms typically include headaches, fatigue, dizziness/vertigo, sleep deficits, difficulties with memory and attention, and mental health-related manifestation such as depression or anxiety-related issues (Figure 1). The majority of concussion symptoms resolve within two weeks, but some may linger for a month or longer depending on the severity of the injury[2]. However, there are cases where the symptoms continue to persist well after a few months. The persistence of symptoms is known as post-concussion syndrome.

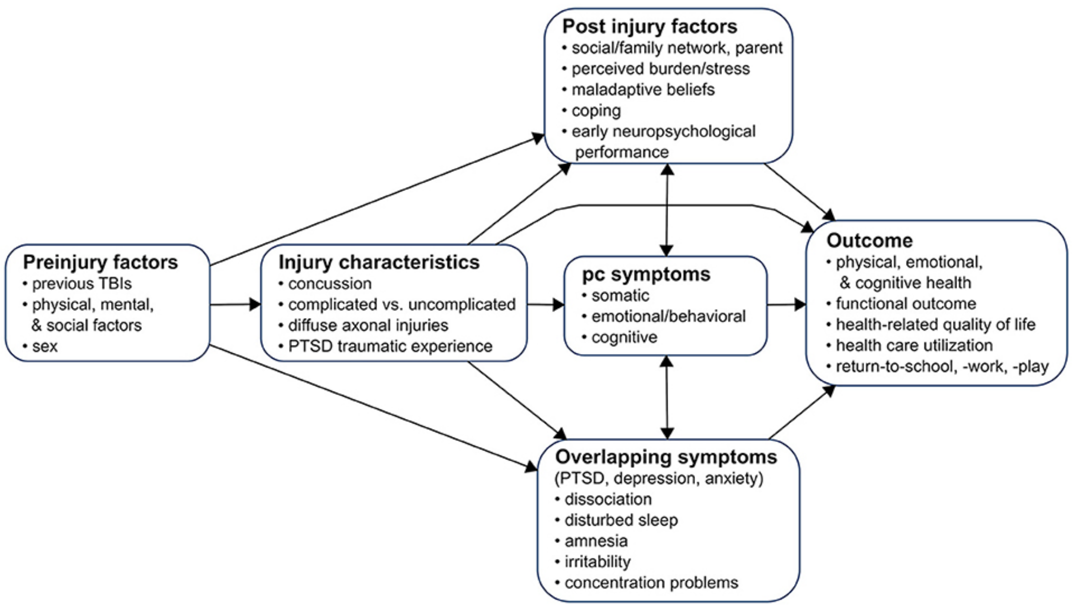

Figure 1 Flowchart model of post-concussion symptoms and their overlaps & manifestations. Published by Cambridge University Press, 2010[3].

Previous research raises the question if there is a common molecular pathophysiological cause of migraines and post-traumatic headaches. To start, cortical spreading depression (CSD) used to be illustrated with migraines in mind as they involve possible neurophysiological changes within the central nervous system[3]. This is because CSD consists of a self-propagating wave of cellular depolarization in the cerebral cortex. Additionally, there has been evidence of increased intracellular sodium, calcium, and chloride, and extracellular potassium concentrations in the brain after suffering a migraine or TBI. Furthermore, post-traumatic headaches and migraines seem to stem from an overproduction of excitatory neurotransmitters such as glutamate and dopamine. Glutamate is the primary excitatory neurotransmitter in the brain and dopamine can be excitatory depending on the dopaminergic receptor it binds to[4].

Concussions and other such TBIs can activate trigeminal nociception, which, as aforementioned, reflects that of migraines. This activation leads to an activation sequence of the second and third-order neurons. With this sequential process within the hypothalamus, thalamus, and brain stem, the manifestation of CSD can occur. Also, the trigeminal nucleus caudalis has cervical sensory roots that converge upon it, which could play into the activation of nociception, as the trauma stimulus results in extension and flexion of the cervical part of the spine[5]. The trigeminal nerve acts as a network of wiring that receives sensory information from the greater occipital nerve, branches of the upper cervical roots, and some anterior parts of the brain. According to the National Institute of Health, this network and its pain system may contribute to the initial formation of headaches after a concussion or TBI. The nociceptive information received from the trigeminal and cervical territories can thus activate the neurons in the trigeminal nucleus caudalis, as its convergence can extend to the lateral C2 spinal segment and its cervical nucleus located in the dorsolateral cervical area[2].

Another factor in the persistence of symptoms, mainly migraine-like headaches, is that of changing weather and barometric pressure. It has been previously reported that patients with migraines had headaches triggered by cloudy or rainy weather that was preceded by an area of low pressure. It's also been known that different environmental changes can have various effects on the body and its immune and nervous systems[6]. Research has shown that headaches can occur after a drop in barometer pressure as a natural bodily reaction. This reaction may also include cases of nausea and vomiting.

