Biometeorology: Review and analysis with regard to Traumatic Brain Injury acquisition in professional football, as well as traditional and digital economic markets

by

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Abstract

This research explores Biometeorology, which is the relationship between the environment and human behavior. Previous research has indicated that meteorological events such as lunar cycles, solar activity, temperature, and humidity have been extensively documented to affect human psychophysiology through systemic variation. The purpose of this document is to explore the effects of environmental factors on typical everyday aggregate behaviors in distinct, unique and separate investigations that relate to participation in sporting events and economic activities in order to determine if these naturally occurring influences are genuine. For example, local weather related and extra-terrestrial phenomena were collected during time-stamped Traumatic Brain Injury (TBI) acquisition in the National Football league (NFL) for 645 concussed players from 2012-2015. Components of the Earth's geomagnetic field were also documented in relation to global search tendencies for highly emotional states in addition to stock market indices. Furthermore, solar and lunar cycles were recorded during the monumental rise in the cryptocurrency market in order to identify if these cyclical background patterns systemically altered interest in Bitcoin (BTC) and Ethereum (ETH) or influenced their price index in-and-of-itself. The results indicate that intrinsic capacities of the game of football inherently impacted injury severity and return to play considerations. TBI's did however, vary as a function of geo-coordination and were most pronounced in the Northwest U.S. Injury severity was also found to be greatest during increased geomagnetic intensities. Lunar contributions also appeared to play a central role in injury acquisition insofar as TBI player height weight and injury severity were predicted by solar and geomagnetic variables of interest during the full moon. Aggregate search behavior on the Internet of Things (IoT) was found to correlate with magnetic variability, geomagnetic intensity as well as Dow Jones price movement and trading volume. Finally, traditional technical analysis indicators closely followed cryptocurrency price.

However, Bitcoins Aroon up and down was found to cycle with the Moon, while Ethereum's Heiken Ashi displayed a relationship with the Sun. Internet interest in Ethereum was found to have significant associations with the Earth's geomagnetic field, the Sun and the Moon which was enhanced during specific alignments of these heavenly bodies. In summary, seemingly random events and aggregate group behaviors are intimately associated with external interconnected dynamics.

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Chapter 1 – General Introduction

Biometeorology is the study of the relationship between the environment and living organisms. Bio refers to life, while meteorology refers to processes associated with the atmosphere. As an interdisciplinary field, biometeorology goes beyond the emotional states brought on by changes in weather, and uses complex scientific approaches and analysis in order to understand how external stimuli affect human behavior. The purpose of this dissertation is to report on three separate investigations of this interaction. The first explored possible meteorological contributions towards Traumatic Brain Injury (TBI) susceptibility in the National Football League (NFL) with the goal of identifying reduction and prevention strategies. The next two examined environmental correlates of emotional states associated with participation in two different financial spheres: digital economics (which includes the novel cryptocurrency market) and traditional stock market.

The structure of this document begins with an introduction to Biometeorology, focusing on: historical perspective, geomagnetism, lunar cycles, solar activity and other considerations. The paper then outlines the anatomy, physiology, and pathology most associated with biometeorological responses, including psychological and emotional states which are measurable in aggregate group behaviors. The second section details the nature of TBI's, including: prevalence rates, health effects, and findings within the literature. Models which accommodate traditional economic markets will also be presented. Methods for exploring potential environmental preconditions of TBI susceptibility will be explored, identifying relationships between TBI diagnosis and weather related phenomena, like lunar cycles and the associated discrepancies in the Earth's geomagnetic field. The consistencies between meteorological forces and TBI severity will then be documented. The next section outlines methods observations and approaches applied in investigating the environmental correlates of emotional states and the economy. Systemic interactions between meteorological influences with market movement will then be presented. Market indicators which measure volatility, trend strength & direction will be proposed for application in digital finance. Background will then be provided regarding cryptocurrency including an introduction to Bitcoin (BTC), blockchain technology & the Ethereum Virtual Machine (EVM).

The document concludes with an overarching synthesis that explores the overlapping biometeorological effects on human behavior from these separate ecological approaches, including the inter-correlations which enhanced the most pervasive findings.

Biometeorology

Biometeorology is concerned with the results of aspects of the physical environment on behaving organisms. An overview of the field should include the varieties of stimuli, the structures and mechanisms affected, and outcomes; which may be structural, experiential, or behavioural. After a brief historical note, this introduction follows that pattern.

Space and time are overarching aspects of both stimulus and response. Meteorological aspects of the environment vary in scale from planetary to continental features to local areas experiencing weather systems. Aspects of time scale include not only the duration of a stimulus but its predictability and the time lag between exposure and outcome. These considerations are somewhat intertwined and complicate attempts at categorization. Furthermore, scientific investigation is limited to what is observable and measurable, so the effect of time on technological advancement is evident in the literature. Excellent work in the field has been ongoing for over a century and retains relevance even if it is limited by the investigative tools available.

Historical Overview

Hippocrates' *Airs, Waters, Places* may be the first treatise on biometeorology in Western literature. About two thousand years later, in 1915, Ellsworth Huntington's *Civilization and Climate* was published at Yale University. Considered at branch of geography at the time, its notions would now be considered part of bioclimatology. Before his death in 1950, William F. Petersen, a former pathologist, spent many years collecting data on the effects of weather on human health. Although the germ theory of disease predominated at the time, Petersen was convinced that environmental factors were important influences on human health. His theories involved blood oxygenation and circulation, prenatal influences on the developing nervous system, and solar influence, among others.

In the 1950's, when biometeorologists were organizing in both Europe and North America, S.W. Tromp was a key figure in uniting the groups to form The International Society of Biometeorology. He continued publishing for decades, and his work is still considered standard reference. *The Weather Matrix and Human Behavior*, was Michael A. Persinger's book-length contribution to the field in 1980. A clinical psychologist, neuroscientist and polymath, he was well equipped to understand how human behavior could be affected by the environment. He emphasized interdisciplinary approaches together with sophisticated statistical analytical procedures that could reveal subtle influences, and stressed the need to study variables from both the human and environmental aspects in combination, so as to reveal synergistic phenomena that would not be apparent in single variable studies.

Meteorological Stimuli

The word meteorology is most commonly associated with forecasting weather events such as daily temperature and precipitation, which are consciously perceived. Other components of the environmental context are imperceptible as stimuli but have acutely perceptible consequences; such as ultraviolet radiation which is neither warm nor visible but causes painful Sunburn. An overview of meteorological context involves consideration of the entire planet, rather than simply local weather phenomena, for imperceptible extra-terrestrial phenomena are sources of and influences on weather events in Earth's atmosphere.

The Earth is a spheroid, slightly bulging at the equator, which orbits the Sun, rotates on an axis slightly tilted from vertical, and is orbited by its own satellite – the Moon. It has an iron core which produces a large magnetic field, the magnetosphere, which permeates and surrounds the Earth, extending into space. Humans and other life forms live on the surface of the Earth; either in the oceans which cover most of the Earth's surface, or on land which has geographic features such as mountains, plains, deserts, and coastlines. The atmosphere is a gaseous layer that lies between the Earth's surface and the magnetosphere. Its lower layer, the troposphere, is where most weather occurs. As the Earth rotates, different areas are heated as they are exposed to the Sun. Temperature of air masses, evaporation of water, and differences in heating/cooling rates for water and land are primary factors resulting in wind and weather. The tilt of the Earth's axis and the characteristics of a rotating spheroid lead to seasons, latitudes with characteristic climates, and other weather phenomena.

Electromagnetic radiation from the Sun in the visible and infrared spectrums reaches the Earth's surface and provides light and heat which sustain most life forms. Radio waves, ultraviolet, and ionizing radiation, along with a variety of charged particles (ions) also blast toward Earth on the solar ‘wind’ (Sanford, 1936, Nelson, 1949; Siedentopf, 1050; As cited in Tromp, 1963; p. 150). Much of this is blocked by Earth’s magnetosphere or affects the ionosphere, which is a thin layer below the magnetosphere. At the poles where Earth’s magnetic field is weaker, a greater amount of solar radiation is able to reach farther into Earth’s atmosphere where it interacts, releasing the coloured light. The resulting Aurora Borealis (or Australis) displays provide a means of visualizing the invisible. Solar flares or coronal mass ejections intensify Earth’s bombardment with these energies and can cause the magnetosphere to deform. Disturbance of a magnetic field causes electrical perturbation, so Earth-orbiting satellites and electric grids on the Earth’s surface may be affected by strong solar events (Kleusberg, 1993; as cited in Campbell, 2003; p. 219). The electro-chemical nature of the human nervous system makes it susceptible as well (see discussion below).

The Moon exerts a gravitational force on the Earth, which is mostly perceptible because it results in tides that occur about twice daily with the Earth’s rotation. Sunlight reflecting from the Moon’s surface makes it visible, but its orbit around the Earth means that different aspects become visible. These are referred to as Moon phases. When Sun, Moon, and Earth align, in that sequence, the Moon’s Sun-exposed aspect is not visible from Earth and the Moon appears dark. This is termed a ‘new Moon’ and is considered the beginning of lunar cycle. Half-way through the cycle a ‘full moon’ appears when the alignment sequence is Sun-Earth-Moon. As the visible area increases (or ‘waxes) from new moon to full moon, the phases are termed waxing crescent, first quarter, and waxing gibbous. The ‘waning’ gibbous, last quarter, and waning crescent represent the phases as the cycle returns to the new moon. During an alignment (also known as a conjunction or syzygy) the gravitational forces of the Moon and Sun combine to produce higher tides (known as ‘spring’ tides), while during other phases the Moon’s gravitational pull offsets that of the Sun. With a somewhat elliptical orbit, the Moon may be nearer or farther from the Earth, having a larger appearance and stronger gravitational pull at perigee (closer) than at apogee (more distant) (Markson, 1971).

The troposphere is the location of more easily perceptible environmental phenomena based on the temperature, movement, and water content of air. The relationships between air temperature, altitude, density, and water vapor capacity make it difficult to discuss or study temperature, barometric pressure and humidity in isolation (Persinger, 1980; p. 194).

Air becomes less dense and rises as the Sun. Warmer air heats it also has a greater capacity to hold water vapor which displaces heavier molecules such as nitrogen. Higher temperature, humidity and altitude are all associated with lower air pressure. Higher altitudes are colder, however, so rising air cools and may release its water vapor as rain or snow. A cool, dry mass of air will be dense and descend as a high pressure area, displacing air away from it. Weather within such an air mass would be Sunny and dry. Low pressure areas are warmer, more humid and are associated with weather disturbances as surrounding air is drawn toward the area and water vapor rises to form clouds, possibly with some precipitation. Air masses with different temperatures and densities may not blend smoothly into one another; rather, they collide as warm or cold fronts. In such cases warm humid air displaced quickly upward by dense cooler air may result in storm cloud formation and the quick release of precipitation, the electrostatic discharge of lightning, and the pressure wave from rapid air expansion due to heating with associated thunder (Persinger, 1980; p. 13).

Water vapor, air, electromagnetic radiation and fields, ionized particles, and gravity, together with the shape and process of the Earth are the fundamentals of the human meteorological context. Their interplay makes it essential that biometeorological investigations should be interdisciplinary and multivariate. Air masses are affected by the geographic features over which they pass. Mountains, inland bodies of water, and coastlines produce changes in the altitude, moisture content, direction, or velocity of moving air. Lightning discharges and auroras remind us that Earth is surrounded by charged particles. The electromagnetic fields of the planet are extraordinarily complex. Not only does Earth's geomagnetic field have an Extremely Low Frequency (ELF) component, but ELF pulses are associated with lightning (Konig, 1974b), passing weather fronts (Lotmar et al., 1969; as cited in Persinger and colleagues, 1973; p. 1134), and they are influenced by both solar eruptions and geographical features (Aarons and Henissart, 1953; as cited in Ossenkopp et al., 1972; p. 276). Geomagnetic disruptions that follow solar disturbances display a main phase that lasts from 12 to 24 hours, and a slow phase that may last a month after prolonged intense solar storms (Persinger, 1980; p. 232).

The relationship between solar activity, geomagnetic activity, and weather is the basis for using tree-ring measures for historical research (Carapiperis, 1962; Robert and Olsen, 1975; Hines, 1974; King, 1975; Gnevyshev and Ol', 1977; Herman and Goldeberg, 1978; McCormac, 1983: as cited in Campbell, 2003; p. 219). A direct correlation has been found between wind speed and geomagnetic storms, and in the Pacific Northwest specifically, geomagnetic activity accompanied by an aurora would be followed by a low pressure trough a few days later (Beynon and Winstanley, 1969; Roberts and Olsen, 1973; as cited in Persinger, 1980; p. 233). Solar activity and thunderstorms were positively correlated in Northern and mid latitudes but negatively correlated in equatorial regions (Likhter et al., 1968; Sao, 1967; Reiter, 1969; as cited in Markson, 1971; pp. 181-184), and a relationship was seen between the annual variation of the geomagnetic field and global temperatures from 1860-1980 (Courtillot et al., 1982; as cited in Campbell, 2003; p. 238).

The Moon's changing orientation could affect geomagnetic forces (Becker, 1963; Friedman et al., 1965; Persinger, 1975), ELF waves (Ossenkamp and Ossenkamp, 1973; Beal, 1974; Playfair and Hill, 1978), or air ions (Sulman, 1976; Soyka, 1977) by modulating solar particle flux and cosmic radiation, which reaches the atmosphere. Norwegian investigators found that auroras peak and decrease with tides (Egedal, 1929). Geomagnetic measures change in association with lunar phase, particularly when the Moon is close to the Earth (Stolov, 1965; as cited on p. 170). Precipitation on Earth has been correlated with phases of the Moon (Adderly and Bowen, 1962; Bradley and colleagues, 1962) with maximum rainfall occurring midway through the 1st and 3rd quarter lunar phases (Briere, 1965). An index of thunderstorms index from 1942-1965, revealed not only that thunderstorm frequency had a direct correlation with geomagnetic activity and cosmic radiation, but also that thunderstorm activity was correlated with lunar position (r=.54); the relationship being amplified in Northern latitudes, with maximum storms occurring two days after a full moon (Lethbridge, 1969; as cited in Markson, 1971; p. 167).

Additionally, several researchers have attempted to identify the relationships between injuries and lunar phase. Specifically, Coates and colleagues (1989) have identified that the notion injuries are more severe or occur more frequently during full moons is false. There is no statistical increase in injuries during the full moon phase when compared to all other moon phases. However, Stomp (2009) and colleagues found a mildly significant effect when comparing the full moon phase to the new moon phase. They reported a lower incidence rate of injuries during full moon phases when compared to the new moon phase.

It is evident that single variable studies are insufficient for understanding biometeorological influences on human health and behavior. Factors within the weather matrix are inter-correlated in both space and over time. Disturbances in the Earth's magnetic field have been found 1-3 days after significant changes in solar activity, and unstable weather conditions systemically manifest 2-3 days after disturbances in the Earth's magnetic field. Analysis should therefore include lag or lead times as well as combinations of solar, geomagnetic and weather variables. Clustering environmental factors that contribute to alterations in behavior can be of use in determining if interactions between natural phenomena are necessary for the change in behavior. Other factors could also influence the weather matrix such as larger cycles with slower periods of occurrence such as monthly and yearly changes in solar activity, or the physical consequence of the transition of the Moon through its lunar phases. Outcomes might be contingent on the celestial alignment of the Sun and Moon in relation to the Earth, such that the inclusion of these variables is of crucial importance in understanding human behavior (Persinger, 1980; pp. 110).

Mechanism of response to the Environment

This section will provide a brief overview of anatomy and physiology closely involved in responses to biometeorological stimuli.

Essential Anatomy

Aspects of human anatomy closely associated with biometeorological response include the nervous, endocrine and cardiovascular systems. Only the most relevant structures will be mentioned.

The Nervous System

The nervous system is composed of the central and peripheral nervous systems. The peripheral nervous system is further divided into sensorimotor and autonomic branches. These are then divided into sensory and motor components, and sympathetic and parasympathetic components respectively. It is critical to note that the nervous system function relies on electro-chemical relay of information and is therefore susceptible to disruption from electromagnetic sources.

Central Nervous System (CNS)

The central nervous system (CNS) consists of the brain and spinal cord. Due to the complexity of the brain, only two, highly relevant structures will be discussed. The main function of the spinal cord is transmission of information from peripheral sensory structures to the brain.

The Thalamus and Hypothalamus

The thalamus receives and integrates sensory information, then relays it other areas of the brain. The hypothalamus is a portion of the CNS involved in regulation, as it functions in hormone release, food intake, and circadian rhythms. Furthermore, it can be associated with behaviors that can vary as a function of weather, such as regulation of body temperature (Persinger, 1980).

Pineal organ and the Earth's geomagnetic field

Convection of molten iron within the liquid outer core of the Earth produces and maintains the Earth’s geomagnetic field. The strength of the field is roughly 50 micro-teslas, although sources of variance exist between polar and equatorial regions, of up to 30% due to variations in conductive ore depositions. Local fluctuations in the field can be as intense as a shift of several hundred nanoteslas' (nT's). People can subsequently be sensitive to extreme changes in the Earth's geomagnetic field, at intensities between 200-300 nT/m. The pineal organ within the adrenal gland is most sensitive to these changes. Slow changes in the direction of static magnetic field can reduce melatonin in the pineal organ, although the gastrointestinal system produces the most within the body. Reduced field exposure around the head, enhanced autonomic response to emotional stimuli, by means of altered skin conductance in response to emotional pictures. Attenuation or - reduction in intensity - of the Earths geomagnetic field produced analgesia or - the inability to feel pain – in rats (Merrill et al., 1998; Kerhonen et al., 2007; Del Seppia et al., 2006; as cited in Mulligan and colleagues, 2010; pp. 116-119).

Peripheral Nervous System

The sensory portion of the PNS contains sensors and nerves which conduct information to the spinal cord and brain (thalamus).

Autonomic nervous system

The sympathetic branch is responsible for general arousal and responds emotional stimuli such as anxiety and fear, as well as environmental extremes such as cold stress. This allows the organism to respond quickly to sudden changes in the environment. The sympathetic system, when stimulated results in the production of adrenaline, and can produce physiological response such as pupil dilation, increased; heart excitability, blood pressure and oxygen intake. Sympathetic activation can also result in elevations in blood glucose, calcium, and acidity. Increased blood acidity has been associated with capillary contraction and migraines or depressive states, other physiological changes associated with sympathetic activation include increased cerebral electrical activity and faster blood clotting. These changes can lead to behaviors that are egocentric in nature including increased energy, euphoria, self-confidence that can lead to elevated aggression (Persinger, 1980, p. 24). Sympathetic activation has been associated with increased acidity in blood and urine, whereas parasympathetic activation leads to more alkalinity in these fluids. Increased blood acidity can lead to capillary contraction, and ultimately result in migraines or depressive states (Hoff, 1934-1935; as cited in Tromp; p. 201).

The parasympathetic nervous system is primarily concerned with the regulation and recovery of disturbed long-term homeostasis of the organism due to external changes, as well as immunological and healing responses. When stimulated the parasympathetic nervous system produces acetylcholine (ACh), which has very opposite effects to that of adrenaline insofar as it causes pupils to contract, it also dilates peripheral blood vessels and slows the beating of the heart. ACh can also promote the production gastric and pancreatic juices, and increase digestive, stomach, intestine, and bladder movements (Tromp, 1963; p. 193). Other increases, which result from parasympathetic activation, include potassium levels and alkalinity in blood content (Persinger, 1980; p. 25). Parasympathetic activation can also lead to decreased blood glucose levels and brain activity.

Taken together these systems play a critical role in the nervous systems response to climatic or meteorological stressors such as abrupt changes in weather. The complementary capacities of the parasympathetic and sympathetic components of the nervous system imply that neither system is predominately active in the healthy individual, although sympathetic activation is most prevalent during the day, while parasympathetic activation is most active during the night, which results in lower body temperatures. Feelings of tiredness during the day however - such as after eating - can lead to brief parasympathetic activations, while increased activity during the night, such as; fights, arguments, or sex can lead to periods that are temporarily sympathetically dominant (Persinger, 1980; p. 25).

Endocrine system

The endocrine system amplifies and maintains homeostatic adjustments instigated by the autonomic nervous system. It relies on chemical signalling through hormones, which regulate other cells in the body. Examples of endocrine glands include the pituitary, thyroid, and adrenals which regulate growth, metabolism, and blood pressure, among their many functions (Melmed et al., 2015).

The cardiovascular system

The cardiovascular system includes the heart, arteries, veins and capillaries within the human body (Persinger, 1980; p. 26). It is essentially a multitude of tubes that originates from the heart - with larger vessels proximal to it - but with smaller formations as the system extends into the outer limbs and external visceral components resulting in capillaries and arteriole formations. This system supplies cells with oxygen and nutrients through the blood, therefore every tissue relies on and is connected by it. Stimulation of the nervous system, as well as hormone secretion from the adrenal medulla maintains functioning of the cardiovascular system.

Responses to Biometeorological Stimuli

Environmental influences on human health and behavior have been a long-standing and consistent subject of interest. The term ‘lunatic’ reflects observations from at least the time of Paracelsus to the Industrial age that Moon phases, especially near a full moon, correlated with agitated behavior, especially in sensitive individuals (Paracelsus, 1967; Esquirol, 1845; Hering, 1881; as cited in Raison and colleagues, 1998; pp. 99-105). Early researchers were limited by available sources of data and social conditions of their time.

Many early studies focused on climate or season and used data obtainable from hospital or public records. Birth weight and congenital malformation rate were linked to unstable weather and certain regions or seasons and it was hypothesized that ionic aspects of blood chemistry might enhance or suppress genetic susceptibility (Peterson, 1934; p. 29-37). Studies of cognitive outcomes such as ‘criminality’ and ‘genius’ may illustrate the need to consider variables other than meteorological environment that may explain a great deal of variability in outcomes. Early studies indicated found that differences in regions and climates were associated with performance on psychological tests and proportions of alpha (literate) versus beta (illiterate) army recruits, however availability of education is probably responsible for most of the differences between Boston and the Southern states, or between Maine and the Pacific coast in the first half of the nineteenth century (Peterson, 1934; p. 41-53). Similarly, seasonal variation in some infectious diseases is probably largely mediated through seasonal social activities rather than primary meteorological influences.

Despite the limitations of their times, many of the early researchers investigative patterns are still valid in the 21st century. Many focused on outcomes based on sensitive periods during prenatal development. Birth weight is a predictor of outcomes in adult life and continues to be studied today, although with the addition of social variables to biometeorological considerations such as latitude. The influence of meteorological variables is studied with respect to many of the same diseases: arthritis, asthma, atherosclerosis, diabetes, eczema, glaucoma, ulcers, (Tromp, 1963, pp. 579-583). Inflammatory processes are common to all of these and careful, multivariate studies might find a biometeorological link to exacerbations in these and other inflammatory conditions.

The sensory and response aspects of the nervous system extend throughout the body. Similarly, the circulatory system supplies the needs of every cell. The nervous system carries information, is electrochemically based and is a likely source of interaction with electromagnetic phenomena. The circulatory system is chemically based, with its basic function of oxygen and nutrient transport and waste removal. It is, however, electrically regulated at its central pump and is the pathway by which endocrine system hormones distribute and continue responses initiated by the nervous system (Persinger, 1980; pp. 26-27). The following summary of research findings on responses to biometeorological influences includes cardiovascular system, autonomic function, and emotional or behavioural responses. Some literature with particular relevance to the current investigations is highlighted. Blood chemistry was extensively studied by biometeorological researchers in the last century. Blood volume, pressure, pH, cells, proteins, ions, hemoglobin, antibodies and oxygen-binding capacity were all found to vary according to environmental conditions (Tromp, 1963, pp. 575-579). A particularly robust finding was that a number of measures of blood clotting were reduced just prior to cold fronts, and during colder seasons (Tromp, 1963, pp. 374-375). This dovetails with clinical reports that subarachnoid hemorrhage and intracerebral hemorrhage both increase during cooler temperatures and winter months (Field and Hill, 2002; p. 1751).

Thermoregulation is a critical function of the autonomic system, and one that is carried out largely through regulating vasoconstriction and metabolic rate. Alteration in autonomic processes relating to the thyroid (the primary regulator of metabolic rate) and the urinary system (eliminating metabolic waste) have shown increases with cold stress (Tromp, 1963, p. 376).

Peterson (1934) commented that the Northwest Coast, the Northern Midwest, and the cyclonic pathway in the United States presented the greatest demand on autonomic responses, including high demand for thermoregulatory adjustment due to the unstable weather and clashing warm and cold fronts.

Influences on emotion and behaviour cover the entire range of stimuli from solar radiation to local weather. Increased sunspot activity has been associated with increased agitation in hospital wards, particularly among patients with depression or addiction problems (Faust and Ludewig, 1972; Luce, 1970; as referenced Banziger and Owens, 1978; pp. 427-428). Higher rates of psychiatric admissions were recorded on full moon days than other days of the year in a 1961 report (Pokorny, 1968; as cited in Campbell and Beets; p. 1124). Emergency psychiatric cases increased 30% in a mental health center during full moon days (Blackman and Catalina, 1973; as cited in Rotton and Kelly; p. 298) and state hospital admissions, peaked during the *3rd quarter* lunar phase (Weiskott and Tipton, 1975; as cited in DeVoge and Mikawa, 1977; p. 387-388). Some early U.S. statistics indicated latitude and longitude effects for 'psychosis' admissions, with higher rates for northern latitudes and westward longitudes (Peterson, 1934; p. 42-43), but this may be confounded by social variables.

Wind velocity mediated work productivity of gold miners, with strong winds negating losses in productivity at high temperatures. Low temperature, humidity, winds and sunshine enhanced scholastic performance, and low humidity and high barometric pressure correlated with self-reported positive mood scores (Wyndham, 1969; Auliciems, 1972; Goldstein, 1972; as cited in Howarth and Hoffman, 1984; p. 16). People are most helpful when the sky is clear and when sunshine is abundant; people tip more during increased sunshine (Cunningham, 1979). The effects of weather on numerous aspects of mood have been investigated which include concentration, cooperation, anxiety, potency, aggression, depression, sleepiness, scepticism, control and optimism. The results indicate that humidity, temperature and number of hours of sunshine had the greatest effects on mood. Vigour, social affection, and elation correlated negatively with high relative humidity and increases in humidity decreased concentration and increased sleepiness, while rising temperatures lowered skepticism and anxiety (Howarth and Hoffman, 1984).

Decreased atmospheric pressure has been associated with increased restlessness in female schizophrenia patients, despite controlled housing temperatures (Tromp, 1963; as cited in Persinger, 1980; p. 186). High ambient temperatures above 93 degrees Fahrenheit with humidity levels of 40% were associated with self-reported negative affect and increased willingness to administer electric shocks to another person. Subsequent studies also found a curvilinear relationship between aggression and negative affect, as well as increased aggression during naturally occurring high ambient temperature (Bell and Baron, 1976; Palamerek and Rule, 1979; Baron, 1976; As on pp. 15-16). Studies of self-reported scores on a multidimensional mood scale with temperature found that subjects in a 'hot room' scored low on mood scores for elation and social reflection (Griffith, 1970).

Seasonal Affective Disorder (SAD)

Seasonal Affective Disorder (SAD) is a major depressive disorder affecting 10 million Americans annually (Rosenthal, 1998) with similar rates in Canada and Italy (William and Schmidt, 1993; Faedda et al., 1993). Symptoms of SAD include concentration difficulties, disinterest in sex, social withdrawal, loss of energy, lethargy, sleep disturbance and weight gain (Mayo, 2001). SAD typically results from diminished sunlight from fall to winter and is enhanced at extreme latitudes. Annual onset occurs as early as the autumn equinox in September

(Dilsaver, 1990). Positron Emission Tomography (PET) scans indicate a physiological source as anomalies in the prefrontal and parietal cortex have occurred in patients (As cited in Kamstra et al., 2018; p. 325).

A link between depression and heightened risk aversion is seen in depressed individuals who score lower on 'sensation seeking' scales, which correlates with psychological and biological phenomena (Zuckerman, 1980; 1984). Sensation seeking is a reliable indicator of risk-taking behavior in financial decision-making. Studies indicate that heightened measures of anxiety and depression, rather than passivity, are associated with a reduced willingness to take risks (Eisenberg, 1998). Stock market traders affected by SAD can affect market equilibrium, as demands for risky assets will determine the prices at which marginal buyers and sellers are willing to exchange (Hicks, 1993). A seasonal pattern with regard to daylight hours has been found to correspond with market returns, specifically in extreme latitudes where SAD peaks around the winter solstice (Palinkas, 2000; as cited in Kamstra et al; p. 325).

Sunshine was found to affect mood and market returns in 26 international stock markets from 1982-1997 (Saunders, 1993; Shumway, 2003 Hirshleifer and Shumway, 2003). Temperature within major market cities affected market returns in eight different international markets, and environmental factors including such as sunshine, length of day, temperature, cloud cover, precipitation, global radiation, and barometric pressure have indicated that length of day was the strongest correlate of seasonal depression (Cao and Wei, 2001; Molin et al., 1996; as cited in Kamstra et al., 2003; p. 5).

Aggregate group behaviors

Aggregates of individuals within a species function as an integrated whole. These large populations can display emergent properties through self-organized collective decision-making and in responding to the environment, such as intra-species aggression traditionally referred to as war (Persinger, 1999). Conflicts such as these could be aggregate responses to the environment since all human beings are immersed within the Earth's magnetic field.

Studies indicate positive correlations (.4) between increased global geomagnetic activity and aggression in rats with labile limbic systems that exhibit electrical sensitivity. Group aggression was evoked in rat models during application of artificially induced electromagnetic fields, which mimic GMS's. Furthermore, as the density of rats increased, the intensity threshold to elicit aggressive behaviors decreased. A positive correlation between global geomagnetic activity and the number of armed conflicts in the first half of the twentieth century was subsequently identified (as cited in Persinger, 1999; p. 1352).

Social conflicts such as war correlate with geo-psychological and solar cycles, insofar as social revolutions occur during solar maxima (Tchijevsky, 1938; Mikulecky, 2007; as cited in Mulligan et al., 2010; p. 122). Religious motivations have also been found to be correlated with the hale cycle (21 years) of the Sun, which is considered the completed component of the Schwabe (10.5 years) cycle (Starbuck et al., 2002; p. 189).

Maximum solar periodicities that occur every 50-60 years correlate with the major creative achievements in theoretical physics. Other social phenomena including the emergence of historic poets display 500-year cycles in regions such as Japan, China, Persia, and Arabia. Functional asymmetries of the brain correlate with solar-geomagnetic cycles, such that oscillations between right and left hemisphere dominance flip every 20-25 years (Vladimirskii and Kislovskii, 1995; Pales and Mikulecky, 2004; Volcheck, 1995; as cited in Mulligan et al., 2010; p. 122).

Human Response to Electromagnetic Stimuli

Weak current can influence the functioning of neural gap junctions within the brain, and regions of the brain such as the amygdala within the temporal are prone to electrical excitability. A reduction of convulsive thresholds in human patients and rats during natural variations in the Earths geomagnetic field of 19 nT occurred when coupled with a solar eclipse (Korn and Faber, 1979; Keshaven et al., 1981; as cited in Persinger, 1987; p. 98).

The human body also has primary sources of ELF-EM generation, which include the brain and spinal cord, as well as, the heart. The human brain elicits an electric field between 10-100 microvolts, and a magnetic field 10^{-9} gauss. The heart furthermore, displays a frequency of approximately one hertz (Presman, 1970; Cohen, 1967; as cited in Persinger, 1974; p. 3). ELF's are also present at the microscopic level, as they occur from the firing of neurons (.01Hz- 1 kHz). Activation of sympathetic and parasympathetic divisions of the nervous system can occur in humans as nerve fibers discharge a synchronous signal between 10Hz-15Hz. This intrinsic electrical capacity is a strong candidate for physiological interaction between humans and the Earths electromagnetic field (Guyton, 1971; as cited in Persinger, 1974; p. 4).

Reiter measured the relationship between electric fields and human behavior, specifically the biological effects of naturally occurring VLF fields (4 kHz-50 kHz). Reaction time of visitors to a traffic exhibition in Munich during various types of naturally occurring electric fields, revealed that reaction times decreased after local field fluctuations of roughly 3Hz, but increased during electromagnetic waves associated with the Schumann resonance (Reiter, 1951 and 1953; as cited in Konig, 1974a; p. 81).

Migraine headache rates nearly doubled during increased geomagnetic activity, but severe headaches in migraine patients were extremely (6%) low during quiet geomagnetic periods. A weak (r=.20) association was found between aversive headache experiences and sferics, which are electromagnetic pulses associated with weather processes. Similar correlation strengths (r=.33) between headaches and sferics were found also found during the fall months in Germany (Stoupel, 2002; Walaeh et al., 2001; Vaitl et al., 2001; as cited in Mulligan et al., 2010). Increased monthly and yearly geomagnetic disturbance in Russia was associated with over 2000 heart failures (Novikova and colleagues, 1968; as cited in Persinger, 1980; p. 235).

Significant correlations between heart attacks and magnetic activity indicated increased self-destructive psychiatric behaviors occurred 1-3 days following intense GMS's (Malin and Srivasta, 1979; Traute and Dull, 1935; as cited in Persinger, 1987; p. 98). Positive correlations between the number of grand mal seizures and geomagnetic activity resulted from lower convulsive thresholds due to changes in the magnetic field (Rajaram and Mitra, 1981).

Geomagnetic storms (GMS) can directly influence the physiology of humans, and global GMS's with variations in intensity over 50 nT have been associated with approximately 10% increase in blood pressure and myocardial infarction (Dimitrova, 2006; p. 1251). A majority (72%) of human patients with myocardial infarction have reduced capillary blood flow during the days of GMS's. Increased (14-20%) stroke incidence rates have been documented the day following large fluctuations in solar and geomagnetic activity, with similar instabilities observed the day following intense (K=5) GMS's in Arctic and Antarctic regions. Cerebrovascular dysfunction related deaths were associated with geomagnetic activity; however, patient age played a significant role (Breus et al., 2002; Felgin et al., 1997; as cited in Mulligan et al., 2010; p. 119).

Sudden Infant Death Syndrome (SIDS)

The Earths geomagnetic field was strongly (.91) correlated with the number of cases of sudden infant death syndrome (SIDS) in Ontario between 1960 and 1961. SIDS is a major cause of infant mortality, in babies aged one month to a year old. A seasonal effect in SIDS revealed that 70% of cases were found to occur between the fall and winter months. Sex differences have been determined, wherein boys outnumber girls in SIDS deaths by an odds ratio of 1.47. Different researchers have noted that SIDS deaths cluster together temporally even over great geographical distributions (Peterson et al., 1988; Miller and Hill, 1993; as cited in O'Connor and Persinger, 1997; pp. 395).

Post-mortem studies have indicated physiological anomalies in SIDS victims, including abnormal carotid bodies, irregular proliferation of astroglial fibers within the brain stem, specifically within the lateral reticular nucleus, microglia aggregation within the hippocampus, namely the dentate gyrus and brown adipose tissue retention. Studies have also indicated uncharacteristic changes in bodily fluids in SIDS deaths such as increased levels of T3-thyroxine and tryptase levels in blood, as well as a reduction of melatonin within cerebrospinal fluid relative to deaths of other variety (O'Connor and Persinger, 1997; pp. 395-396).

The primary source of SIDS with regard to genetic anomalies in the neuroendocrine system results from the pineal gland, as desynchronization of descending pathways from the amygdala and insula have manifested in SIDS babies from suppression of circulating melatonin, which is normally produced by the pineal gland. Regular melatonin production is associated with rhythmic organization of respiration in sheep fetus (Weisbluth and Weisbluth, 1994; Persinger, 1995; McMillen et al., 1990; as cited in O'Connor and Persinger, 1997; pp. 396-397).

It is unclear whether the Earths geomagnetic field induced the anomalies associated with SIDS. The most common suppression of melatonin is white light, but investigators have considered the possible effects of low-intensity ELF magnetic fields on SIDS, as well as mechanisms by which power lines and/or geomagnetic anomalies could be involved. Aside from the strong correlative nature with SIDS, increased geomagnetic activity is a viable candidate as it significantly increases seizure activity by lowering thresholds in both humans and non-humans, and increased vestibular experiences are noted in humans the day following geomagnetic storms (Persinger and Richards, 1996; as cited in O'Connor and Persinger, 1997; pp. 397).

Traumatic Brain Injuries (TBI) in professional sports

This section provides background on TBI's, discussing rates across collision sports including football, hockey and soccer. The long term health risks of concussions are outlined including neurodegenerative diseases such as Alzheimer's disease (AD), Chronic Traumatic Encephalopathy (CTE), and Second Impact Syndrome (SIS). Responses to the issue of TBI in college football and the National Football League (NFL) are also considered.

The term concussion is derived from the Latin verb 'concutere' which means to shake violently (Maroon et al., 2000). Concussions have been considered one of the earliest illnesses in human history, and skull fractures have been found in Homo erectus skulls in burial sites around the world (Finger, 1994; Dart, 1949; Tung, 2007; as cited in Shively et al., 2012; p. 1245).

A concussion may be defined as: a type of traumatic brain injury caused by a blow to the head which induces complex pathophysiological processes as a result of biochemical forces (McCrory et al., 2009). It is important to understand the effects of concussions, as there are increased risks of developing neuropsychiatric disorders, such as: personality change (Parker, 1996; Lannoo et al., 1997; Kurtz et al., 1998; Gualtieri and Cox, 1991), schizophrenia (Silver et al., 2001, Malaspina et al., 2001), depression (Rosenthal et al., 1998; Jorge et al., 1993; Federoff et al., 1992; Varney et al., 1987; Robinson and Jorge, 1994), mania (Shukla et al., 1987; Starkstein et al., 1987), anxiety disorders (Epstein and Ursano 1994), post-traumatic stress disorder (Bryant and Harvey, 1998; Ohry et al., 1996), and Parkinson disease (Stern, 1991; Bower et al., 2003). Concussions can also lead to increased risk of Alzheimer's disease (Lye and Shores, 2000), dementia (Shively et al., 2012), second impact syndrome (Bey and Ostick, 2008), as well as development of chronic traumatic encephalopathy (Asken et al., 2017).

Most concussions occur without losing consciousness, however concussions can result in immediate and transient loss of consciousness, which can be accompanied by brief anterograde and retrograde (Cantu, 2001) amnesia. While retrograde amnesia has been found to extend from moments before the injury to several days before, anterograde memory loss is typically shorter (Ropper and Gorson, 2007; as cited in Bey and Ostick, 2009; Introduction, para 3). TBI's include symptoms such as; imbalance, headache, confusion, memory loss, fatigue, disorder, hearing and mood changes, and can be considered a complex pathophysiological process. Population based studies have also suggested long-term implications of TBI's (Teasdale and Engberg, 2003; Gottlieb, 2000). One of the major problems with an acquired injury such as concussion is the wide variety of definitions used to explain and diagnose it. This inconsistent understanding of TBI signs and symptoms can lead not only to early misdiagnosis, but might also lead to premature return to regular work activities. Mismanagement of concussion stems from belief that athletes can return to play when observed symptoms subside, however prolonged effects can occur long after the disappearance of typical symptoms including impacts which are sub-concussive, cognitive difficulties, disturbances with regard to emotion, depression, and chronic headaches (Slobounov et al., 2012; Iverson et al., 2012; Tremblay et al., 2013; Stern et al., 2011). The principles of a concussion were outlined by Persinger (1995) and can be reviewed in Appendix A.

Etiology of Traumatic Brain Injuries

Age-specific factors of TBI acquisition indicate that very young and old people are high risk groups (Silver et al., 2005). After a concussion occurs, risk for subsequent brain injuries are three times greater, and after a second TBI is acquired, the risk of a third injury is eight times as high as baseline risk (Annegers et al., 1980). Full contact sports expose athletes to risk of single or repeated head traumas that can result in subdural hematomas, loss of cognitive function and even death (Clark, 1998). TBI's also occur in noncontact sports such as snowmobiling (Pediatrics Prevention, 2000), soccer (Pediatrics Fitness, 2000) and in-line skating (Heikamp et al., 2000). Males are not only more prone to TBI's than females, but are also more likely to avoid treatment, minimize complaint and suffer subsequent injuries, such that concussions in young males are underreported (McRea et al., 2004). Causal contributions to TBI are complicated insofar as loss of consciousness need not occur, however sudden rotations can produce injury (Kiraly and Kiraly, 2007)

Epidemiology of Traumatic Brain Injuries

TBI is the most common neurological disorder and affects 180 people out of 100,000 (Kiraly and Kiraly, 2007). It produces more deficits than any neurological disorder other than headaches (Kurtzke, 1984, and 15% of TBI patients are persistently symptomatic (Alexander, 1995). TBI's which result from motor vehicle accidents, falls, assaults, and sports related activities affect 7 million North Americans annually (McNair, 1999) and, in 1999 between 2.5-6.5 million U.S. citizens were living with long term effects of TBI's (NIH, 1999). Recent analysis indicates that more than 2% of the U.S. population suffers from TBI disability (CDC, 2001). TBI has cost over $48 billion dollars annually; $31.7 billion dollars for hospitalizations and $16.6 for fatal brain injuries (Lewin, 1992). From 2001-2009, hospital emergency visits regarding sports and recreational concussion related injuries in youth under 19, increased 62% from over 150,000 injuries to just fewer than 250,000 per year (Gilchrist et al., 2011). The Centers for Disease Control and Prevention (CDC) estimate that over 1 million patients are treated annually for nonfatal traumatic brain injuries in emergency departments within U.S. hospitals (McCrory, 2001; CDC, 2007; as cited in Bey and Ostick, 2009; p. 6).

Traumatic Brain Injury rates in Football

A cohort study of over 17,500 football players from 249 high schools and colleges during 1995-1997, found an overall incidence rate of .71 concussions per 1000 athletic exposures, with an incidence rate in high school students of 1.63/1000 (Guskiewicz et al., 2000). Almost half (47.2%) of 234 high school football players examined in Ohio and Pennsylvania, were reported as having sustained a concussion, while 34.8% reported having suffered multiple concussions, however a large majority of the TBI's were classified as grade 1, such that most players kept on playing (Langhurt et al., 2001). Symptoms of a TBI in the previous year were reported in 70.4%

of 328 football players, with defensive lineman displaying the highest incidence rates (Delaney et al., 2002). Investigation of 2,905 college football players revealed an overall TBI rate of .81/1000 athletic exposures, with a 3.81 incidence rate during games and .47 odds ratio during contact practices, linebackers were found to be most susceptible to injury (Guskiewicz et al., 2003).

Division 1 players during the 2001 season were found to have .73 TBI's per 1000 athletic exposures in 791 games, 2,839 contact practices and 1,708 noncontact practices, however almost one quarter (24%) of eligible teams chose not to participate in the study (Wisniewski et al., 2004). A three-year case control cohort study on 2,141 male high school football players demonstrated that 5.3% of athletes who wore improved helmet technology (revolution helmet) were concussed over the duration of the study, in comparison to 7.6% of those who wore standard helmet equipment (Collins et al., 2006). An investigation of 100 high schools and 55 NCAA 1-3 division teams, which represented over 830,000 athletic exposures, revealed a .48 incidence rate in the high school athletes, and a .63/1000 rate in the college athletes (Shankar et al., 2007). An epidemiological study which required certified athletic trainers (ATC) to report information online, revealed an incidence rate of .52/1000 athletic exposures, however ATC's did not attend all the practices and games (Yard et al., 2009). A retrospective case control study collected through a questionnaire from 168 college football players, found that 59% of the control group reported concussion symptoms following a head impact the previous year but were undiagnosed, and that 80% of diagnosed cases reported symptoms following impacts to the head during the year previous (Mansell et al., 2010).

Traumatic Brain Injury rates in Hockey

A prospective cohort study of 642 male hockey players with an average age of 22, found an incidence rate of 1.55 concussions per 1000 athletic exposures, and that the protection of a full-face shields reduced facial and dental injuries but not TBI's (Benson et al., 1999). A descriptive 15-year epidemiological study investigating women's field hockey at the collegial level, found that the risk of acquiring a concussion during game play was 6 times greater than during practice, and furthermore that 9.4% of all in game injuries were concussions, while 3.4% of injuries during practice were TBI's (Dick et al., 2007). A prospective cohort study of 67 male hockey players aged 16-21 found a rate of 21.52 concussions per 1000 athletic exposures, with a rate of 36.5% per game which far exceeds reports of 3.1% from the NHL (Echlin et al., 2010).

Traumatic brain Injury rates in soccer

A retrospective survey of 529 soccer and football athletes including 110 females and 419 males indicated that 62.7% of soccer players displayed TBI symptoms the previous year. Players had a three times greater risk of future brain injury, and females had higher risk of concussion than males (Delaney et al., 2002). A descriptive epidemiological study of male and female soccer player indicated that TBI's accounted for 10.8% of total injuries in 637,446 total athletic exposures, and furthermore represented 9.3% and 12.2% of all male and female injuries, respectively (Yard et al., 2008).

Traumatic Brain Injury rates across multiple sports

An observational cohort study investigating varsity high school athletes from 1995-1997, found that 5.5% of all injuries were concussions, while 63.4% of TBI's manifested from football, and verified that TBI rates during practice are lower (Powell and Barber-Foss, 1999). A prospective cohort study of male and female athletes from 12 sports found an overall rate of 17.5 concussions per 100,000 athletic exposures, with the highest rate in football (33.09/100,000) (Shulz, 2004). A retrospective survey on 93 males and 79 females in various college contact and collision sports found that 71% of athletes reported symptoms similar to those of a TBI, despite not reporting a concussion history during the pre-participation physical (LaBotz et al., 2005).