Concussions occasionally have affected behavior in the sense of depression-like symptoms and anxiety/panic-related disorder manifestation. There have also been behaviors related to inappropriate behavior and aggression/anger. As serotonin is involved in mood stabilization, cognition, learning, memory, and sleep, 5-HTP reuptake is important for the regulation of serotonin production and prevention of overstimulation[7]. In many cases of post-concussion syndrome, there are reports of increased irritability and aggression, or inappropriate outbursts[4]. This could be a result of low serotonin levels as regulation deficits with 5-HTP can cause dysfunction in the prefrontal cortex. Such dysfunction can make it difficult for the PFC to control emotional responses to anger and other related emotions[4].

Low levels of serotonin can also lead to an overproduction of dopamine as it can inhibit certain dopamine receptors. Dopamine plays a key role in movement and motivation, perception of life, and the brain's ability to experience pleasure[4]. Inhibition of dopamine receptors can cause a disruption in the body's sleep/wake cycle as it disables the brain's ability to produce melatonin[8]. Additionally, dopamine can cause the inhibition of norepinephrine, causing one to feel more alert. Norepinephrine plays a role in the body's stress response and helps to regulate sleep, alertness, and blood pressure. These disruptions in neurotransmitters as a result of sustaining a concussion have only been briefly researched, in terms of their correlation.

All of these previously mentioned symptoms and behaviors of post-concussion syndrome have been researched individually, but the interactions and relationships between them, such as the symptom outcomes and/or the effects of barometric pressure changes, have yet to be deeply explored.

Exploring if there is a correlation or connection between these possible effects of PCS can be crucial in finding a treatment method for PCS and other such post-concussion disorders. In seeing if these variables, which were chosen based on common symptoms and what the subject thought might be causing her symptoms, have any intersection at all, we might be one step closer to understanding why the brain reacts to trauma the way that it does. It may also help researchers understand why the effects of brain trauma are so individualized.

2. Methods

This case study was conducted over the course of 28 days. During this time, data was collected regarding the subject's daily activities and daily symptoms/behaviors. These were collected through the form of a survey that was filled out electronically every day. Additionally, the weather conditions for each day were collected. After the data was collected, Pearson's correlation statistics measured any association between the subject's behaviors/symptoms and weather conditions/activities.

3. Results and Discussion

The weather data was collected using a spreadsheet, which noted high temperatures, low temperatures, relative humidity, precipitation of each day, and barometric pressure averages (mmHg).

Date	High	Low	Humidity Ave	Precipitation	Barometric Pressure (Hg)
2-Mar	61	51	89	rain	29.8
3-Mar	65	53	93	rain	29.7
4-Mar	59	44	68	sunny	29.6
5-Mar	63	35	76	sunny	30.2
6-Mar	71	35	65	sunny	30.2
7-Mar	68	45	45	sunny	29.9
8-Mar	62	40	29	sunny	30.2
9-Mar	61	34	44	sunny	30.2
10-Mar	64	37	62	sunny	28.9
11-Mar	54	34	48	cloudy	29.6
12-Mar	43	32	90	rain	29.9
13-Mar	45	31	78	cloudy	29.9
14-Mar	38	28	54	sunny	30

Figure 2. Part of the table showing weather data recorded over the course of 28 days.

After the data was analyzed, it can be concluded that there is no correlation between her symptoms and the weather, but a very mild correlation between her symptoms and activities. Four of the recorded daily activities had a p-value less than .05; water intake & headache, mental fatigue & consumption of sweets, mental fatigue & mental activity, and overall feeling & mental activity.

```
> cor.results
            headache       nausea         vertigo        mental.fatigue overall        phy.act
phy.fatigue "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated"
sleep       "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated"
sweets      "Uncorrelated" "Uncorrelated" "Uncorrelated" "Correlated"   "Uncorrelated" "Uncorrelated"
water       "Correlated"   "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated"
mental.act  "Uncorrelated" "Uncorrelated" "Uncorrelated" "Correlated"   "Correlated"   "Uncorrelated"
screen.time "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated" "Uncorrelated"
```

Figure 3. Correlational analysis of recorded daily activities and symptoms with highlighted correlations.

Using Pearson's correlation, evidence showed that water intake vs. headaches had a correlation coefficient, or r-value, of .4345, where p=.0338. This illustrates that water intake is inversely related to the incidence of a headache. It was also found that consumption of sweets vs. mental fatigue has a correlation coefficient of -.4815, where p=.0172, illustrating that the more sugar ingested, the more mentally tired she feels.

The same correlation test was used on mental fatigue vs. mental activity and overall feeling vs. mental activity. It was discovered that mental activity vs. mental fatigue had an r-value of -.5392, where p=.0065 and mental activity vs. overall feeling had and r-value of -.4371, where p=.0326. This suggests that the more stimulated her brain is, the more mentally tired she feels and the worse she feels overall.