An epidemiological study collected by online reports as well as injury surveillance systems investigating high school and college athletes, found that TBI's account for 8.9% of all high school injuries and 5.8% of all college athletic injuries (Gessel et al., 2007). A retrospective cohort study investigating males and females over a 16-year period in 15 different sports found that 55% of all TBI's reported were from football (.54/1000; concussions/athletic exposure) (Hootman et al., 2007). Another descriptive epidemiological study of injuries in high school sports between 2005 and 2008, found that TBI's were the third most frequent reoccurring injury at 11.6% (Swenson et al., 2009). Sports related injury surveillance on a national level between 2008-2009, investigating male and female high school athletes from nine different sports, found 68.5% of concussions occurred during competition as opposed to practice and that 10.5% of TBI's were not the athletes' first (Meehan et al., 2010).

An epidemiological review of male and female high school athletes found that first time concussions occurred 22.2 times per 100,000 athletic exposures, and that repetitive TBI's (3.1/100,000) accounted for 13.2% of all concussion related injuries (Castile et al., 2012). A descriptive prospective epidemiological study from 1997-2008 investigating 158,430 male and female high school athletes from twelve different sports found a rate of .24 TBI's per 1000 athletic exposures, and that rates significantly increased after 2005 (Lincoln et al., 2011). A descriptive epidemiological study of male and female athletes in 20 different sports from 2008-

2010 found an overall rate of 2.5 concussions per 10,000 athletic exposures, and that TBI's accounted for 13.2% of all injuries which were reported (Marer et al., 2012).

These epidemiological studies reveal several distinguishing features of TBI acquisition. Of note are the high incidence rates among varsity and collegial athletes. Football had the highest incidence rates across the major contact sports, and incidence rates were higher during game play than practices. A TBI history was also evident in many athletes who sustained a concussion during athletic exposure, which raises concerns that participation in contact sports in high school and university may increase risk of developing permanent neurodegenerative diseases.

Literature trends in Multiple Traumatic Brain Injuries

Trends in multiple TBI (mTBI) literature indicate that: concussions are almost certainly under reported in athlete populations; the neuropathology of mTBI's is initially imperceptible and becomes evident over time; correlation exists between reoccurring concussions (under 5) and long-term neuropathologies; mTBI acquisition leads to increased probability of acquiring future injuries; and protective equipment reduces but does not eliminate risk of brain injury (Golberg, 2008; p. 349). These issues are specifically concerning for individuals, who have high exposure to repetitive brain trauma such as football, soccer, wresting and ice hockey, as well as military personal, domestically abused individuals and head bangers (Asken, 2017; p. 2).

Traumatic Brain Injuries and links to Alzheimer's disease

TBI acquisition has been associated with early development of Alzheimer's disease (AD) which is a chronic neurodegenerative brain disease which can lead to severe deterioration of memory. Post mortem findings of plaques of beta amyloid protein as well as neurofibrillary tangles of tau protein are diagnostic markers of AD (Esiri, 1994; Perry and Perry, 1988). The link between TBI and AD is supported by epidemiological research including case control and cohort studies, theoretical implications, as well as pathological and biological links (Lye and Shores, 2000; 115-126). Longitudinal studies support findings of increased risks of dementia and AD within TBI populations (Plassman et al., 2000; Schofield et al., 1997). Moderate brain injuries have been found to lead to a 2.3-fold increase of AD, while severe TBI's have been found to quadruple the risk (Plassman et al., 2000).

TBI has been linked to AD due to similar neuropathology and symptomology between AD and dementia pugilistica (discussed below), which can result from concussions (Rasmusson et al., 1995). The tangles which are persistent within dementia pugilistica have been found to be morphologically identical to the neurofibrillary tangles evident in AD (Allsop et al., 1990; Roberts, 1988). Furthermore, analysis of protein composition reveals that beta-amyloid protein omnipresent in AD is also diffusely dispersed within dementia pugilistca plaques within tangle formations (Roberts et al., 1990). It has been found that although the morphology of the plaques is different, the ones in dementia pugilistica have been found to be the most predominant plaque types in AD (Clinton et al., 1991). Mutations which have been found to facilitate AD have also been found to produce beta-amyloid proteins (Cummings et al., 1998).

TBI injuries can trigger beta-amyloid proteins within the cerebral cortices, thereby indirectly increasing risk of AD (Nicoll et al., 1995). Over-expression of the beta-amyloid precursor protein (APP) – which has been observed in the brains of humans after brain injuries, may encourage beta-amyloid protein development, and subsequently neurodegenerative cascade of AD (Roberts et al., 1994; Storey and Masters, 1995).

Traumatic Brain Injuries and Chronic Traumatic Encephalopathy (CTE)

Research regarding exposure to repetitive brain trauma and its link with dementia began in the early 19th century (Asken et al., 2017; p. 1). The clinical syndrome 'punch drunk' was first diagnosed in retired boxers in the late 1920's by Martland (1928). Punch drunk was later labelled as Traumatic Encephalopathy and was further diagnosed in professional pugilists or boxers (Parker, 1934). The term dementia pugilistica (DP) was later coined to describe symptoms in retired boxers (Millspaugh, 1937; as cited in Montenigro et al., 2014; p. 12).

The term CTE was first used to describe persistent symptoms in retired boxers (Bowman and Blau, 1940; As cited in Asken et al., 2017; p. 2) and was studied extensively in boxers by other investigators such as Critchley (1957), and Brandenburg and Hallervoden (1954) who first characterized AD pathology in a case study of a former boxer. Nervous system lesions were reported in samples of 37 retired boxers (Roberts, 1969; as cited in Asken et al., 2017; p. 2) and neuropathological investigations on 13 retired boxers, found that dementia pugilistica resulted from irregular neurofibrillary tangle deposition without plaques in the brain (Corsellis et al., 1973; As cited in Montenigro et al., 2014; p. 6). A later re-examination of these brains with novel staining techniques indicated the presence of AD-like plaques (Roberts et al., 1990).

Investigations of young cohorts who have sustained multiple mTBI's noted neurofibrillary tangles around blood vessels in the brain (Geddes et al., 1999). The first case of CTE in a retired football player was reported by Dr. Omalu and colleagues (2005). Correlations between concussion history, mild cognitive impairment and depression have been noted (Guskiewicz et al., 2005; 2007). Specifically, players who sustained three or more concussions were three times more likely to have significant memory problems, and five times more likely to develop early onset dementia. CTE was also found in a cohort of 68 brains with a history of repetitive mTBI's (McKee et al., 2009).

Chronic Traumatic Encephalopathy (CTE) and the National Football League (NFL)

The NFL denied links between the NFL and CTE in a series of publications by Pellman from 2004-2006. The conclusion was problematic since it was only a six-year study (1996-2001) of players in their 20's and 30's, data on loss of consciousness was not recorded, there was no mention of previous concussion history, and because it was unclear how many players from 1996 continued to play. Furthermore, the study occurred within numerous sites, used numerous examiners and no uniform method of evaluation was employed. Return to play guidelines used on players who sustained head trauma, included factors such as player importance to the team, the upcoming team schedule, as well as playing pressure from owners, families, coaches, agents and the media (Cantu, 2007).

Further analysis needs to take place on those living with neurodegenerative diseases such as retired football players in the Hall of Fame wherein long-term, longitudinal, multi-institutional, and multidisciplinary studies, investigate genetic makeup, schedule intermittent neuropsychiatric testing, and neuroradiological monitoring. These measures along with full autopsies and comprehensive post-mortem neuropathological examinations should be performed on the same individuals for brain tissue analysis and clinicopathological correlations, which could form the basis for prophylaxis (disease prevention) and therapeutic purposes (Omalu et al., 2006; p. 1091).

Traumatic Brain Injuries and Second Impact Syndrome (SIS)

Second Impact Syndrome was first described as occurring when athletes suffering from post-concussive symptoms return to play too early and subsequently sustain a second brain injury which can result in diffuse cerebral swelling, brain herniation and even death. This condition is rare, and only 35 probable cases between 1980 and 1993 were identified by the National Center for Catastrophic Sports Injury Research (Saunders and Harbaugh, 2009; Cantu, 1998; as cited in Bey and Ostick, 2009; p. 6). SIS exhibits a 90% mortality rate in 30 reported cases in the medical literature, and frequently manifested in high school or college aged athletes.

An investigation of high school and college athletes found 94 catastrophic head injuries during a thirteen-year period, which resulted in intracranial bleeding or edema. Another study of high school students found that 71% of individuals who suffered a concussion had suffered a previous one earlier that season, and 39% of the athletes played with residual symptoms (Boden et al., 2007; Cifu et al., 2008; As cited in Bey and Ostick; p. 6). SIS's primary feature of diffuse cerebral swelling is often observed in TBI's acquired in children.

SIS rapidly increases health risks, which include death (Kelly and Rosenberg, 1997) and can occur due to physicians' underestimation of appropriate recovery time. Three months after a concussion, 30-50% of patients still demonstrated symptoms, relative to control groups (Alexander, 1995; Dikman et al., 1995; As cited in Kiraly and Kiraly, 2007; p. 1773). Psychological and physiological stress can elicit periodic impairment in well-recovered patients, however sensitivities to alcohol, sleep, travel and work which last over two years are considered permanent (Binder, 1986; Stuss et al., 1985). 10-15% of patients investigated in several studies did not recover from a TBI one year following the injury and felt worse. Furthermore, 15% of this high-risk group developed persistent post-concussion syndrome (Kiraly and Kiraly, 2007; p.

1773). Elderly TBI populations, as well as those with demanding work are at further risk of always being aware of performance deficit (Binder, 1986; Mazzuchi et al., 1992).

Traumatic Brain Injuries in college football

Brogley Webb (2014; p. 107) notes that despite the apparent ignorance at the professional level, college football has warned about the effects of TBI's from as early as 1933. The National Collegiate Athletic Association (NCAA) stated within its medical handbook that concussions are treated too lightly and that, 'players must rest and be supervised, and not be permitted to return to play for up to 48 hours after the head trauma has occurred'. The 1930's collegiate handbook also suggested that individuals who suffer from the effects of head injuries for more than 48 hours should, 'not be permitted to compete for 21 days or longer, if at all.' It was not until 1937, however, that the American Football Coaches Association (AFCA) declared at its annual meeting that, 'sports demanding personal contact should be eliminated after an individual has suffered a concussion' (as cited in Brogley Webb, 2014; p. 107). Players who suffered three concussions were suggested to leave football forever. In 1991, the NCAA incorporated a grading system for measuring concussion severity, developed by The Colorado Medical Society (Thorndike, 1952; Weinstein et al., 2013; as cited in Brogley Webb, 2014; p. 107).

Traumatic Brain Injuries and the National Football League (NFL)

It was not until 1994 that the NFL (NFL) acknowledged the dangers of concussions for the first time by forming the Mild Traumatic Brain Injury (mTBI) Committee. The mTBI committee began the study of brain trauma, but discarded the results from hundreds of players, which led the Sports Medicine Research Laboratory to state that, 'the data that hasn't shown up makes their work questionable industry-funded research' (p. 107). This led Elliot Pellman, the co-chair of the mTBI committee to respond by stating that, 'concussions are a part of the profession, an occupational risk, like a steelworker who goes up 100 stories or a soldier' (as cited on p. 107).

Guidelines for returning to play were published in 1997 by The American Academy of Neurology, which recommended that players who get knocked out during gameplay be removed from the game. Features of a concussion were identified in a literature review of a thirty-year period from 1966-1996 and included: vacant stare; delayed verbal and motor response; confusion and inability to focus attention; disorientation; slurred or incoherent speech; gross, observable incoordination; inappropriate emotional outbursts; memory deficits; and loss of consciousness. Early symptoms of a concussion included headaches, nausea and vomiting, and lack of awareness of surroundings, while late symptoms included persistent low-grade headaches, light headedness, poor attention and concentration, memory dysfunction, fatigue, irritability, low tolerance to bright lights or loud noises, difficulty sleeping, anxiety, depression and sleep disturbance (Practice parameter, 1997; p. 582; table-1).

The NFL rejected the guidelines by responding that, 'We see people all the time get knocked out briefly and have no symptoms.' In spite of this, in 1999 the NFL's retirement board quietly began to give out millions of dollars' worth of disability payments after findings confirmed that former players had become 'totally disabled' due to 'league football activities' (as cited in Brogley Webb; p. 108).

Summary

Given the fact that young athletes are susceptible to TBI acquisition and the severe long-term health risks associated with injury related diseases such as SIS, CTE and AD, research needs to focus on the mechanisms that can influence TBI rates. Environmental contributions have been found to influence both physiological and psychological states in humans, and these effects vary according to season and geographic region. Given that NFL Football is played during the meteorologically unstable transition from the autumn to winter from coast to coast within the United States, biometeorological factors might increase injury susceptibility, or promote increased aggression in an already hyper-competitive professional athletic environment.

Geomagnetism and the economy

Given the pervasive influence of geomagnetic activity on environmental weather systems and human physiology, one might consider that geomagnetic fields naturally produced by the Earth might influence aggregate human behaviors such as economic stock market involvement. GMS's that are distinct from diurnal variation might also influence global stock markets, since bad mood is associated with cautious financial decisions (Wong and Carducci, 1991), misattribution (Shwarz, 1990), pessimistic choices and judgments (Wright and Bower, 1992) (Hirshleifer and Shumway, 2003 As cited in Krivelova and Robotti, 2003; p. 7), and can also lead to a hyper detailed and critical analytical approach (Petty et al., 1991).

The role of emotions in economic behavior should not be underestimated as studies have also indicated that mood can affect risk taking (Johnson and Tversky, 1983) and abstract judgments in the absence of concrete information (Clore et al., 1994; Forgas, 1995). Emotions influence the decisions made by professional securities traders (Lo and Repin, 2011; as cited in p. 2). Due to the fact that stock markets have been demonstrated to clear at prices where marginal buyers are willing to buy from marginal sellers, and that seasonal affective disorder and sunshine have been demonstrated to affect international stock market returns, GMS's which promote SAD should affect price and volatility. GMS's are most common during unstable meteorological conditions, such as spring and fall conditions, but are not purely a product of season insofar as depression associated seasonal affective disorders (SAD) can manifest as a result of GMS's, and last for several days following. Increased admissions [36.2%] of diagnostically depressed patients occurred during heightened geomagnetic activity relative to normal levels (Kamstra et al., 1993, Saunders et al., 1993; Kay, 1994; as cited in Krivelyova and Robotti, 2003; p. 2). Investigation of the relationships between geomagnetic activity, melatonin and depression found that storms influence pineal gland activation and its ability to produce melatonin, which is essential for sleep cycles and mood (Tarquini et al., 1998).

Geomagnetic variations in intensity correlate with anxiety, sleep disturbance, altered mood (Persinger, 1987). Pilots exposed to increased helio-magnetic (solar) exposure demonstrated intensified homeostatic levels and increased anxiety, which resulted in decreased functional activity of the central nervous system, and ultimately declined flying ability (Usenko, 1992; as cited in Krivelyova and Robotti, 2003; p. 3). The average number of patients with mental and cardiovascular disease has been seen to double during GMS's, in comparison to quiet days, with cases of myocardial infarction, angina pectoris, and disrupted cardiac rhythm twice as frequent during storms (Kuleshova et al., 2001; as cited in Krivelyova and Robotti, 2003; p. 3).

Investigations of diurnal urgent hospitalizations within Moscow indicated that attempted suicide, mental disorder, myocardial infarction, as well as cerebral, arterial, and venous diseases increased between 30-80% during at least three out of four storms. Conditions of enhanced stress and inhibition of the central nervous system can occur in normal healthy people during the recovery phase of storms. This would imply an effect of geomagnetic activity on circadian rhythm (Oraevskii, 1998; Zakharov and Tyrnov, 2001 As cited in Krivelyova and Robotti, 2003; p. 4).

Lunar effects and the economy

Studies indicate that investors display behavioral and psychological bias in investment decisions including mood fluctuation, overconfidence, and loss aversion. Mood has also been determined to affect human behavior and judgments, as well as asset prices (Yaun and colleagues, pp. 1-23). Mood change attributable to lunar phase could act as a mechanism by which lunar transit effects stock markets.

Biological research has extended into the lunar effects on mood, which encompasses the domain of Moon-related human cycles also known circatrigintan cycles. For example, a synchronous relationship between women's menstrual cycles and lunar phase has been identified (Law, 1986; As cited in Yuan et al., 2006; p. 7) and peak births occur during the third quarter lunar phase (Criss and Marcum, 1981). Nutrient uptake in humans can also cycle with the lunar phase, as full moons elicited about 8% increases in meal size, and 26% decreases in alcohol intake (de Castro, and Pearcy, 1995). Increased general practice consultations occur during the full moon (Neal and Colledge, 2000) and studies found increased criminal offences during full moons (Tasso and Miller, 1976; Liber, 1978). Higher numbers of crisis calls occur during full moon and waning phases. Developmentally delayed, institutionalized women furthermore, 'act out' during the day of full moons. Studies indicate decreased absenteeism occurred during full moons, even after controlling for day of week, month and holiday proximity (Weiskott, 1974; Hicks Caskey and Potter, 1991; Sands and Miller, 1991; As cited in Yuan et al., 2006; p. 7). The cyclic pattern of the Moon has predicted stock market price patterns and returns, insofar as differences occur between extreme lunar conditions, such as that of new and full moon lunar phases. Full moons have specifically yielded lower returns then new moons, not only in the United States (Dichev and Janes, 2003; as cited in Floros and Tan, 2013; p. 109) but also in 48 countries worldwide (Yuan et al., 2006). Silver and platinum investigations indicate that precious metals are susceptible to this effect (Lucey, 2010; as cited in Floros and Tan, 2013; p. 109).

Belief in lunar effects on behavior varies. For example, less than half (49.4%) of survey respondents were documented as believing in lunar related influences on behavior (Rotton and Kelly, 1985), but 74% of psychiatric nurses, and 80% of nurses and 64% physicians within emergency departments believed that the cycles of the Moon affect behavior. The influence of the Moon on human behavior could be due to effects on the human brain, which include; sleep deprivation, heavy nocturnal dew, tidal effect, weather patterns, or magnetism and polarization of the Moons light (Agus, 1973; Vance, 1995; Danzl, 1987; As cited in Yuan and colleagues, 2006; p. 8).

Literature indicates that psychological factors play an active role in economics and financial markets. Behavioral finance theories such as the efficient-market hypothesis (EMH), states that stock prices reflect all available information and might have explanations through the psychological principles of decision-making. Behavioral finance incorporates the psychological bias, emotions, and moods of market participants, such that overconfidence and optimism can lead decision makers to overestimate probabilities of success and underestimate the risk of outcomes (Garling et al., 2009; Alt et al., 2011; Nofsinger, 2003; As cited in Floros and Tan, 2013; p. 108).

Research demonstrates that mood affects asset returns (Yuan et al., 2006). Affective states such as mood and anticipation influence financial decision making, such that optimism and overconfidence are psychological factors, which could have disastrous consequences in financial situations (Garling et al., 2009; As cited in Floros and Tan, 2013; p. 124). Researchers insist that psychological and behavioral theories are closely associated. Optimism associated with calendar events have impacted stock markets, which could be attributable to the association between optimism and feelings of personal control, such that the stock market is a mechanism by which confident people can exert their influence (Ciccone, 2011; As cited in Floros and Tan, 2013; p. 124).

Summary

SAD has been studied with regard to traditional finance, wherein economic models include a host of environmental predictors of the disorder which have been hypothesized to influence market fluctuations. GMS's have been studied within economic investigations due to the fact that they have an influence on the individuals who participate in the market. Links between emotional states and financial decision making has also been investigated in relation to the Moon. The literature attempts to identify a quantifiable link between aggregate emotional states with background environmental processes in relation to financial market fluctuations. Studies consider psychological and behavioral theories in addition to physiological considerations. Recent technological advances have created a need for a paradigm shift regarding aggregate emotional states in the age of the internet of things (IoT), with big data analytics now available which can track global online behaviors such as Twitter, Facebook and Google.

Furthermore, studies which explore the relationship between GMS's and lunar phase are limited by the time increments they explore, as daily measures would be necessary. Measures of the Earth's static magnetic field would require larger windows of time such as weekly averages.

Introduction to Cryptocurrency

Digital currency has become a global phenomenon since the 2008 inception of Bitcoin, which acts as a borderless currency, a medium of exchange, a distributed ledger, a store of value, and a cryptographically secure method of payment which is self-governed and protects against both fraud and double spending.

Cryptocurrencies however, have long been attempted throughout recent history such as Digicash (Chaum, 1983), Hashcash (Back, 1997) b-money (Szabo, 2002) as well as micropayments (Shirky, 2000). Furthermore, Cypherpunk was an activist group in the 1980's who advocated cryptography for social and political change in the 1980's (As cited in Nian and Chuen, 2015; p. 10). Satoshi Nakamoto (2008) published a whitepaper detailing a concept known as BTC; which described a peer-to-peer electronic system and borderless digital currency, which would allow for near real time online payments without the reliance on tertiary financial institutions.

Bitcoin (BTC) was subsequently created in 2009 and served as a Libertarian response to the financial crisis which arose in 2008, as a result of the central banks inability to address the traditional markets collapse that year (Bariviera et al., 2017). BTC has since emerged as a digital asset and medium of exchange, and has become a global phenomenon (Barrdear et al., 2014; As cited in Bariviera et al., 2017) which is regularly addressed by capitalists, the media, government and financial institutions (Glaser et al., 2014).

BTC as a medium of exchange

The BTC system is an open-source, peer-to-peer cryptocurrency which allows quasi-anonymous transactions through the application of public-private key technology and decentralized clearing of payments (Nakamoto, 2008). During a BTC transaction, both the sender and receiver have private and public wallets. Users can send and receive BTC's while collective validation of the transaction is provided in a transparent and decentralized manner on the blockchain. The blockchain is the primary technology associated with BTC, and is an open public ledger which is shared between traders and requires validation of transactions from decentralized community members who are rewarded through mining or acquiring BTC. The blockchain utilizes cryptography in order to secure transactions and control the creation of additional currency units (Pagliery, 2014; Vigna, 2015; As cited in ElBahrawry et al., 2017; p. 1).

Blockchain technology

Blockchain can be defined as a digital database which contains information that can be simultaneously used or shared in a large network which is decentralized and publicly accessible (Karels, 2018; p. 3). Blockchain technology allows for cryptocurrencies to be verified and secured by network users, whereas the blockchain itself can be considered a chain of connected blocks which contain records of information kept in a public ledger which is distributed across all of the computer nodes within the network and is accessible to anyone in it (Karels, 2018; p. 3). Blockchain can also be defined as a replicated state machine, insofar as it is a distributed system that relies on consensus protocol, which supports communication through the transmission of data among its components (Xu et al., 2016; p. 7). Several studies (Glaser, 2017; Risius and Spohrer 2017; As cited in Hawlitschek, 2017) indicate that the primary feature of blockchain, which makes it an interesting technological development, is that it can also be considered a shared database amongst users allowing them to publicly and pseudo-privately trade valuable assets without a dependence on a third party or central authority.

Blockchain can also be considered a database that is distributed over many computers, and is composed of three separate technologies; peer-to-peer networking, asymmetric cryptography and cryptographic hashing. Peer-to-peer networking is a group of computers that communicate without reliance of a centralized authority. Asymmetric cryptography is a method by which encrypted messages - such as public and private keys – allow verification of sender authenticity but ensure that only intended recipients receive the contents. Cryptographic hashing is the generation of small but unique data fingerprints, which allow quick comparisons of big data to ensure it remains unaltered. This allows for a structured record of the canonical order of transactions, so that the network can be synchronistic (Dannen, 2017; p. 4). This is accomplished as each block is assigned a header and time stamp which is hashed. The hash includes the encrypted reference to the underlying data within the block. The data can be removed but the hash remains in the block which provides a high level of security insofar as possible hacks of the hash do not reveal the data it refers too. Thus, encryption, distribution and the hash which keeps the data out of the blockchain, make the database highly secure (Pike, 2017; As cited in Karels, 2018; p. 4).

Blockchain adoption

Blockchain technology has considerably contributed to the Internet of Things (IoT), which is a network of physical objects that are connected through the web. The problem with the

IoT is that private data is collected from these objects and may not be stored securely by the organization. The technology of the cryptocurrency market thus has applications within society which are independent of cryptocurrency such as data storage management, trades of goods and data, identity management, and rating system (Conoscenti et al., 2018; p. 2).

The usage of blockchain technology in data storage, include management of access policies and references to user's data (Zyskind et al., 2015a), data storage contracts (Vorick and Champine, 2014), document storage contracts (Bocovick et al., 2015), tamper-proof log of events and management of data access control (Zyskand et al., 2015b), and automatic compensation of clients lost data from storage servers (Ateniese et al., 2014). Blockchain applications have been implemented in the trading of goods and data which include the purchase of assets such as data from IoT sensors on humans and devices and (Zhang and Wen, 2015; As cited in Conoscenti et al., 2018; p. 2) (Worner and Bomhard, 2014).

Blockchain technology has been used in identity management through the verification of PGP certificates (Wilson and Atemiese, 2015), as well as in public key infrastructure, wherein updates, registration, and revocation of keys is managed (Axon, 2015; Fromkecth et al., 2014). Blockchain has also been used as a rating system, as it has been implemented as a tracking method of users in social voting systems, as well as a rating system wherein customers can provide feedback with regard to purchases (Vandervort, 2014; As cited in Conoscenti et al., 2018; p. 2).

Other non-cryptocurrency applications of blockchain technology include the management of software licence validations (Herbert and Litchfield, 2015), a timestamp service in order to verify content is produced before a specified date (Gipp et al., 2015), lottery implementation

(Bylica et al., 2015), banking applications including distributed and automated bank ledgers (Peters and Panayi, 2015), as well as a method of quantifying social influence through the implementation of a social cryptocurrency (Ren, 2014; As cited in Conoscenti et al., 2018; p. 2).

Cryptocurrency mining

Mining is the process by which complex algorithms are solved by computers using processing power. Miners compete with each other to add new transactions to the blockchain and are incentivised by receiving transaction fees from members within the community (Dwyer, 2015; p. 83). The process of mining is computationally demanding on individual nodes and requires a memory-intensive hashing algorithm (Dannen, 2018; p. 111). Nodes, which are operated by miners, verify new blocks on the chain and are rewarded with a payment for their service; this is accomplished through transaction fees and the creation of newly mined coins. With each new verified block, new coins are distributed to the miners for their time and effort, however mining difficulty increases over time, which reduces the reward. BTC is a scarce resource and the number of coins in circulation cannot exceed 21 million (Nakamoto, 2008). For this reason BTC can be considered an asset similar to gold, as the steady addition of new coins by the work of miners is similar to the work of gold miners who expend energy to add gold to the world's circulation.

The generation of BTC through the mining process is merely incentive to ensure that new transactions are added to the blockchain and subsequently confirmed. The verification process is computationally intensive, because miners are required to find solutions to complex mathematical problems which are solved by computers, but is necessary as it ensures that only legitimate transactions are recorded on the blockchain. The idea of a blockchain that had unlimited inter-transaction storage which uses a Turing complete language was later proposed in

2013 by Vitalik Buterin and was built on the concept of transmitting a value signal over the internet through cryptographic proof of work, which was originally proposed in the 1990's by Dwork and Naor (Wood, 2014; p. 1).

Proof of Work (PoW)

Proof of Work (PoW) as a spam deterring value–signal was also attempted by Finney in 2014 (As cited in Nian and Chuen, 2015; p. 10), however Wood (2014; p. 1) notes that its primary function is to carry a strong economic signal without relying upon trust as was similarly attempted by Back in 2002. In 2003, Vishnumerthy and colleagues (As cited in Wood, 2014; p. 1) successfully utilized a proof-of-work system to produce a strong economic signal in order to secure a currency, such that the token was used as a means of consumer micro-payments for supplier services within peer-to-peer file trading networks. PoW performs a given function but at an economic cost, such that it can be considered data which is costly to produce but trivial to verify, which is designed to deter people within the community from double spending digital currencies on the blockchain (Farell, 2015; p. 6).

Forks

There are 3 types of forks which include soft forks, altcoins and hard forks. Soft forks result in a rule changes that manifest in a new cryptocurrency which generates its own blocks, but that are identified as valid by the original blockchain. Altcoins are the creation of a unique cryptocurrency with its own blockchain which is dependent upon the original blockchains source code, but acts independently of it. Hard forks are disagreements between cryptocurrency developers and members of its community, such that it results in the creation of two cryptocurrencies which are technologically incompatible (Trump et al., 2018).

Introduction to Ethereum (ETH)

In 2015, Ethereum (ETH) forked from BTC and was released with the goal of facilitating transactions between people who would otherwise have no reason to trust one another, whether from factors such as spatial displacement, difficulty interfacing, or due to incompatibilities, incompetence, inconvenience, uncertainty, unwillingness or expense associated with the existing legal systems (Wood, 2014).

While BTC can be considered a virtual machine; ETH adds a global messaging framework component, as it allows for creation of altcoins, with protocols that enable them to communicate with each other. Blockchains built on the ETH network are also known as decentralized applications (DApps). ETH is forward thinking as it assumes that the cryptocurrency future will be a distributed network of decentralized systems, as opposed to a singular decentralized system such as BTC (Dannen, 2018; p. 5). Barbados has already issued its own digital dollar using blockchain software.

The ETH network executes programs in lockstep, which is why it is referred to as the Ethereum Virtual Machine (EVM), which can be defined as a shared ownerless computer. Changes in the EVM are achieved through hard forking which requires persuasion of the entire community of node operators, due to the ownerless configuration of the EVM which is intended to maximize security and uptime, as well as discourage sabotage or subterfuge. All ETH transactions are recorded on the blockchain, and subsequently stored on every node in the network. This is why the blockchain is considered a canonical history of state stored in every EVM node (p. 8).

People, governments and corporations use BTC to transfer value, which requires them to pay a small network fee, which is used as incentive for the miners. Ether is used in a similar manner, but can be additionally used as gas to run programs on ETH’s network, also known as smart contracts which can distribute ether at different temporal increments when conditions are satisfied. Smart contracts are executed by the EVM which can be considered an open and distributed virtual computer (Hirai, 2017; p. 1).

Smart Contracts and decentralized applications

Smart contracts were originally proposed in 1993 by Szabo, but the economic and communication infrastructure were not adequate. The Turing-complete contracting language of ETH allows for complex contracts to be created and enforced on its network. Modern corporations can be defined as a set of contracts with investors, management, employees, customers and suppliers, if these contracts were automated then the possibility of distributed autonomous originations (DAO) are possible (Omohundro, 2014). Smart contracts allow for the creation of alt coins which are individual blockchains built on the ETH network.

The ability to create alt coins on the EVM, allowed the cryptocurrency market to explode as a result of the creation of over 1500 alt coins which share the block-chain technology and its incentive structure but provide significant innovations (Hileman and Rauchs, 2017; As cited in ElBahrawry et al., 2017). The primary uses of cryptocurrency are as a medium of exchange and speculation (Ceruleo, 2014; Rogojanu and Badea, 2014). Cryptocurrency can additionally be used as a non-expensive transfer of cross-border payments, or in a non-monetary manner such as time stamping. The cryptocurrency market is highly volatile, insofar as it has self-organized applications both within individual coins, as well as across the market (Yermack, 2013; White, 2015; As cited in ElBahrawy, 2017; p. 2).

Why cryptocurrency?

Millions of private and institutional investors actively exchange cryptocurrencies, such that the cryptocurrency market capitalization surpassed $91 billion dollars by May 2017 (Hileman and Rauchs, 2017). Economic and theoretical interest in the cryptocurrency market has produced studies that focus on the transaction network, projected prices, or top cryptocurrencies within the market (Elbahrawy, 2017).

The traits of cryptocurrency that make it appealing include an open sourced, decentralized, peer-to-peer network that is global, fast, reliable, secure, flexible and sophisticated, with automation and scalability, that can allow it to be a platform for integration. The Open-source software that cryptocurrencies rely on, allows for developers to verify code and possibly implement changes necessary for network adoption. The decentralized manner ensures that the technology and currency is not controlled by a single entity authority. The peer-to-peer protocol eliminates centralized authorities in the exchange of value. The global nature of cryptocurrency denotes its borderless nature and universally accepted exchange rates. The speed of cryptocurrency exchange is currently not ideal; however, transaction speeds can be modified and confirmation times can be shortened.

Cryptocurrency is considered reliable insofar as it protects against double spending through the governance of miners and open ledger on the blockchain, such that there is no settlement risk, which traditionally has the potential to be expensive. Payments are secure because of the entire network’s knowledge of which wallets contain value and those which do not. Cryptocurrencies are sophisticated but flexible which allows them to adjust to or support other types of assets, financial instruments and markets. The scalable capacities of cryptocurrencies allow for the possibility of mainstream adoption. Cryptocurrency can be considered a platform for integration insofar as they can be designed to incorporate digital finance and law within its ecosystem in order to support financial transactions associated with smart contracts (Nian and Chuen, 2015: p. 12-13).

The primary shift away from the traditional financial infrastructure results from technologies and information systems such as cryptographic algorithms and peer-to-peer connectivity that allows for decentralized organisation, operational transparency and security which violate the rules of traditional financial systems as first suggested in the late 1960s by Samuelson. Digital currencies have been considered community currencies (Glaser et al., 2014; p. 1-3).

The rise in cryptocurrency has been considered the product of human engagement with money and debt (Graeber, 2011). Interest in cryptocurrency originates from a general rise in attention to technology and finance (Davis and Greenberg, 2011). The cryptocurrency market is highly speculative and extremely volatile, and as such has risen at unprecedented speeds over a relatively short period of time, which was speculated to be largely driven by investor excitement. Research has begun to explore the mechanisms by which investors choose cryptocurrency as a partial (Delmolino et al., 2016) or even full substitution for traditional fiat currencies (As cited in Chohan, 2017; pp. 1-8).

Factors that drive Cryptocurrency price

Cryptocurrency prices are determined by internal and external factors. Internal factors include transaction costs associated with PoW, the reward system, mining difficulty, the number of coins in circulation, and rule changes also known as forks. External factors which influence cryptocurrency prices are their popularity, the market trend, and the speculative nature of the market. Macro-financial factors such as traditional stock markets, exchange rates, gold prices and interest rates can also influence cryptocurrency. Political factors such as legalization and restriction can determine who is a market participant (Poysner, 2017; As cited in Sovbetiov, 2018; p. 7).

Government regulation can encourage cryptocurrency growth by adding legitimacy, and reducing volatility through limiting fraud, protecting consumers, complying with economic sanctions as well as introducing methods of taxation. Public interest is also essential for the cryptocurrency market as its structure is largely maintained by the people within the community, such that the largest indicators of success are currently the market capitalization, number of users and daily trading volume. Retailers have begun to accept cryptocurrency as a payment method

Summary

The unregulated and 24-hour nature of cryptocurrency makes it highly speculative and appealing to risk takers in financial markets. The borderless nature of digital currency makes it easy for peers to make digital transactions worldwide which are verified by the self-governed network and protected against fraud and double spending. The public record of verified transactions on a distributed open ledger allows for trust within a community of strangers. The scarcities in BTC that is available, due to the limited amount that will ever be in circulation make it a possible disrupter to traditional financial and governmental institutions. The volume of investors and day traders within the market is beginning to grow, transitions from early to mainstream adoption have begun to occur, and regulated institutional infrastructure and adoption is beginning to take form. Both individual humans and financial markets are susceptible to environmental influences, whether from SAD, geomagnetic, solar, or lunar sources. Micro changes in human physiology due to meteorological context might be reflected in macro observations such as economic market participation, so that environmental models exploring optimal combinations of external contributions may have predictive value in understanding future cryptocurrency market movement and popularity interest.

Due to the aforementioned juxtapositions of the traditional and cryptocurrency markets, along with the collective engagement of all members within the community, and the novel, volatile and speculative nature of cryptocurrencies such as ETH, one might question whether the environmental predictors, if any, might be opposite of those obtained in models which predict traditional markets. As a global phenomenon, Cryptocurrency is highly volatile and has produced the greatest economic Bull Run in the history of markets. Price is driven by a myriad of internal and external factors which could make the industry susceptible to environmental contributions. Furthermore, the decentralized governance and community driven production of new tokens within circulation, suggests a direct mechanism by which factors which influence human behavior could directly influence price. Interactions between independent variables such as solar activity and lunar transit on the intensity of the Earth’s geomagnetic field may enhance the effect of potential environmental contributions to Cryptocurrency market movement.

Conclusion

The mechanisms by which the environment can influence human behavior are extensive, whether from changes in the reflexivity of the nervous systems in response to environmental input, or entrainment of circadian rhythms. Intrinsic thermoregulatory mechanisms can furthermore alter physiological factors including cardiovascular functioning, blood composition, metabolism and even disease.

The biometeorological candidates which may influence human behavior abound. Variations in temperature occur throughout the day and over longer increments of time and space, which include seasonal or climactic considerations. Variables such as humidity can alter the atmospheric water vapor which can influence biological heat loss. Barometric pressure furthermore fluctuates relative to factors including thermal agitation, which varies as a function of temperature, as well as geospatial considerations such as latitude and altitude. Changes within the ionosphere which alter atmospheric charge influence mood and performance, and can result from extra-terrestrial contributions including solar activity. Energy from the Sun has also been demonstrated to significantly alter the naturally occurring magnetic field produced by the Earth. Geomagnetic field intensity variation alters not only weather systems, but individual and aggregate human behavior as well.

Other external forces include lunar cycles, which can influence atmospheric activity, geomagnetic intensity, and biological function through gravitational contributions. These complex interactions between biological systems with their external environment underscore the critical importance of incorporating interdisciplinary approaches within scholarly investigations, because research questions drive methodological process and therefore are integral with regard to discovery. This research will explore biometeorological contributions to human behavior in three separate investigations. The first chapter concerns occupational health and will explore the meteorological conditions during TBI acquirement which will be collected from open source databases in order document trends and incidence rates during specific environmental factors in order to synthesize injury prediction models for the purpose of enhancing safety. Aggregate social behaviors including participation in traditional and digital economics will be explored in separate chapters.

Chapter 2 - Investigation of potential influences on Traumatic Brain Injuries (TBI's) in The National Football League (NFL)

This chapter introduces and defines the environmental and player variables, and method used to investigate the influence of biometeorology on TBI in the NFL. The purpose of this study is to measure the intrinsic capacities within the sport of football that may enhance or inhibit TBI acquisition during participation in football. This study furthermore aims to determine if less traditional factors such as geography, weather related phenomena, or celestial alignment of the Earth, Moon and Sun can also predict TBI occurrence and severity.

The structure of the National Football League (NFL)

There are 32 teams in the NFL. Teams play 16 weekly games in the regular season from Labor Day until the end of the regular season in late December. The NFL is split into two conferences, the American Football Conference (AFC) and National Football Conference (NFC). Each conference is subdivided into four divisions which are composed of four regionally clustered teams in proximally located cities. Twelve teams make the playoffs based on their win-loss record, including six from each conference. The top team from each of the eight divisions automatically qualifies for the post-season, and the two highest seeded teams that did not win their division, also make the playoffs in each conference and are considered 'wildcard' teams. The playoffs include four rounds: Wildcard, Divisional, Conference championship, and the Superbowl.

The game of football

The objective of the game is to move the football, either by carrying (rushing) it or throwing (passing) it to another player, down the field into the opposing team's end zone. Each NFL team is composed of 53 men on the roster, who have specific roles including offensive, defensive and special team responsibilities. There are 22 players on the field at any given time, 11 on offense and 11 on defense. The offensive positions are: quarterback; wide receiver; running back; tight end; offensive tackle; guard; and center. The defensive positions are: defensive tackle; defensive end; linebacker; cornerback; and safety. The center touches the ball on every play and snaps it to the quarterback, at the beginning of a new play. Due to the heavy involvement of the center and quarterback, these positions can largely dictate the flow of the game. The offensive line is composed of bigger but slow moving players who block for the quarterback.

The offense is granted four attempts to score a touchdown. If this unit moves the ball 10 yards down the field (a first down), they are granted four new opportunities to reach the end zone (an additional set of downs). Touchdowns result in six points, and require an extra point be scored for a seventh point from the team's special unit. If the offense fails to score a touchdown, they can still kick a field goal for three points if they are close enough for the kicker to execute the kick. Coaches typically design plays to take advantage of mismatches between offensive and defensive players. If a cornerback is shorter than average, an offensive coach may match him against a tall wide receiver, or if linebackers are bigger than average, coaches may design running plays which require the linebackers to move from sideline to sideline as opposed to up and down the field. These mismatches can make certain player profiles more susceptible to injuries.

Football Statistics

Player statistics are based on the duties of each position: movement down the field; passing or receiving the ball; or stopping the movement of the opposing team. Offensive players are rated on yards moved down the field, passing distance, rushing yards, and success at passing, receiving or running the ball. If a player averages 100 yards per game, he has contributed a football field's worth of work and is considered both consistent and productive. Defensive player ratings are based on success at moving the opposing team backwards, intercepting passes made by the opposition, or forcing an opposing player to fumble the ball. Aggregate scores can be calculated from these player-specific statistics, which give both an indication of the player's approximate value and overall rank. Player statistics determine annual salary, athletic exposure, and their ability to be nominated into the pro-football hall of fame. They are also used in 'fantasy football' in which each participant creates their own custom team chosen from the entire roster of players in the league and tracking their team's success by assigning points based on those players' statistics.

Methods

Variables for the 645 TBI's which occurred in the NFL between 2012 and 2015 were collected from frontline.org/concussion-watch. The dataset tracked which players were removed from gameplay after a hit to the head in association with Quintile Analytics and Injury Surveillance (QAIS). Variables include: player position, organization, games missed due to injury, injury type (concussion/head injury), week injured, average athletic exposure in games before injury, snap count in return game from injury, as well as specific qualitative notes and media coverage regarding each TBI case. For the TBI cases that were time stamped, other independent variables of interest (VOI) collected from *nfl.com* included: date and location of injury, and whether the injury occurred in gameplay or in practice.

Player profile

Measures of TBI player height, weight, age, years of professional football played, draft profile, athletic exposure, and hall of fame reference groups were collected from *pro-football-reference.com*. Height and weight were subsequently converted into body mass index (BMI) using U.S. units [BMI = weight (lb)/height^2 (in^2)], and then confirmed using standard metrics [BMI= weight (kg)/height^2 (m^2)].

Body Mass Index

Body Mass Index (BMI) estimates body fat of adult men and women by relating weight (mass) to height. The 'healthy' BMI range is between 18.5 and 24.9, and higher values indicate obesity. The healthy range is based on assumed 'healthy' proportions of fat and muscle; therefore, since muscle weighs more than fat, muscular athletes usually fall outside the normal range. The average BMI of an NFL player is 31.35, while the average BMI for TBI cases was 30.63.

Position relative BMI classifications were determined for TBI players. These clusters were determined according to all players from 2012 to 2015 in reference to all players who played in the NFL during the 2012 NFL season (As cited on *https://www.sportingcharts.com/articles/nfl/what-is-the-average-bmi-of-an-nfl-player).*

Table 1 League wide average BMI of all players who played in the NFL during the 2012 season

Position	Average BMI
Running back	30.98
Quarterback	27.78
Wide Receiver	26.61
Tight End	30.62
Offensive tackle	36.73
Guard	38.05
Center	36.72
Cornerback	26.58
Defensive end	33.83
Defensive tackle	38.22
Linebacker	31.34
Safety	27.97

Athletic exposure

Annual athletic exposure for TBI players was determined from data provided by *footballoutsiders.com*. Annual athletic exposure data was also collected for all players (N=8674) who played in the National Football League (NFL) between 2012 and 2015, and were used as a reference group.

Offensive player statistics

Offensive annual statistics were collected for all running backs (N=492), quarterbacks (N=216), wide receivers (N=600), and tight ends (N=318), who played in the NFL between 2012 and 2015.

Table 2 League wide statistics collected for all offensive skilled positions

Age	Pass complete	Reception Targets	Rush attempt
Games played	Pass attempt	Receptions	Rush Yards
Games Started	Pass yards	Receiving yards	Rush Y/A
Fantasy points	Pass TD	Receiving y/r	Rush TD
Position Rank	Pass interception	Receiving TD	Year

Fantasy football statistics

Yearly and weekly football fantasy statistics were calculated for the 229 National Football League (NFL) skill position TBI players who acquired them during in-game circumstance. The skill positions include; quarterback (QB), running back (RB), tight end (TE), and wide receiver (WR).

Table 3 Fantasy football point structure by position

1 point per 25 yards passing
4 points per passing touchdown
-2 points per interception
1 point per 10 yards rushing/receiving
6 points per Touchdown
2 points per two-point conversion
-2 points per lost fumble

Value approximation and player rank

Value Approximation (VA) scores were collected from *pro-football-reference.com* for the TBI players. The VA method obtains a single value from a host of position specific variables that contribute to NFL success; and is weighted with regard to games played, games started, and pro bowls selections. This allows investigators to assign an approximate rating to every player in the NFL since 1950. VA is formulated with three primary assumptions: (1) the offensive line is exactly as good as the offense; (2) the offensive line is equally important in the running game as it is in the passing game; and (3) the ratio of pass-thrower importance to pass-catcher importance is constant from team to team. NFL *rank* is a rank relative to every other player who has played the same position since 1950.