5. Conclusion

The conducting of this case study aimed to help determine if there was any connection between certain environmental factors and daily activities in relation to daily symptoms in a subject who has been suffering from post-concussion syndrome for about two years.

Based on the data, there is no statistical significance to say there is a relationship between weather-related factors and symptom occurrences. Additionally, only the four previously mentioned relationships were significantly associated between the subject's daily activities and symptoms suffered each day.

While these results do not answer the question if there is any overlap or relationship between these factors and the effect of PCS, the subject can be provided with some advice as to how they can try to control their symptoms. The evidence suggests the consumption of sweets could be a warning sign of mental fatigue, which could mean they either consume more than their normal amount when stressed or consumption occurs when they feel a sense of brain fog, etc. Additionally, the subject may limit mental activity to inhibit mental fatigue and possibly improve her overall feeling.

Limitations of this study had to do with the amount of time given to complete this study, the overall amount of data collected, and the amount of literature present on the subject for research. With only a month to conduct the case study, it became difficult to ensure that all the proper variables were used. The study would need to be continued in order to not only give the subject clearer answers in regard to her condition but to help others in the future suffering from PCS.

Given the case study was continued, data collection would need to be conducted longitudinally and more individually tailored to the subject in question. This would include taking barometric pressure readings more frequently, i.e. every hour or every four hours, and making sure the activities and symptoms survey is completed at the same time every day. Additionally, the symptoms would need to be more related to the subject, in terms of where her headaches occur, what time they occur, how frequent were they, what time of day did she feel nauseous, etc.

Acknowledgment

The author would like to thank the UNC-Asheville Undergraduate Research Board for the opportunity to conduct research on a topic that is in its infancy. The author would also like to acknowledge the Neuroscience and Statistics departments and faculty who supported this research and made this possible.

References

1. Centers for Disease Control and Prevention. Traumatic Brain Injury & Concussion. Last Reviewed: Dec. 15, 2022
2. Biagianti, B., Stocchetti, N., Brambilla, P., Van Vleet, T. Brain dysfunction underlying prolonged post-concussive syndrome: A systematic review. Journal of Affective Disorders, Volume 262, 2020, Pages 71-76, ISSN 0165-0327. https://doi.org/10.1016/j.jad.2019.10.058
3. Distriquin, Y., Vital, JM. & Ella, B. Biomechanical analysis of skull trauma and opportunity in neuroradiology interpretation to explain the post-concussion syndrome: literature review and case studies presentation. *Eur Radiol Exp* 4, 66 (2020). https://doi.org/10.1186/s41747-020-00194-x
4. Bear, M., Connors, B. M., & Paradiso, M. A. (2020). *Neuroscience: Exploring the Brain* (4th ed.). Jones & Bartlett Learning.
5. Piovesan, E.J., Kowacs, P.A. & Oshinsky, M.L. Convergence of cervical and trigeminal sensory afferents. *Current Science Inc.* 7, 377-383 (2003). https://doi.org/10.1007/s11916-003-0037

6. Kimoto, K. et al. Influence of Barometric Pressure in Patients with Migraine Headache. Japanese Society of Internal Medicine, 2011.
7. Levin, H., Eisenberg, H., & Benton, A. (1989). *Mild Head Injury.* Chapter 5 & Section V. Oxford University Press, Inc.
8. Levin, H., Eisenberg, H., Grafman, J. (1987). *Neurobehavioral Recovery from Head Injury.* Sections II & VIII. Oxford University Press, Inc.
9. *Voormolen, D., Cnossen, M., Polinder, S., von Steinbuechel, N., Vos, P., & Haagsma, J.* Divergent Classification Methods of Post-Concussion Syndrome after Mild Traumatic Brain Injury: Prevalence Rates, Risk Factors, and Functional Outcome. Journal of Neurotrauma 2018 35:11, 1233-1241
10. Polinder, S., Cnossen, M. C., Real, R. G., Covic, A., Gorbunova, A., Voormolen, D. C., Master, C. L., Haagsma, J. A., & von Steinbuechel, N. (2018). A Multidimensional Approach to Post-concussion Symptoms in Mild Traumatic Brain Injury. *Frontiers in Neurology*, *9*. https://doi.org/10.3389/fneur.2018.01113

11. Gilkey, S.J., Ramadan, N.M., Aurora, T.K. and Welch, K. (1997), Cerebral Blood Flow in Chronic Posttraumatic Headache. Headache: The Journal of Head and Face Pain, 37: 583-587. https://doi.org/10.1046/j.1526-4610.1997.3709583
12. Anghinah, R. et al. (eds.), Topics in Cognitive Rehabilitation in the TBI Post-Hospital Phase, https://doi.org/10.1007/978-3-319-95376-2_12
13. Brodal, P. *The Central Nervous System*. 1992.