TBI history

Documented cases of previous TBI injuries sustained by TBI players were determined from various online sources including *frontline.org* and *kffl.com*. This data was used to determine whether injury diagnosis considered players with accumulated and repetitive head trauma.

Spatial considerations

Stadium details of the location the TBI occurred was obtained from *Google.com*, including: year the stadium opened, seating capacity, field type and roof type. Field type was clustered into the following categories: field turf, artificial, bluegrass, synthetic, grass, Tiffway Bermuda, Voyager Bermuda, and Latitude Bermuda Grass. Roof types clustered into open, closed and retractable roofs.

Longitude, latitude, and altitude of injury origin

The latitude and longitude of the NFL stadiums in which TBI's occurred was determined from *latlong.net*. Altitude for each stadium within the NFL between 2012 and 2015 was also determined from *mapcoordinates.net*. The average elevation above sea level for all NFL Stadiums during this period was 159.84 meters (524.28 feet). Stadium manual cluster classifications were determined in relation to these values.

Latitude cluster classifications of NFL stadiums in which TBI occurred

The 31 NFL stadiums were split into high/low latitude cluster-classifications based upon the league average. This resulted in a low latitude cluster ranging from 25.96-39.05 degrees and a high latitude cluster ranging from 39.10-47.60 (see Table 4).

Table 4 High and low latitude clusters of all 31 NFL stadiums

latitude cluster classifications			
Low	latitude	Hi	latitude
Miami	25.96	Cincinnati	39.1
Tampa Bay	27.98	Baltimore	39.28
Houston	29.68	Denver	39.74
New Orleans	29.95	Indianapolis	39.76
Jacksonville	30.32	Philadelphia	39.9
Arizona	32.23	Pittsburgh	40.45
Dallas	32.74	New York	40.81
San Diego	32.78	Cleveland	41.51
Atlanta	33.82	Chicago	41.86
Carolina	35.23	New England	42.09
Tennessee	36.17	Detroit	42.34
San Francisco	37.4	Buffalo	42.77
Oakland	37.75	Green Bay	44.5
St. Louis	38.63	Minnesota	44.97
Washington	38.91	Seattle	47.6
Kansas City	39.05		

Biometeorological considerations

Atmospheric variables were analysed as potentially promoting injury susceptibility and severity or potential increased aggression during gameplay. These meteorological considerations include, weather, lunar cycles, local geomagnetic intensity, and solar activity.

Weather

Weather measures during TBI acquisition were determined from *nflweather.com*. These included: temperature, humidity, dew point, wind strength, wind direction, and visibility. These variables clustered into pre-specified classifications in order to determine potential influence on TBI severity.

Moon

Lunar data during day of injury were collected from *calender-12.com* and included phase, percentage full, and moon age. The lunar phases used were new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter, and waning crescent. Percentage full (percent of Moon visibility) and moon age (number of days since last new moon) allow for parametric analysis of Moon phase. Secondary lunar variables of interest, collected from *https://ssd.jpl.nasa.gov/horizons.cgi*, were: visual magnitude; surface brightness (Visual magnitudes/square arcsecond); range of center (AU); relative motion (KM/S); Sun-Observer-Moon angle (Moons Solar Elongation seen from Earth observer); and Sun-Moon-Observer angle (interior vertex angle at Moons center).

Solar and geomagnetic data

Daily average global sunspots (S) for the day of TBI origin were determined from *www.sidc.be/silso/datafiles*. Measures of the Earth's local magnetic field including intensity measures from the overall geomagnetic field (F; nT=10^{-9} Tesla), horizontal component (H), north/south component (X), east/west component (Y), and orthogonal (Z) component, as well as degrees of field declination (D) and inclination (I) were collected from *http://www.geomag.nrcan.gc.ca/calc/mfcal-en.php*. Also obtained from this source were annual changes in these measures.

Competitive considerations

For TBI's that occurred during games, team opponent and game outcome were determined from *NFL.com* in order to investigate whether competitive considerations might play an active role in injury diagnosis or severity. Yearly league wide aggregate play calling statistics for the period between 2010 and 2015 obtained from *operations.nfl.com* might reveal trends within the gameplay. These statistics include; passing plays (percentage), passing attempts, percent passes complete, passing yards/game, passing touchdowns/game, total yards/ game, rushing plays (percentage), rushing attempts, yards/ rushing attempt, and rushing yards/game.

Hall of fame references

Career weighted Approximate Value (AV) scores were collected from pro-football-reference.com for TBI players. AV was also determined for the entire 266 Pro Football Hall of Fame (HOF) inductee class (1963 until 2017). Sixteen TBI players and 59 HOF inductees had a career weighted AV of zero and were therefore omitted from the analysis, which therefore had an N=836. Dividing career weighted AV by the number of years the player has or had played obtained a career weighted AV annual average (AA) for TBI cases and Hall of Famers. Value approximation (VA – described above) was also used in this analysis.

Overall rank and TBI player salary

Overall rank (described above) and annual salaries (determined from *spotrac.com*) during year of TBI acquisition were used to investigate a possible relationship between TBI players' diagnoses and the value they provided to the team.

Data cleaning and statistical tests

Raw data is transformed into z-scores within this chapter for comparison of observed values in relation to mean distributions. Data was also manually clustered into groupings in order to obtain more statistical power and in order to run the appropriate procedures. Statistical tests used within this chapter include; one-way analysis of variance (ANOVA), independent samples t-testing, Pearson r and spearman rho correlations, multiple regression analysis, chi-square analysis, as well as discriminant analysis.

Results

The data indicate that from 2012-2015 over 4 seasons of investigation, there were 645 reported TBI's (161.25/season average) which were officially listed on the *National Football League* (NFL) injury report. Week 12 had the highest number (57) of reported TBI's of any in-season week, and the Cleveland Browns doctors diagnosed the most TBI's (39). The most susceptible player position was cornerback with 117 TBI's over the 4 years.

TBI player profile

A one-way ANOVA (Figure 1) analysing total TBI's acquired by position played explained 78% of the variance in concussion totals over the four-year period, with the results indicating that centers (M=4.25, SD =3.40) sustain less TBI's than cornerbacks (M=28.5, SD =8.43) [$F_{(11, 36)}$=11.30, r^2=.78, $p<.001$].

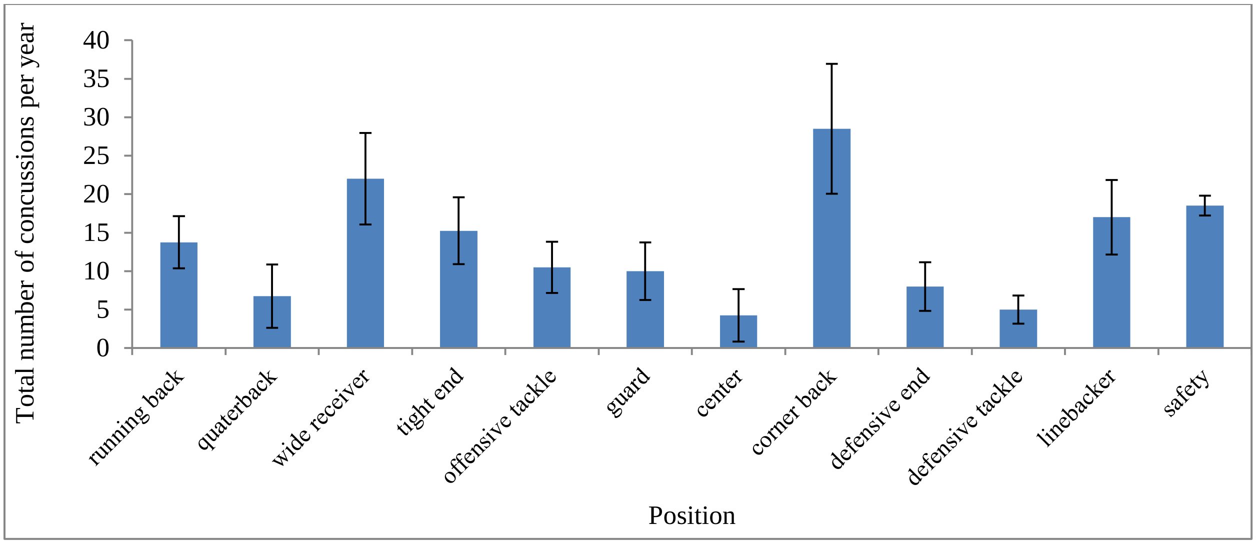

Figure 1 Total number of TBI's per year by position played

Weight of players who sustained a TBI by position

A one-way ANOVA exploring weight by position (Figure 2) indicated significant differences between the means [$F_{(11,632)}$ =504.63, r^2=.90, p<.01] and indicated that position explained 90% of the variance in weight played for TBI players, with offensive tackles weighing the most in kilograms (M=145.23, 4.86), and cornerbacks weighing the least (M=88.11, 5.77).

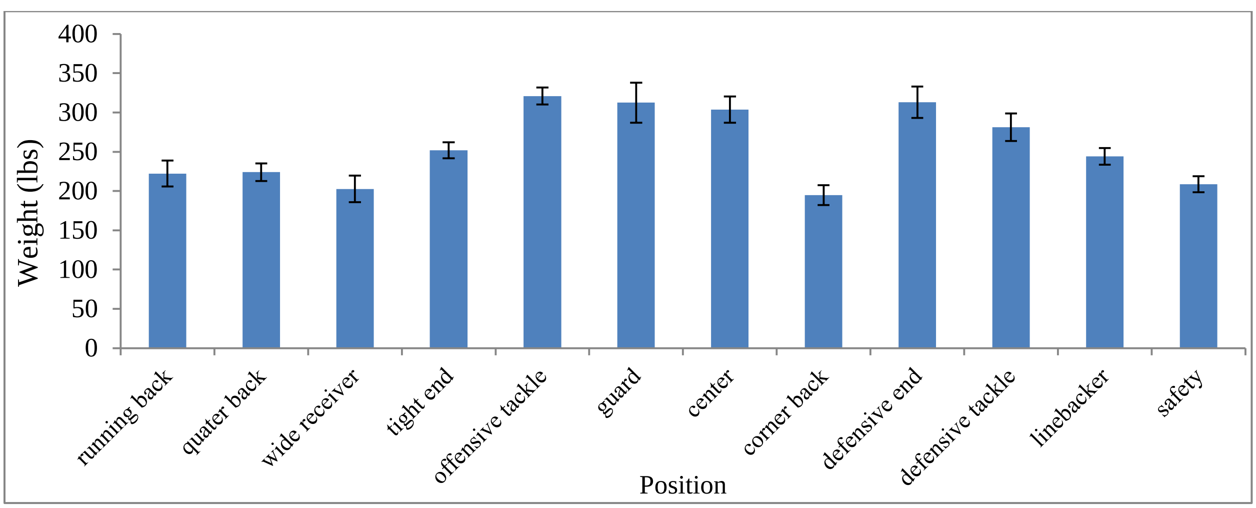

Figure 2 Weight of players who sustained a TBI by their position played

TBI player Weight (kg) by team role

When position played is recoded into offense or defense, and body weight (kg) is entered into an independent samples t-test by these groupings (Figure 3) a significant difference was observed ($t_{(631)}$ =7.40, p<.01). Players in offensive positions who acquired a TBI were heavier (M=113.33, SD=21.71) than TBI players in defensive positions (M=101.88, SD=17.43).

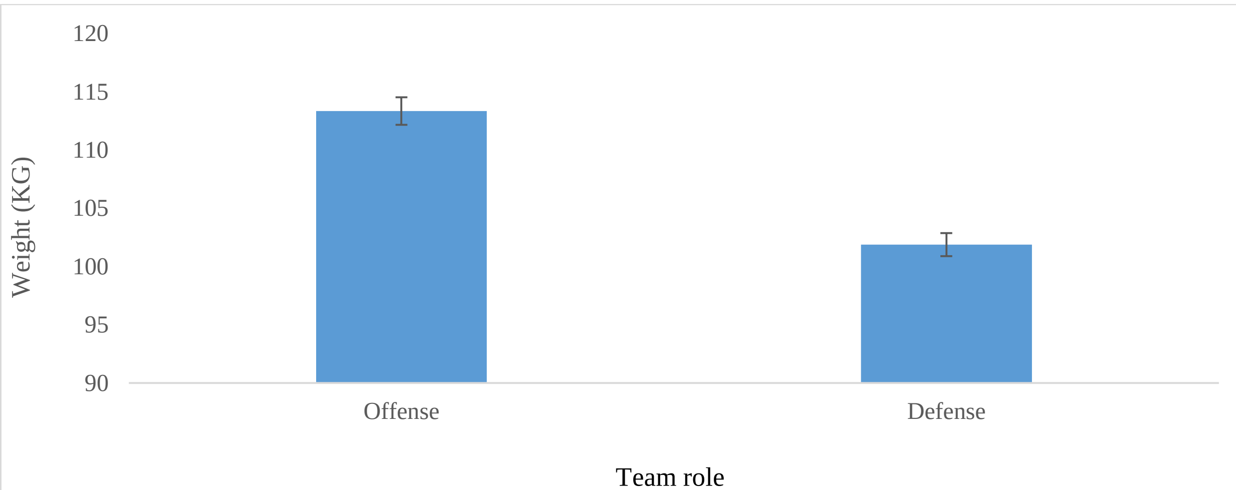

Figure 3 Weight of players who sustained a TBI by team role (offense/defense)

Height of players who sustained a TBI by position

A one-way ANOVA explored TBI Player height (inches) by player position (Figure 4). The results indicated that height explained 62% of the variance in position played [$F_{(11,632)}$ =92.86, r^2=.62, p<.01].

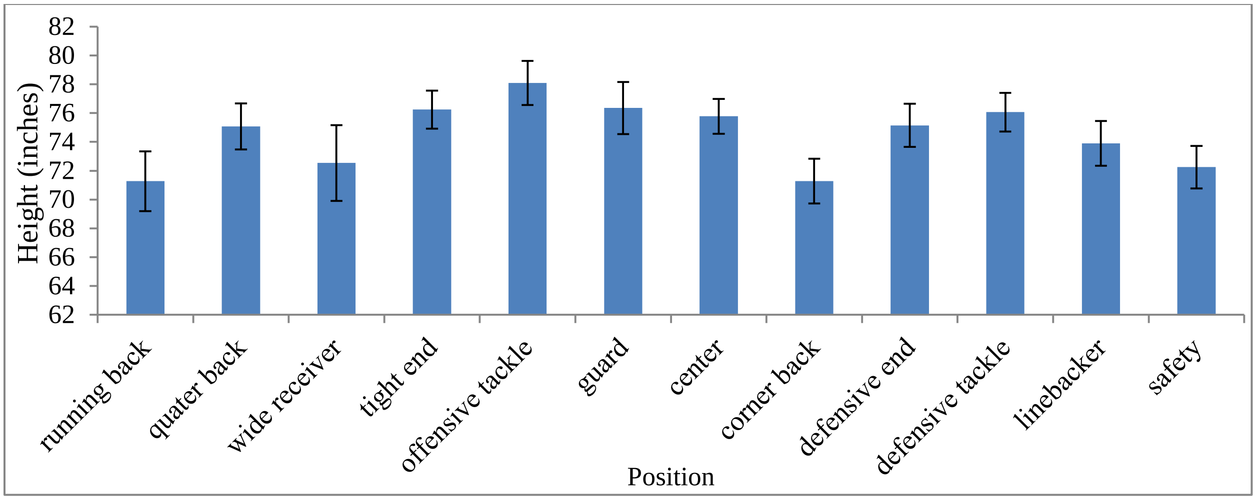

Figure 4 Height of players who sustained a TBI by position played

TBI player Height (m) by team role

An independent samples t-test (Figure 5) explored TBI player height (meters) by team role (offense/defense). The results indicated that those in offensive positions were significantly taller (M=1.89, SD=.08) than players who played on defense (M=1.84, SD=.06) who sustained a TBI ($t_{(642)}$ =8.11, $p<.01$).

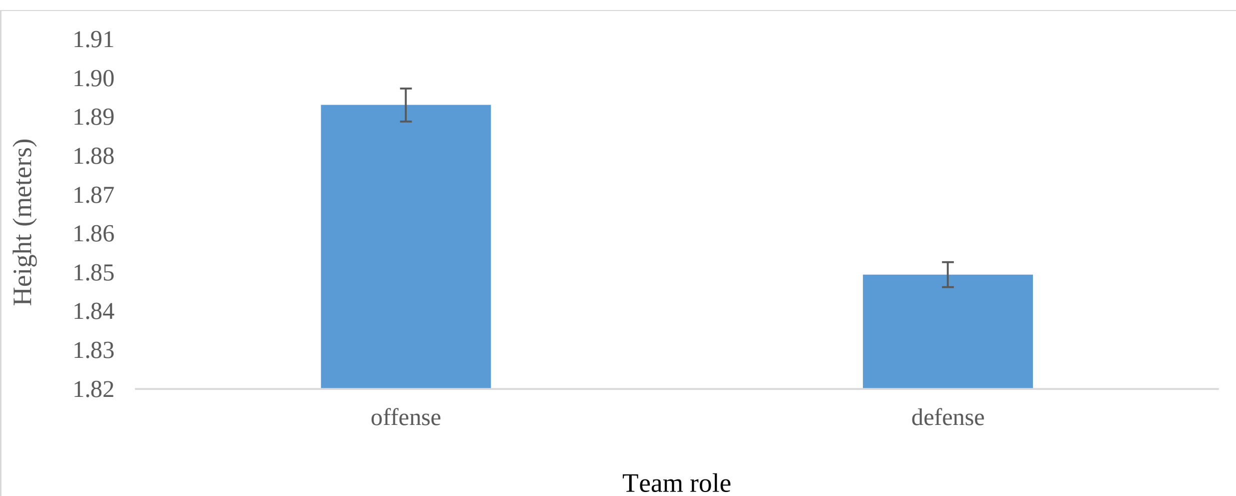

Figure 5 Height (meters) of players who sustained a TBI by team role

Average number of games missed due to injury by position

Number of games missed due to injury is used as a measure of injury severity, so average games missed per TBI was determined by dividing the total number of TBI's per position by the number of games missed. Values greater than 1 in this case, indicate that the player failed the Standardized Concussion Assessment Tool (SCAT) 2, and impairment of neurological function was sufficient for the player to miss at least a week due to injury. A one-way ANOVA examining average number of games missed after a concussion by position (Figure 6) indicates that running backs, quarterbacks, and tight ends, are most likely to miss at least one game after a concussion, whereas players at the center and safety positions rarely do [$F_{(11,47)}$=1.78, r^2=.35, p=.093]. Although the differences between the means were not found to be significant, results indicated that centers (M=.54, SD=.41) missed the fewest games per TBI, and running backs missed the most (M=1.54, SD=.64).

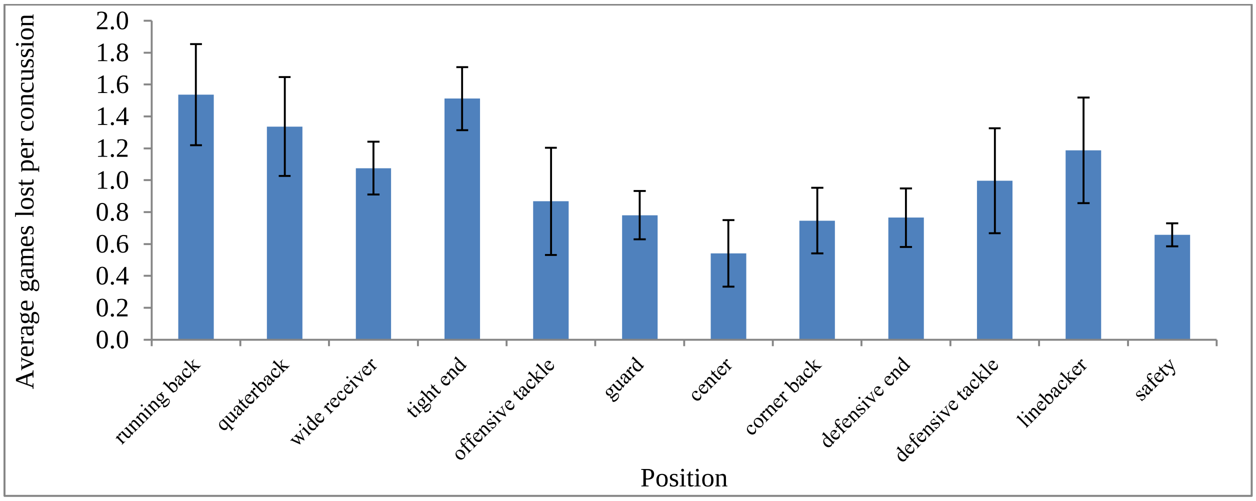

Figure 6 Average number of games missed per concussion

Total games missed due to injury per concussion by position

There are always at least two offensive tackles, guards, cornerbacks, defensive ends, defensive tackles, linebackers, and safeties on the field at during gameplay, along with a variable number of running backs, wide receivers, and tight ends. The only positions represented by one player at all times are quarterback and center. Analysis of total number of games missed by position (rather than average number of games) indicates that defensive tackles (M=4.25, SD=2.06) missed fewer games per year due to TBI then did wide receivers (M=23.5, SD=9.47) [$F_{(11, 36)}$ =3.81, r^2=.54, p=.001] (Figure 7).

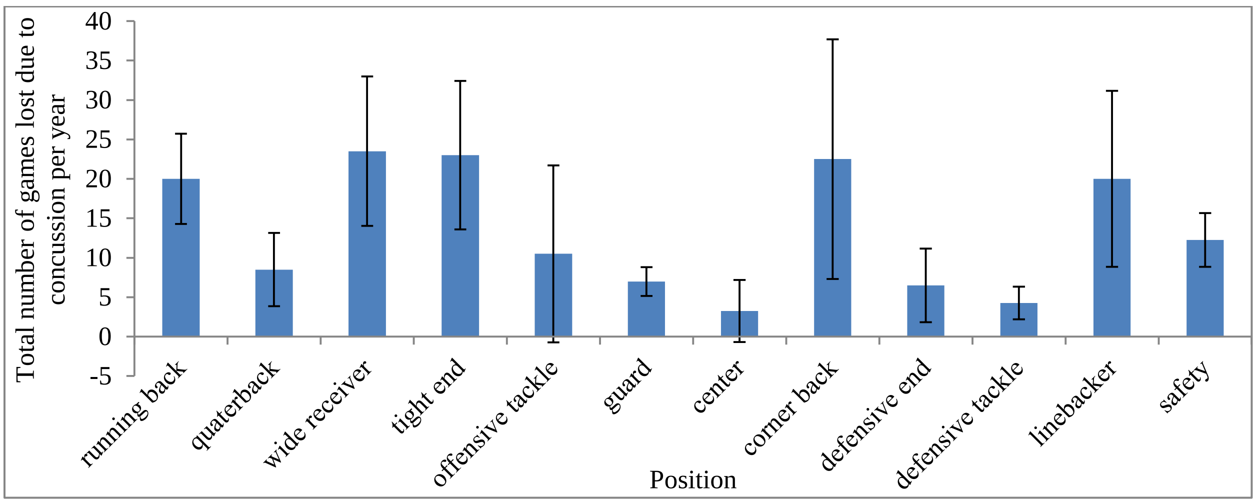

Figure 7 Total number of games lost due to concussion by position

Athletic exposure during year TBI acquisition

The average number of plays (snaps) in games before a documented TBI was 46.70, whereas the average number of plays in games for players after returning from injury was 40.87 snaps. Number of games missed has a weak to moderate negative relationship with snap count in the first game played after missing play due to a concussion (return game) ($r_{(594)}$=-.36, rho=-.36) suggesting that a player is likely to play fewer snaps in the return game after injury.

Average athletic exposure per game before TBI by average athletic exposure per game for offensive players

Annual athletic exposure was converted into a per game average by dividing annual athletic exposure by the players' total number of games played during the season in which the injury occurred. Separate analyses were conducted for offensive and defensive TBI players. A strong correlation was found between the average per game snap count before injury and for the entire season ($r_{(297)}$=.83, rho=.87) (Figure 8).

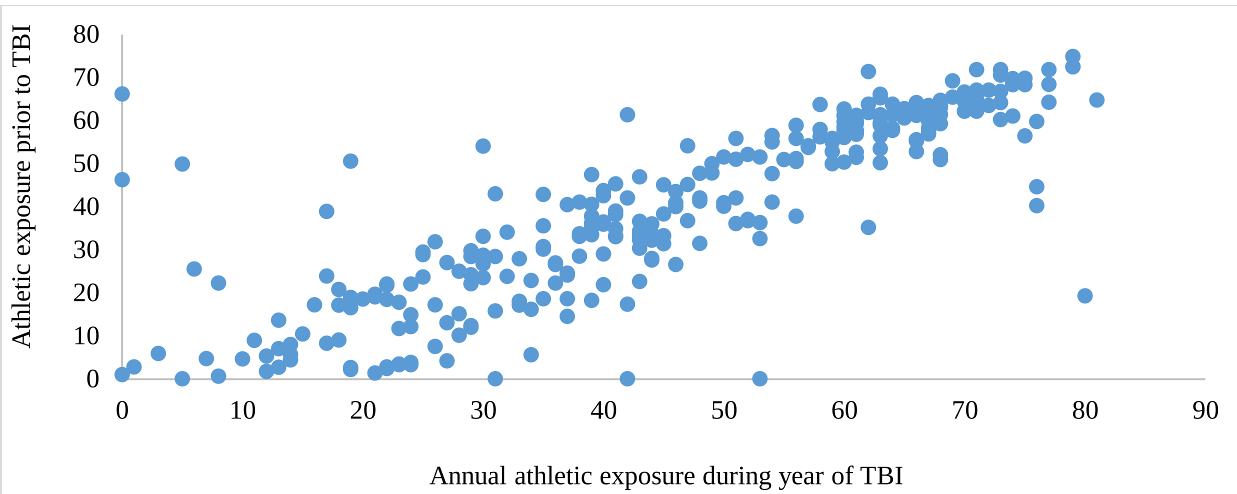

Figure 8 Average offensive snaps per game per season by average play in games before TBI injury

Average athletic exposure before TBI by average athletic exposure per game for defensive players

Average snap count per game before injury strongly correlated with the average athletic exposure before injury for defensive players who sustained a TBI ($r_{(261)}$=.84, rho=.84) (Figure 9).

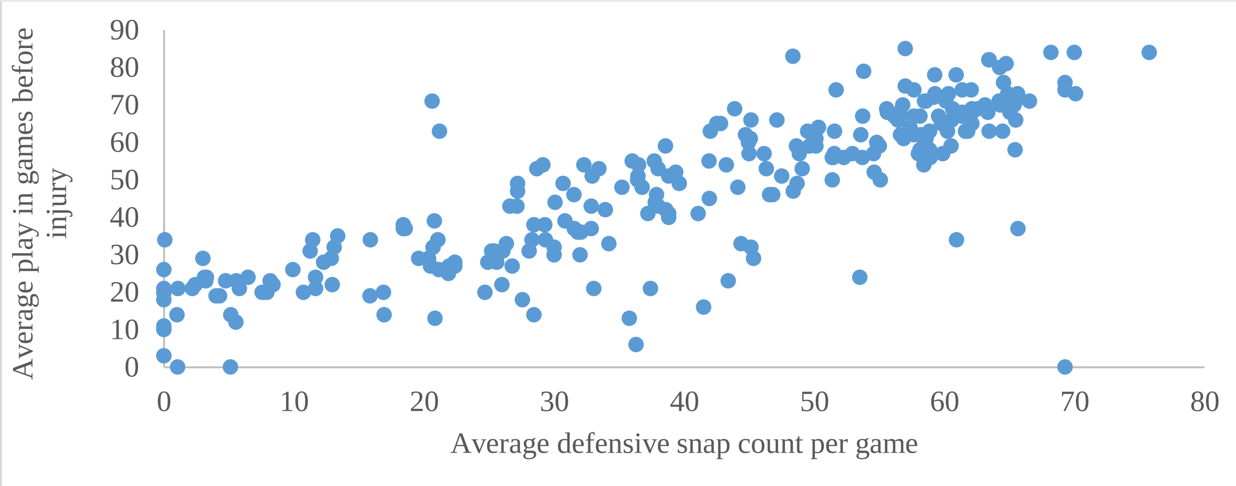

Figure 9 Average defensive snaps per game per season by average play in games before TBI injury

Athletic exposure during TBI game for offensive skilled players

Quarterback, running back, tight end, and wide receiver are considered offensive 'skilled' positions. One-way analysis of variance exploring offensive athletic exposure during the game in which the injury occurred by skilled position indicates that quarterbacks (M=48.14, SD=19.44) had significantly more athletic exposures during these games than the other skilled positions, and that running backs had the fewest athletic exposures (M=21.31, SD=17.11) [$F_{(3,190)}$ =16.00, r^2=.20, p<.01] (Figure 10).

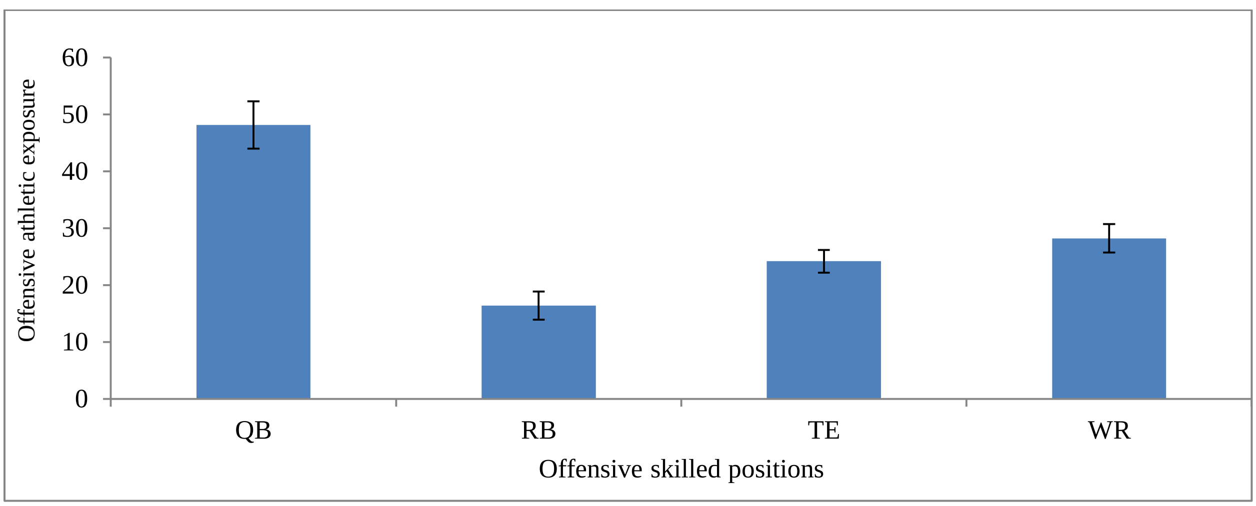

Figure 10 Offensive snap count during TBI by offensive skill positions

Athletic Exposure in return game by games missed due to injury

In order to explore workload in the first game on return from injury, snap count in return game from injury by number of games missed due to injury was analysed. One-way ANOVA results indicate that players who missed than six games did not return to play football during year of injury (Figure 11) [$F_{(13,580)}$=7.80, r^2=.15, p<.01].

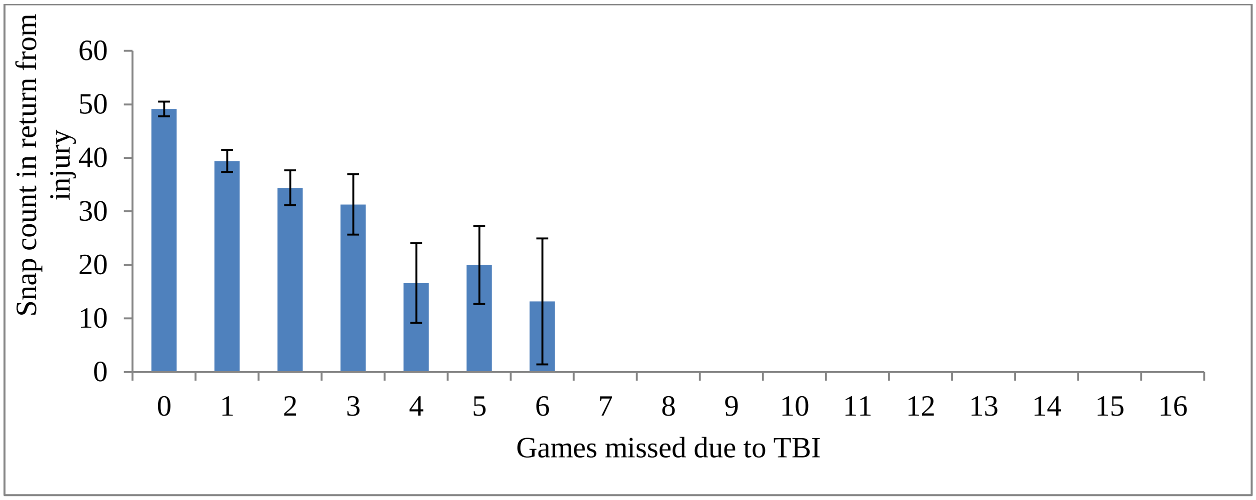

Figure 11 Athletic exposure after return game from injury by games missed due to TBI

Average athletic exposure in all games after return from injury by number of games missed due to injury was also analysed (Figure 12). The results revealed significant differences between the means, with athletic exposure being greatest in athletes who only missed zero or one game due to injury. [$F_{(5,384)}$ =2.54, r^2=.03].

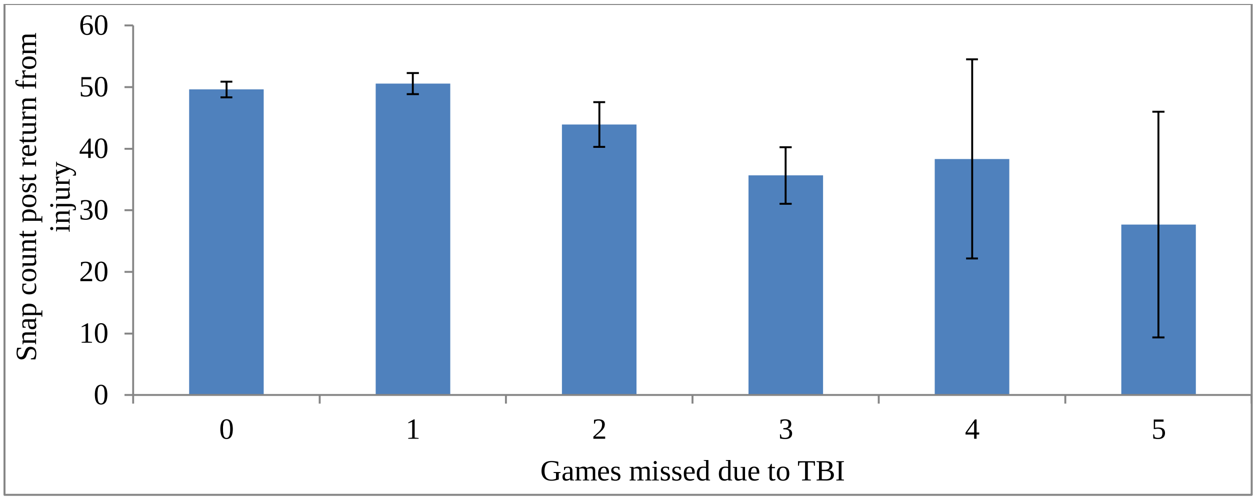

Figure 12 Snap count in return from injury by games missed due to injury

Athletic exposure by games missed due to TBI

Annual as well as per game snap counts were collected for 645 TBI cases which occurred in the National Football League from 2012-2015. A one-way analysis of variance exploring snap count totals, by games missed due to an acquired TBI (Figure 13), clearly demonstrates a distinct decrease in exposure, for the players who required the greatest recovery period [$F_{(13,586)}$ =7.83, r^2=.15, p<.01], which indicates that missing more games systemically reduces athletic exposure, such that players who missed 13 games due to injury had less athletic exposure (M=107, SD=28.28), while players who did not miss time due to injury had more athletic exposure (M=697.86, SD=307.36).

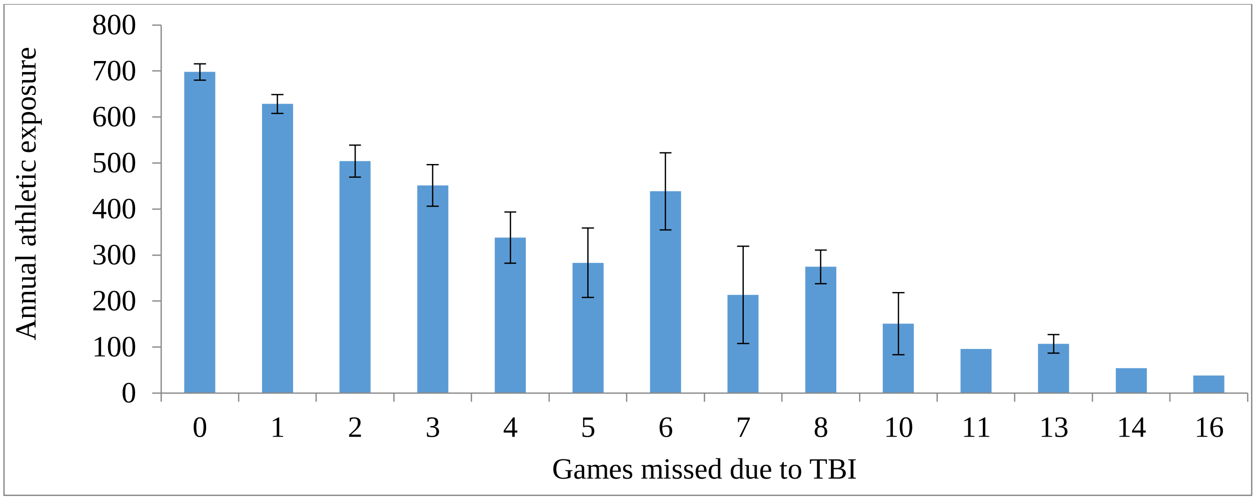

Figure 13 Snap count of injured players by games missed due to TBI

Change in athletic exposure by games missed due to injury

In order to determine whether the reduced exposure after longer absence from play was merely the natural result of having missed more games, or a true reduction in activity per game upon return, a change in snap count variable was used. Average pre-injury snaps was subtracted from average post-injury snaps (post-pre) One-way ANOVA analysis (Figure 14) indicated that players who do not miss time due to a TBI are exposed to greater change in athletic exposure (M=.23, SD=18.29), while players who miss 13 games have the greatest reduction in athletic exposure (M=-46, SD=24.04) [$F_{(12,549)}$=6.03, r^2=.12, p<.01].

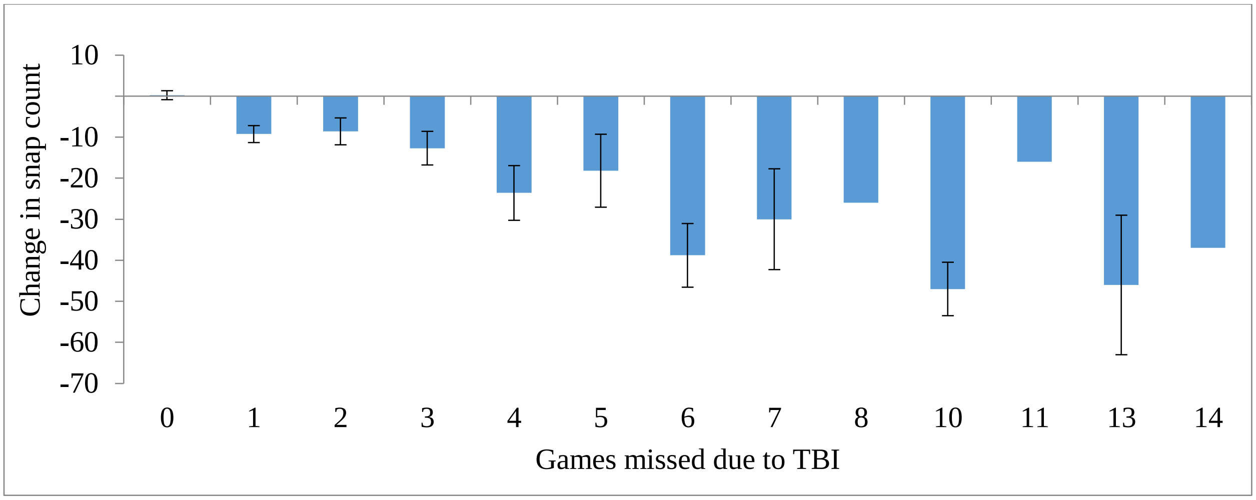

Figure 14 Change in snap count after TBI by games missed due to injury

Predicting change in athletic exposure using games missed due to injury

Regression analysis predicting Effect of Injury (change in snap count upon return from injury), with the lone predictor of games missed produced the following equation (Table 5): change in athletic exposure = -1.718 + -4.152*(games missed due to injury). Using this equation, we can predict that a player who missed one game would see a reduction of about six snaps on return from injury.

Table 5 Multiple Regression Coefficient: predicting Effect of injury with games missed due to injury

Change in athletic exposure= -1.718 -4.152*(Games missed due to injury)					
Games missed	1	2	3	4	5
Predicted change in athletic exposure	-5.85	-9.99	-14.13	-18.28	-22.42

TBI severity and change in Athletic Exposure

The number of games missed may be used as a measure of the doctor's assessment of injury, while the change in snap count upon return from injury may be used as a measure of the coach's assessment of injury. Doctors and Coaches are susceptible to making Type I and type II errors with regard to injury detection. If the player does not miss any time due to injury, and returns to an increased work load, the doctors and coaching staff might be making a type 1 error; a false positive wherein the initial diagnosis that there was an injury may have been wrong. If the player misses time due to injury and returns in a reduced workload, the coach and medical staff might be making a type 2 error; deciding there is an injury when there is none (Table 6).

Table 6 Doctors and Coaches may make type 1 or type 2 errors in injury diagnosis

Injury Diagnosis		
Change in Athletic Exposure/games missed due to	0 Games missed	1+ Games missed
Decreased play	Possible Type 1B error	Possible Type II error
Increased play	Possible Type I error	Possible Type IIB error

Association between TBI severity and change in athletic exposure

Subtracting the average athletic exposure before injury from athletic exposure in return from injury (post-pre) provides an indication of change in athletic exposure. There was a weak to moderate negative association between number of games missed due to injury and change in athletic exposure (r=-.31) (Figure 15) The association between injury severity (games missed) and change in athletic exposure was so persistent that partial correlations did not significantly control for this relationship. Partial correlational analysis included; season, position played, team role, month of year, years pro, BMI, game outcome, home/away, organization player plays for, team opponent, week in season, month, (12) Moon phase, (13) full moon percent, (14) Moon age, (15) humidity, (16) grass type, or (17) roof type.

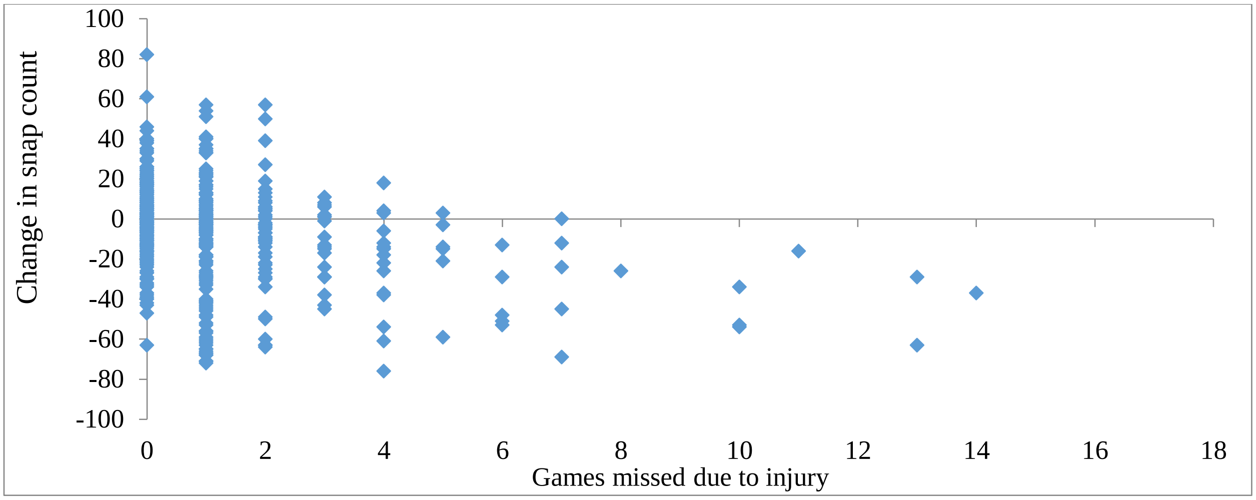

Figure 15 Correlational analysis; Change in snap count by games missed due to injury

Athletic exposure and injury severity

Games missed due to injury was clustered into: (1) no games missed due to injury; or (2) one or more games missed due to injury, while change in snap count was clustered into: (A) decrease in snap count after return from injury; or (B) increase in snap count after return from injury. Chi-square analysis exploring games missed due to injury and snap count cluster classifications indicated that over half the injuries which resulted in no time missed due to injury actually resulted in the player coming back to play in more snaps in the return game following the injury compared to preinjury averages [χ^2=14.78, phi=-.16, p<.001].

Table 7 Exposure change in return from injury by TBI severity clusters

		Effect of injury		Total
		Decrease play	Increase play	
Games missed due to injury	0	130	140	270
	%	23%	25%	48%
	1+	190	106	296
	%	34%	19%	52%
Total		320	246	566
%		57%	43%	100%

Injury label by season

Chi-square analysis was used to explore injury label by season (Table 8). The results indicated that injury label showed significant differences between observed and expected values by year [$\chi^2_{(3)}$= 168.88, Λ=.12, p<.01].

Table 8 Injury label (Concussion/head injury) by NFL season (2012-2015)

		Season				Total
		2012	2013	2014	2015	
Concussion, head or neck injury	Concussion	106	149	121	196	572
	%	16%	23%	19%	30%	89%
	Head	65	3	2	2	72
	%	10%	0%	0%	0%	11%
Total		171	152	123	198	644
%		27%	24%	19%	31%	100%

TBI severity and injury labels

Three hundred and fifty-two (55%) of the TBI's acquired between 2012 and 2015 resulted in the player missing one or more games due to injury, while 45% resulted in no time missed. Of the cases where a game was missed, 91% had a label of concussion, as opposed to head injury. This was confirmed by chi-square analysis which indicated a higher proportion of head injuries within those which resulted in no time missed due to injury [χ^2=4.47, phi= -.083, p=.024], only 43% of HI's resulted in mandatory rest, whereas 56% of brain injuries labelled as concussions resulted in games missed due to injury (Table 9).

Table 9 Chi-square analysis: Games missed due to injury by diagnosis: Concussion or head injury

		Injury type		Total
		Concussion	Head	
Games missed due to injury	0	250	41	291
	%	39%	6%	45%
	1 +	321	31	352
	%	50%	5%	55%
Total		571	72	643
%		89%	11%	100%

TBI severity and change in athletic exposure by injury label

The relationship between injury severity and change in athletic exposure cluster classifications by injury types was analysed for each injury label by chi square (Table 10). The results indicate significant differences between observed and expected values for both concussions [$\chi^2_{(1)} = 13.01$] and head injuries [$\chi^2_{(1)} = 5.18$].

Table 10 *Discrepancies in observed and expected values in the relationship between games missed due to injury and change in athletic exposure cluster classifications*

			Change in Athletic exposure		Total
			Decrease	Increase	
Concussion	Games missed	0	116	112	228
		%	23%	22%	46%
		1+	181	90	271
		%	36%	18%	54%
	Total		297	202	499
	%		60%	40%	100%
Head injury	Games missed	0	21	20	41
		%	34%	32%	66%
		1+	17	4	21
		%	27%	7%	34%
	Total		38	24	62
	%		61%	39%	100%

Temporal ratios TBI severity and change in athletic exposure

Layered crosstab analysis identified potential factors that promoted the relationship between games missed due to injury, and change in athletic exposure. The results (Table 11) indicate that temporal preconditions which amplified this effect include the 2012 [$\chi^2_{(1)=}$8.51], 2013 [$\chi^2_{(1)=}$4.79], and 2015 [$\chi^2_{(1)=}$3.42] seasons, specifically within the months of October [$\chi^2_{(1)=}$4.14] and December [$\chi^2_{(1)=}$11.25], or more specifically during week 6 [$\chi^2_{(1)=}$5.54] and week 14 [$\chi^2_{(1)=}$6.41] of the regular season.

Table 11 Change in Athletic Exposure by Games missed due to injury

			Change in athletic exposure		Total
			Decrease	Increase	
2012 Season	Games missed	0	43	39	82
		%	29%	26%	55%
		1+	50	16	66
		%	34%	11%	45%
	Total		93	55	148
	%		63%	37%	100%
2013 Season	Games missed	0	31	40	71
		%	23%	30%	53%
		1+	40	24	64
		%	30%	18%	47%
	Total		71	64	135
	%		53%	47%	100%
2015 Season	Games missed	0	38	29	67
		%	22%	17%	40%
		1+	72	30	102
		%	43%	18%	60%

	Total		110	59	169
	%		65%	35%	100%
October	Games missed	0	26	31	57
		%	22%	27%	49%
		1+	38	21	59
		%	33%	18%	51%
	Total		64	52	116
	%		55%	45%	100%
December	Games missed	0	40	34	74
		%	24%	20%	44%
		1+	73	20	93
		%	44%	12%	56%
	Total		113	54	167
	%		68%	32%	100%
Week 6	Games missed	0	2	7	9
		%	8%	27%	35%
		1+	12	5	17
		%	46%	19%	65%
	Total		14	12	26
	%		54%	46%	100%
Week 14	Games missed	0	8	10	18
		%	22%	27%	49%
		1+	16	3	19
		%	43%	8%	51%
	Total		24	13	37
	%		65%	35%	100%

Player profile ratios of TBI severity and change in athletic exposure

Layered chi-square analysis explored TBI severity and change in athletic exposure cluster. The results (Table 12) indicated differences between observed and expected values for lower [$\chi^2_{(1)}$ =7.42] and higher [$\chi^2_{(1)}$ =8.22] than average BMI scores. The cornerback position [$\chi^2_{(1)}$ =5.51] also displayed significant differences between observed and expected values, however the relationship was significant for all players on both offense [$\chi^2_{(1)=}$3.18] and defensive [$\chi^2_{(1)=}$13.84] units as a whole.

Table 12 Discrepancies in observed and expected values for games missed due to injury and change in athletic exposure by player profile attributes

			Change in athletic exposure		Total
			Decrease	Increase	
Higher BMI	Games missed	0	60	52	112
		%	23%	20%	43%
		1+	105	45	150
		%	40%	17%	57%
	Total		165	97	262
	%		63%	37%	100%
Lower BMI	Games missed	0	77	80	157
		%	26%	27%	53%
		1+	93	49	142
		%	31%	16%	47%
	Total		170	129	299
	%		57%	43%	100%
Cornerback	Games missed	0	26	30	56
		%	25%	29%	55%
		1+	32	14	46
		%	31%	14%	45%
	Total		58	44	102
	%		57%	43%	100%
Offensive players	Games missed	0	72	54	126
		%	24%	18%	42%
		1+	115	56	171
		%	39%	19%	58%
	Total		187	110	297
	%		63%	37%	100%

Defensive players	Games missed	0	66	78	144
		%	25%	29%	54%
		1+	83	28	121
		%	31%	11%	46%
	Total		149	116	265
	%		56%	44%	100%

TBI severity by team role

Chi-square analysis indicated that the relationship between games missed due to TBI and team role classification was significant [$x^2_{(2)}$=9.05, phi=.12]. Table 13 shows that players who were injured on offense were more likely to miss at least one game due to a concussion in comparison to concussed individuals on defense.

Table 13 Games missed due to TBI injury by Team role of injured player

		Team role		Total
		Offense	Defense	
Games missed due to TBI	0	134	158	292
	%	22%	26%	48%
	1+	183	132	315
	%	30%	22%	52%
Total		317	290	607
%		52%	48%	100%

League Wide NFL reference groups

Every player who sustained a TBI over this period was subsequently ranked according to annual snap counts per year, relative to all other players at their position, within the same season. Annual snap count rank was then divided into quartiles for each position. Descriptive statistics are presented in Table 14 for each quartile rank, including; average athletic exposure (SEM), and number of players, can be observed for each position by quartile in the table below. These quartile references were entered into the database containing 645 players who sustained a TBI during the same temporal window.

Table 14 Athletic exposure quartile ranks by position in reference to all players who played in the NFL between 2012 and 2015

Quartile		RB N=773	QB N=393	WR N=940	TE N=144	OT N=1371	G N=1371	C N=1371	DE N=1256	DT N=1256	LB N=1223	S N=1631	CB N=1631
	Rank	1-20	1-26	1-60	1-36	1-90			0-80		1-75	1-99	
	N	196	104	240	144	360			320		300	400	
1	**Snap count**	581.11 (8.00)	996.73 (12.21)	867.70 (7.41)	830.19 (11.28)	1114.51 (3.44)			832.64 (7.53)		962.21 (7.97)	1048.73 (5.43)	
	Rank	20-40	26-52	60-120	36-72	90-180			80-160		75-150	100-199	
	N	200	104	240	144	360			320		300	400	
2	**Snap count**	337.97 (3.88)	310.88 (17.81)	496.77 (6.53)	498.22 (6.36)	745.11 (9.24)			507.08 (4.40)		563.43 (5.35)	649.29 (6.30)	
	Rank	40-60	53-78	120-180	72-108	180-270			160-240		150-225	200-299	
	N	200	104	240	144	360			320		300	400	
3	**Snap count**	162.16 (3.71)	26.91 (2.68)	210.47 (4.65)	187.87 (8.08)	215.39 (6.15)			243.13 (4.04)		308.75 (4.26)	310.19 (4.09)	
	Rank	60-80	79-105	180-240	108-144	270-360			240-300		225-300	300-399	
	N	177	81	220	114	1371			297		323	431	
4	**Snap count**	31.62 (1.93)	0.01 (.01)	32.29 (1.93)	23.68 (2.33)	9.50 (.81)			36.59 (1.95)		64.58 (3.10)	56.20 (2.39)	

Comparing Athletic exposure of TBI athletes with NFL reference groups

Chi-square analysis was conducted in order to determine the number of TBI cases between 2012 and 2015 that fell below each Athletic exposure quartile rank in reference to all players that played in the NFL between 2012 and 2015. The results indicated significant differences between the observed and expected with regard to the proportion of position specific players who sustained a TBI who fell above or below each quartile. This includes TBI players within the 1st [$\chi^2_{(11)}$=22.66, Λ=.008, Φ=.19], 2nd [$\chi^2_{(11)}$=22.41, Λ=.02, Φ=.19], 3rd [$\chi^2_{(11)}$=22.94, Λ=.002, Φ=.19], and 4th quartiles [$\chi^2_{(11)}$=21.51, Λ=.008, Φ=.18], as can be observed in Table 15.

Table 15 Number of position specific players who sustained a TBI by Athletic exposure quartile rank, in reference to all players who played in the NFL from 2012 to 2015

Quartile 1	RB	QB	WR	TE	OT	G	C	DE	DT	LB	S	CB	Total
Over	13	0	12	7	2	5	1	1	7	6	16	11	81
Under	45	25	76	53	41	35	17	19	24	57	58	104	554
Total	58	25	88	60	43	40	18	20	31	63	74	115	635
Quartile 2	RB	QB	WR	TE	OT	G	C	DE	DT	LB	S	CB	Total
Over	31	20	37	41	27	27	11	10	16	31	45	62	358
Under	27	5	51	19	16	13	7	10	15	32	29	53	277
Total	58	25	88	60	43	40	18	20	31	63	74	115	635
Quartile 3	RB	QB	WR	TE	OT	G	C	DE	DT	LB	S	CB	Total
Over	49	25	72	57	41	34	14	18	29	47	64	100	550
Under	9	0	16	3	2	6	4	2	2	16	10	15	85
Total	58	25	88	60	43	40	18	20	31	63	74	115	635
Quartile 4	RB	QB	WR	TE	OT	G	C	DE	DT	LB	S	CB	Total
Over	56	25	86	60	43	40	18	20	31	59	74	115	627
Under	2	0	2	0	0	0	0	0	0	4	0	0	8
Total	58	25	88	60	43	40	18	20	31	63	74	115	635

Position rank of TBI players relative to all players since 1950 by NFL reference groups

A one-way ANOVA exploring position rank relative to all players who played in the NFL since 1950 by athletic exposure NFL reference groups (during year of injury) revealed significant differences between the means [$F_{(3,631)}$=34.52, r^2=.14, <.01] (Figure 16).

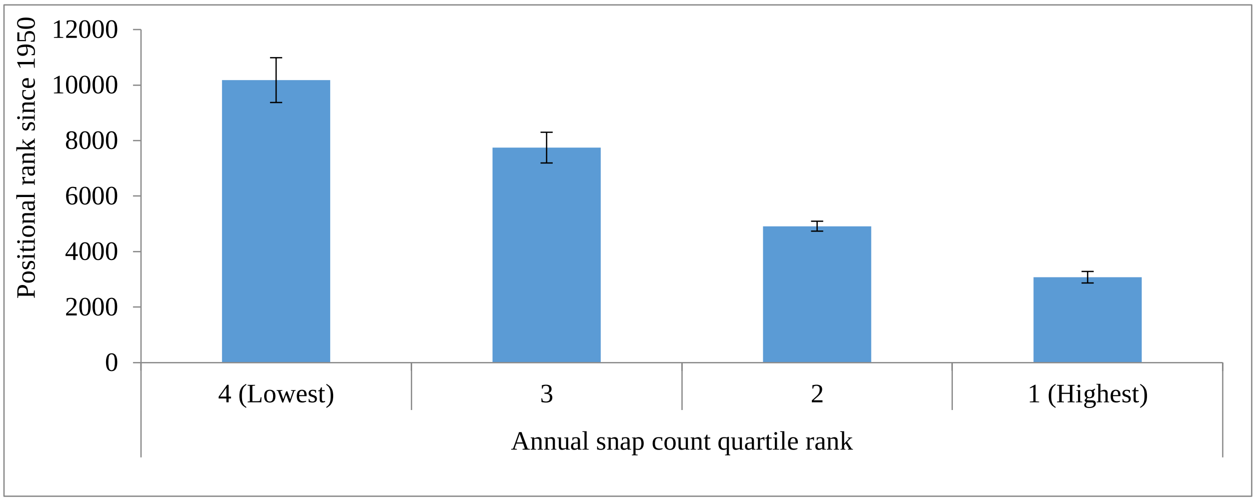

Figure 16 Positional rank since 1950 by yearly snap count quartile rank

Average athletic exposure; before, during, in return and after return from TBI by NFL reference groups

Athletic exposures per game was collected for several injury-critical temporal windows including; (1) preinjury, (2) during injury, (3) return from injury, and (4) after returning from injury. A series of one-way ANOVAs indicated that average athletic exposure before injury [$F_{(3, 557)}$=111.42, r^2=.38, p<.01], during TBI [$F_{(3, 549)}$=27.10, r^2=.13, p<.01], in return from injury [$F_{(3,589)}$=65.74, r^2=.25, p=.001], and after returning from injury [$F_{(3,383)}$=87.71, r^2=.40, p<.01] significantly varied by players who played within each of the league wide snap count quartile ranks (Figure 17).

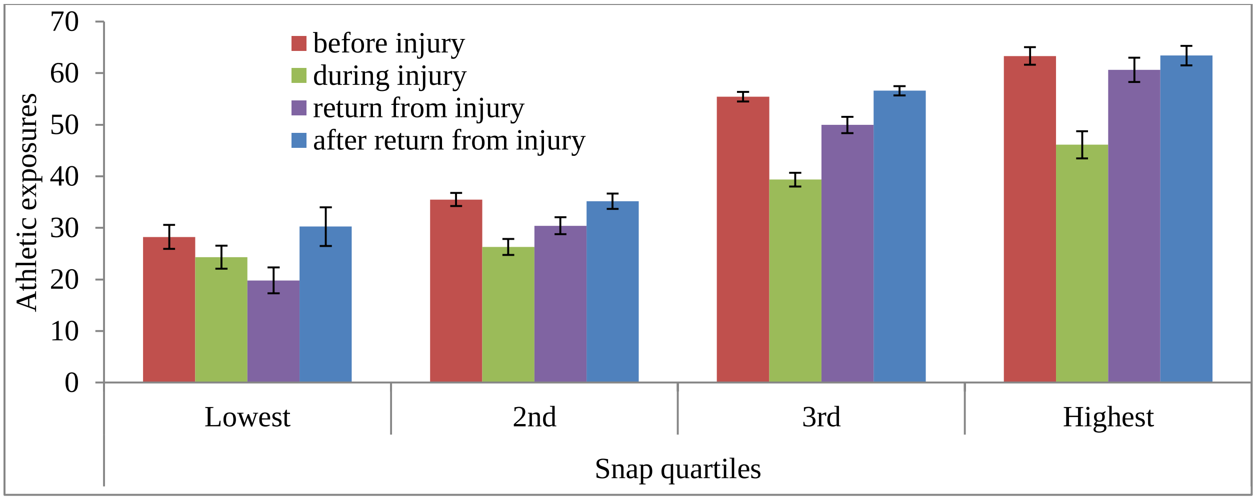

Figure 17 Pre-injury, during injury, return from injury, and snap counts after return from injury by yearly snap count quartiles

Games missed due to injury by TBI players who fall above or below each of the 4 quartile averages regarding athletic exposure during year of injury

A paired samples t-test was conducted in order to determine if games missed due to injury changed as a function of the player's athletic exposure in relation to the 4 league wide quartiles. The results indicated significant differences in games missed due to injury by the TBI cases which were over or under each of the quartile means, with players who fell above or below each quartile representing a unique population with regard to injury severity (Figure-18).

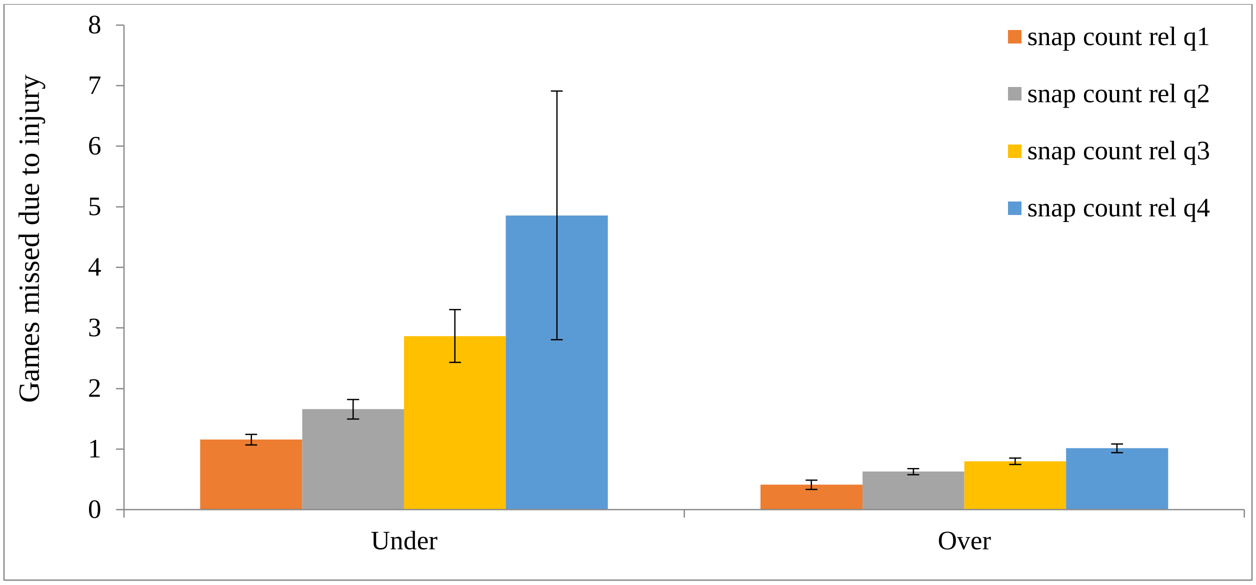

Figure 18 Games missed due to injury by TBI injured players who fell below or above the league wide referenced snap count quartiles

Table 16 Results from a paired samples t-test investigating games missed due to TBI by players who played above or below each quartile rank

	Paired sample statistics	Paired sample correlation	Paired samples test
Pair 1	-321.27	-0.33	293.66
Pair 2	53.71	-0.34	291.55
Pair 3	380.88	-0.35	306.29
Pair 4	582.72	-0.36	310

TBI severity by top NFL Athletic exposure quartile

When games missed due to injury was recoded in binary, as either; 0 games missed, or, 1 or more games, and then entered into chi-square analysis with a recoded binary representation of yearly snap count totals, in relation to the highest quartile, as either lower, or higher, significance was observed [$\chi^2_{(1)}$=10.44, Λ=.07, Φ=-.13].

Table 17 Games missed due to TBI clusters by the highest yearly snap count quartile relative to all players who played in the NFL between 2012 and 2015

		Athletic exposure relative to the highest quartile		Total
		Lower	Higher	
Games missed due to TBI	None	239	51	290
	%	40%	9%	48%
	1+	283	27	310
	%	47%	5%	52%
Total		522	78	600
%		87%	13%	100%

Traumatic and Severe TBI acquisition by NFL reference groups

Games missed due to TBI injury were manually clustered into one of two classifications between 0-4, or 4+ games missed due to injury. These clusters were labelled as traumatic or severe, respectively. There were 26 severe TBI injuries between 2012 and 2015 under these classifications. Chi-square analysis shows the proportion of traumatic to severe injuries by snap count quartile rank (Table 18) [$\chi^2_{(3)}$=52.24, Λ=.04, Φ=.30].

Table 18 Traumatic and severe TBI diagnosis by yearly snap count quartile rank

		Diagnosis		Total
		Traumatic	Severe	
Snap count quartile rank	Lowest	72	6	88
	%	12%	1%	15%
	3	166	8	174
	%	28%	1%	29%
	2	259	2	261
	%	43%	0%	44%
	Highest	77	0	77
	%	13%	0%	13%

Total	574	26	600
%	96%	4%	100%

Annual salary of TBI players by NFL reference group

A one-way ANOVA explored average yearly salary by the league wide athletic exposure quartiles, which indicated significant differences between the means with players in the top half of snap leaders earning more than players on the bottom half [$F_{(3,619)}$=12.70, r^2=.06] (Figure 19).

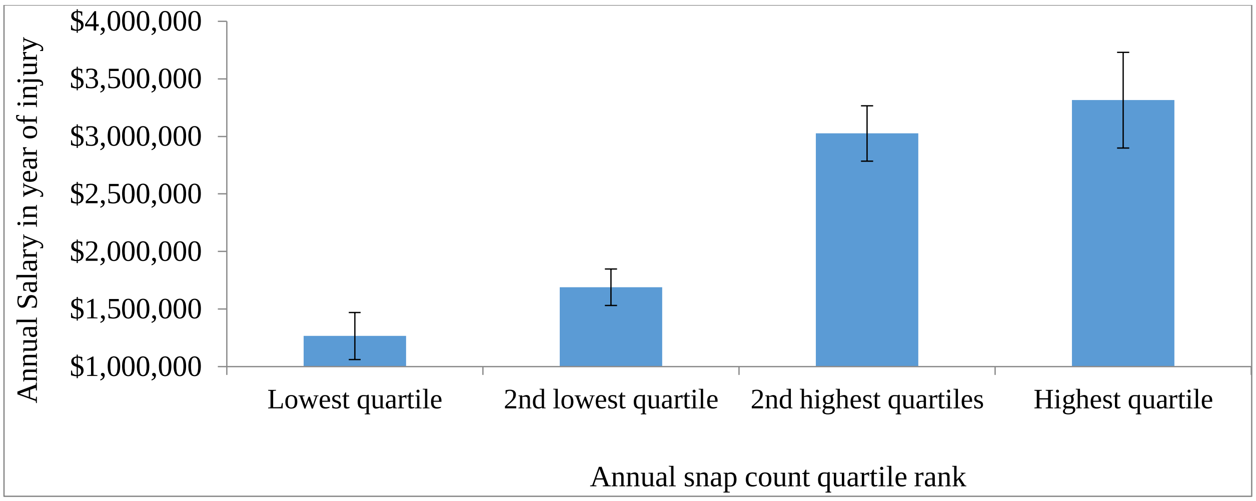

Figure 19 Annual salary during year of TBI by league wide yearly snap count quartile rank

Approximate value of TBI players by NFL reference groups

A one-way ANOVA exploring value approximation by snap quartile rank revealed significant differences in approximate value by athletic exposure quartile rank [$F_{(3, 631)}$= 46.58, r^2=.18,p<.01](Figure 20).

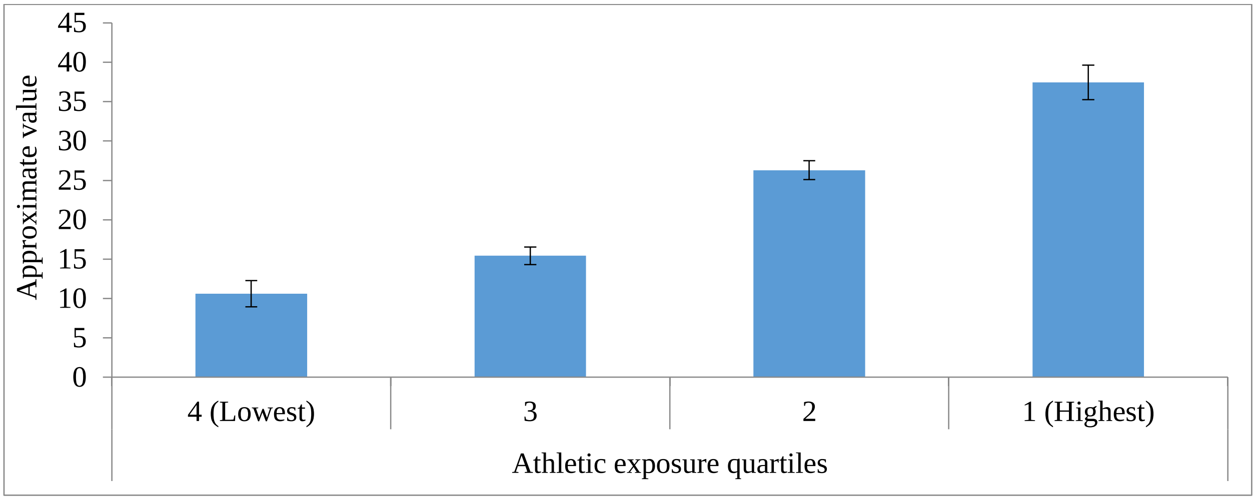

Figure 20 Approximate value of TBI injured players by yearly snap count quartile rank

Accommodating TBI players from HOF inductees with career weighted approximate value

A discriminant function analysis explored whether career weighted approximate value could discriminate between TBI and HOF cluster classifications which the results confirmed, producing the following function (Table 19):

Table 19 Discriminant function coefficient: discriminating between TBI injured players and Hall of Fame players with career

TBI/HOF= -1.8 +.43 (AV-AA)	
F-statistic [$_{(1,834)}$]	414.44
Chi-square [$\chi^2_{(1)}$]	336.25
Wilks' Lambda [Λ]	.67
Eigenvalue [λ]	.50
Canonical correlation [CCA]	.58

This discriminant function correctly classified 80.4% of the originally grouped cases when cross-validated (Table 20).

Table 20 Predicted group membership of TBI injured players with Hall of Fame inductees

TBI/HOF Classification Results			Predicted Group Membership		Total
			TBI	HOF	
Original	Count	TBI	504	125	629
		HOF	39	168	207
	%	TBI	80.1	19.9	100
		HOF	18.8	81.2	100
Cross-validated	Count	TBI	504	125	629
		HOF	39	168	207
	%	TBI	80.1	19.9	100
		HOF	18.8	81.2	100

Draft profiles of players who acquired a TBI

Draft profiles were collected which include: the year the player was drafted; the round in which the player was drafted; and the overall position they were selected for. In a typical NFL draft, there are 7 rounds in which players may be drafted. Thirty-two teams select a player every round, therefore there are 224 newly drafted players each year.

Approximate value of players who acquired a TBI by the draft round selection

A one-way ANOVA explored approximate value by the draft round the player was selected in when entering the NFL. The results indicate that approximate value varies significantly by draft round selection of the TBI injured players from 2012-2015 [$F_{(7,637)}$=25.80, r^2=.11, p<.01] (Figure 21).

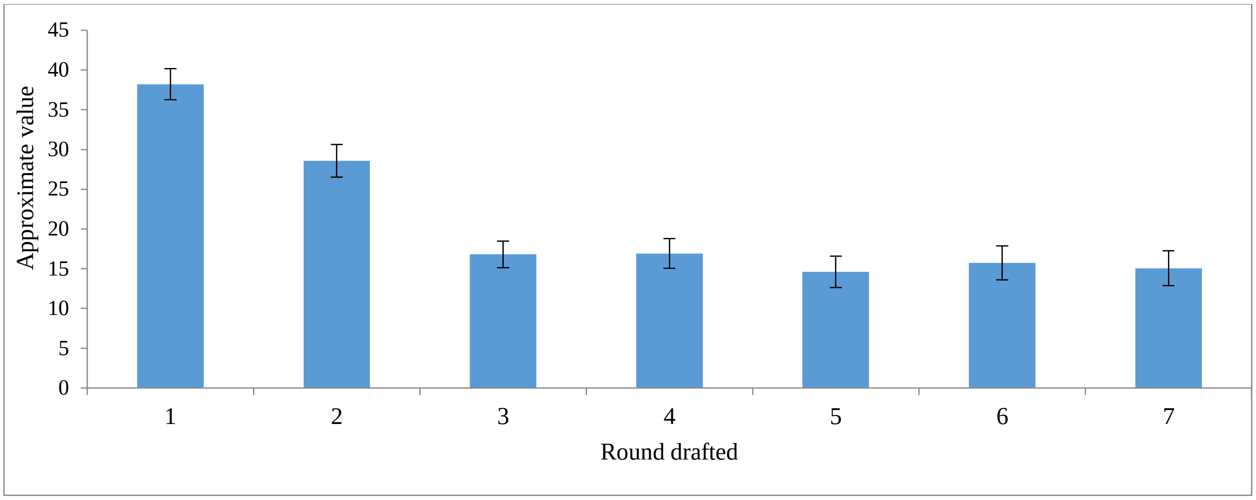

Figure21 Approximate value of TBI injured players by the draft round they were selected in

Overall rank of TBI players by draft round selection

A one-way ANOVA explored overall rank (relative to all NFL players since 1950) of TBI players by the draft round TBI injured players were selected in. The results indicate that players selected in the first round had a significantly greater rank then players drafted in all other rounds [$F_{(7, 637)}$=8.45,r^2=.08, p<.01].

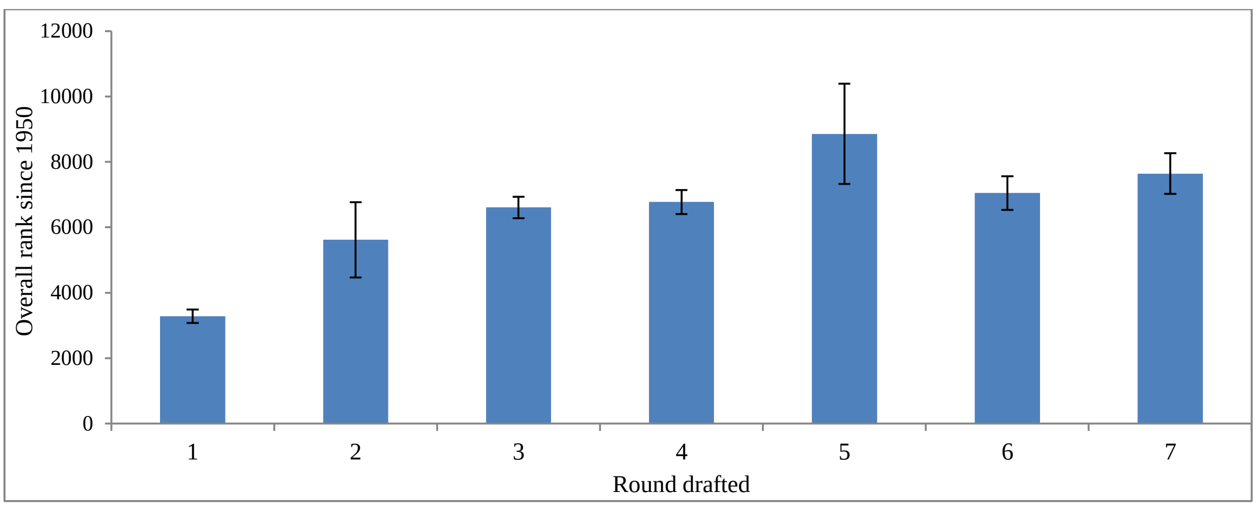

Figure 22 Overall rank since 1950 of TBI players by draft round they were selected in

Yearly salary of players who sustained a TBI by NFL draft round selection

A one-way analysis of variance exploring yearly salary of TBI injured players during year of injury by the draft round in which they were selected demonstrated significant differences between the means [$F_{(7,631)}$=19.56, r^2=.18, p<.01].

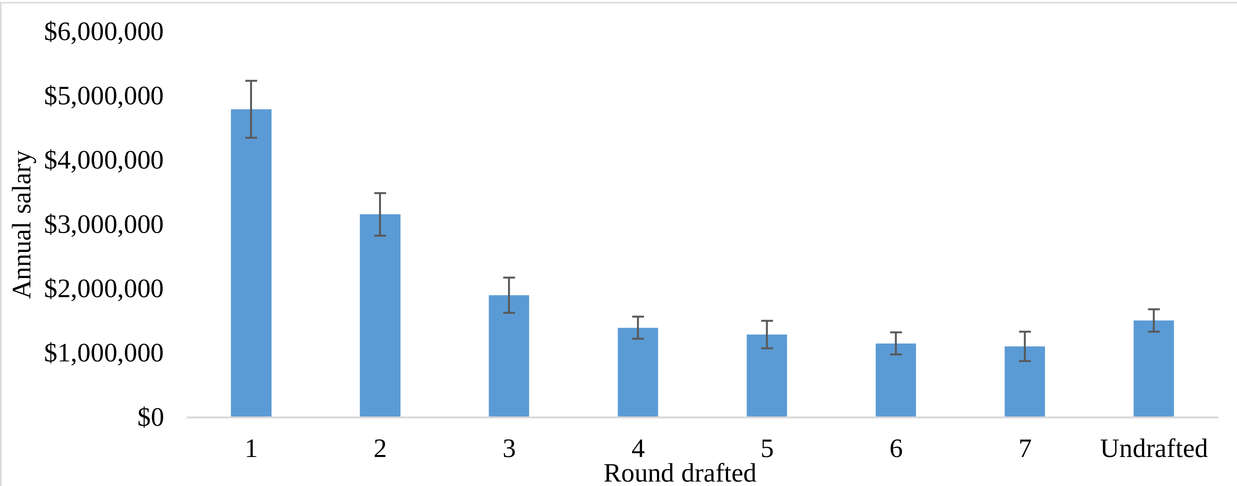

Figure 23 Yearly salary of TBI injured players by draft round they were selected in

Average pre-injury, during injury, return from injury and post return from injury athletic exposures of TBI players by draft round they were selected in

Critical TBI related snap counts including; preinjury [$F_{(6,439)}$=7.86, r^2=.10], during injury [$F_{(6,424)}$=2.37, r^2=.03], return from injury [$F_{(6,457)}$=4.36, r^2=.05], and post return from injury [$F_{(6,303)}$=6.07, r^2=.11] were all found to be significantly different by draft round (Figure 24).

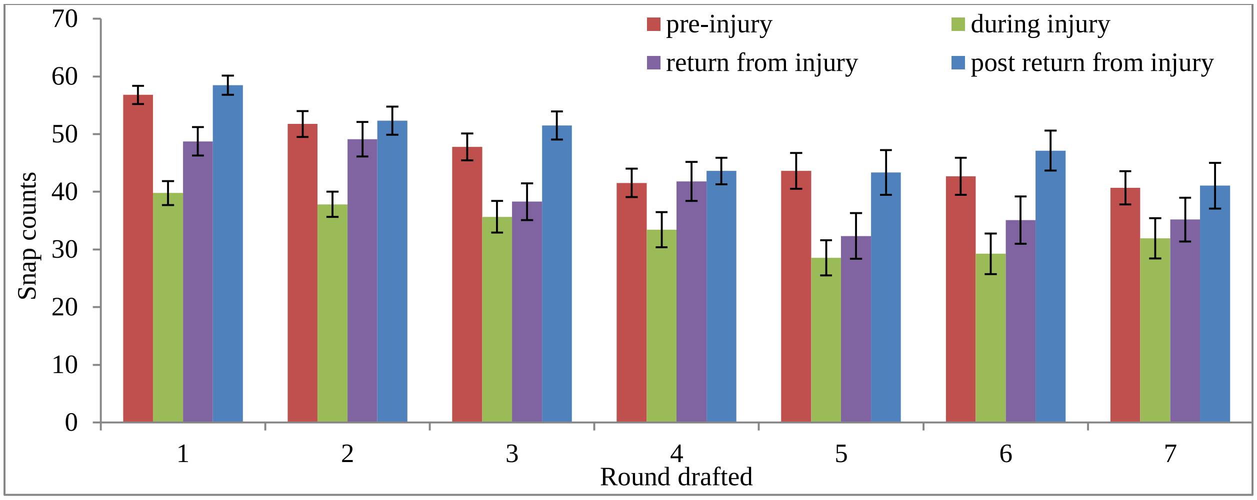

Figure 24 Pre-injury, during injury, return from injury, and post return from injury snap counts of TBI injured players by draft round selected

Annual athletic exposure by draft considerations

The concept that competitive considerations are intrinsic with regard to TBI recovery and healthcare facilitation within professional football, is highlighted when exploring crosstab analysis between two critical features of a players' non-injury related biography. For this analysis the round the injured player was drafted when entering the league was clustered into: (1) 1^{st} and 2^{nd} round; (2) every other draft round. Yearly snap count totals during year of injury were then referenced to all NFL peers during the same temporal as either: (1) top; or (2) bottom half of position specific athletic exposure leaders. When these dichotomous variables were entered into chi-square analysis, results indicate that 1^{st} and 2^{nd} round draft selections participate in more football during year of injury than all other NFL draftee selections [$\chi_{(1)}$=46.57, Λ=.08, Φ=-.27].

Table 21 Yearly snap count clusters by draft round selection clusters

		Athletic exposure		Total
		Bottom half	Top half	
Draft round selection	Early rounds	57	158	215
	Late rounds	231	189	420
Total		288	347	635

Competitive considerations

For the 579 TBI cases which occurred during a game, game outcome with regard to a winning or losing from the injured player's organizations viewpoint was recorded in order to explore possible a potential influence on diagnosis. In total, there were 334 TBI cases during losses, 256 during wins, and 5 during ties. During losses, 56% of Concussion and Neck injuries resulted in the player missing 1 game or more, in comparison to only 33% of Head Injury labels. During wins, 49% of concussion and neck injuries resulted in the player missing 1 or more games in comparison to just 29% for head injuries. Opposing team at time of TBI was examined to ascertain if specific teams are predictors of injury. The Cincinnati Bengals were most frequently the opposing team when a TBI was acquired (29).

Competitive ratios of TBI severity and change in athletic exposure

Chi-square analysis was conducted in order to explore possible discrepancies in TBI severity and change in athletic exposure cluster classifications by in game factors. The results indicate that competitive considerations such as all in-game injuries display significant differences between observed and expected values [$\chi^2_{(1)=}16.8$], wherein 34% of injuries resulted required rest and a decrease in athletic exposure upon returning from injury. Split-file by home/away games indicate these rates were dampened during home games [$\chi^2_{(1)=}6.74$], such that only 32% of home game TBI’s resulted in required rest and decreased athletic exposure. This effect was amplified during away games [$\chi^2_{(1)=}9.23$], wherein 38% of injuries resulted in more severe injuries which required rest. Further analysis by game outcome revealed only 32% of TBI’s during wins [$\chi^2_{(1)=}4.20$] required missing time and reducing play while 38% of TBI’s during losses [$\chi^2_{(1)=}14.15$] demonstrated this effect. Doctors and coaches from the Cleveland Browns [$\chi^2_{(1)=}5.54$], Detroit Lions [$\chi^2_{(1)=}6.74$] and Kansas City Chiefs [$\chi^2_{(1)=}10.12$] consistently followed this trend, wherein 42-68% of injuries were more severe and reduced athletic exposure.

Table 22 Chi-square results: competitive considerations to discrepancies in the relationship between games missed due to TBI and change in athletic exposure after injury

			Athletic Exposure		Total				Athletic exposure		Total
			-	+					-	+	
In game TBI	Games missed	0	133	131	264	During wins	Games missed	0	64	56	120
		%	25%	24%	49%			%	28%	25%	53%
		1+	185	88	273			1+	72	36	108
		%	34%	16%	51%			%	32%	16%	47%
	Total		318	219	537		Total		136	92	228
	%		59%	41%	100%		%		60%	40%	100%
Home games	Games missed	0	63	63	126	Cleveland Browns	Games missed	0	4	4	8
		%	26%	26%	51%			%	12%	12%	24%
		1+	79	40	119			1+	23	3	26
		%	32%	16%	49			%	68%	9%	76%
	Total		142	103	245		Total		27	7	34
	%		58%	42%	100		%		79%	21%	100%
Away games	Games missed	0	75	69	144	Detroit Lions	Games missed	0	3	7	10
		%	24%	22%	45%			%	16%	37%	53%
		1+	119	54	173			1+	8	1	9
		%	38%	17%	55%			%	42%	5%	47%
	total		194	123	317		Total		11	8	19
	%		61%	39%	100%		%		58%	42%	100%
During losses	Games missed	0	66	74	140	Kansas City Chiefs	Games missed	0	1	5	6
		%	22%	25%	46%			%	4%	19%	23%
		1+	111	51	162			1+	17	3	20
		%	37%	17%	54%			%	65%	12%	77%
	Total		177	125	302		Total		18	8	26
	%		59%	41%	100%		%		69%	31%	100%

Influence of altitude on TBI severity during competitive considerations

This effect was also observed during competitive consideration, specifically in stadiums with open roofs, wherein 61% of TBI's which required recovery occurred at elevated altitude, in comparison to 51% of less severe injuries which occurred at lower altitude [$\chi^2_{(1)}$=5.74, tau=.02, φ=.12]. These ratios were also affected during losses, insofar as 65% of TBI's which occurred at elevation required recovery, while 54% of less severe injuries occurred at lower altitude [$\chi^2_{(1)}$=11.23, tau=.04, φ=.19].

Table 23 Games missed due to injury by Altitude cluster classifications

			Altitude (meters)		Total
			<159.84	>159.84	
Open stadiums	Games missed	0	145	59	204
		%	34%	14%	47%
		1+	137	91	228
		%	32%	21%	53%
	Total		282	150	432
	%		65%	35%	100%
Loss	games missed	0	104	45	26
		%	32%	14%	8%
		1+	89	84	24
		%	28%	26%	7%
	Total		193	129	322
	%		60%	40%	100%

Team role of player who sustained a TBI by game outcome

Chi-square analysis was performed exploring team role (offense/defense) by game outcome (win/loss/tie). The results indicated that injuries were more prevalent among offensive players during games lost by their team [$x^2_{(2)}$=10.82, phi=.14] (Table 24).

Table 24 Team role of TBI injured player by game outcome

		Team role		Total
		Offense	Defense	
Game outcome	Loss	184	150	334
	%	(31%)	(25%)	(56%)
	Win	115	141	256
	%	(19%)	(24%)	(43%)
	Tie	5	0	5
	%	(01%)	(0%)	(01%)
Total		304	291	595
%		(51%)	(49%)	(100%)

Fantasy points during year TBI was acquired for offensive skilled positions

Quarterbacks accumulated more yearly fantasy points then did the other skill positions during season of injury [$F_{(3,210)}$=11.08, r^2=.14, $p<.01$].

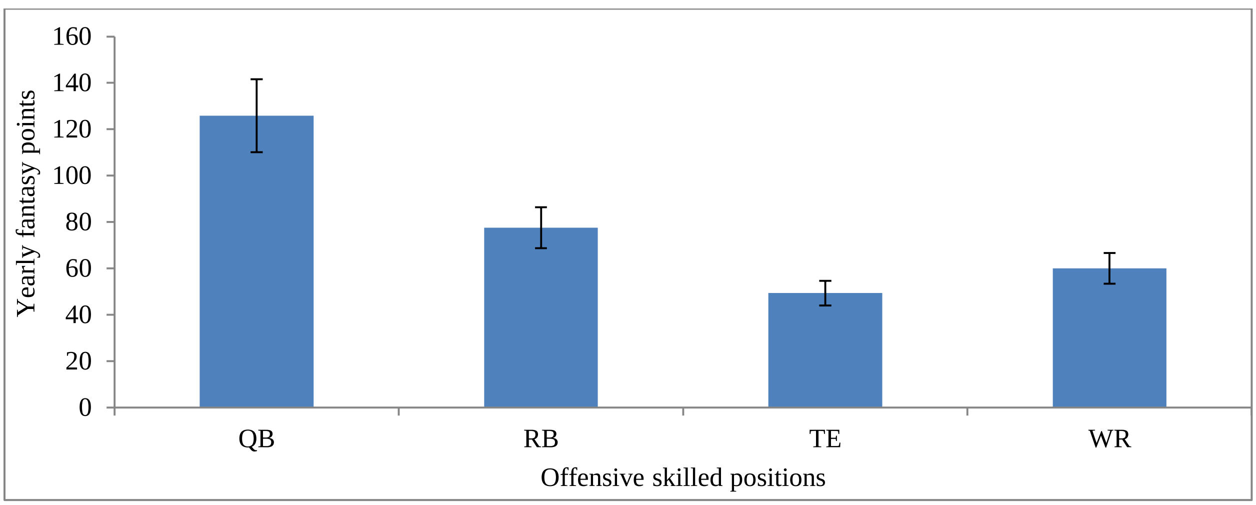

Figure 25 Yearly fantasy points by offensive skilled positions

Fantasy points during game in which TBI occurred for offensive skilled position

The extended play by the QB's during the game of injury was illustrated by analysis exploring weekly fantasy points during injury by position, wherein QB's accumulated more points than other players on day of TBI acquisition [$F_{(3,146)}$=4.55, r^2=.09].

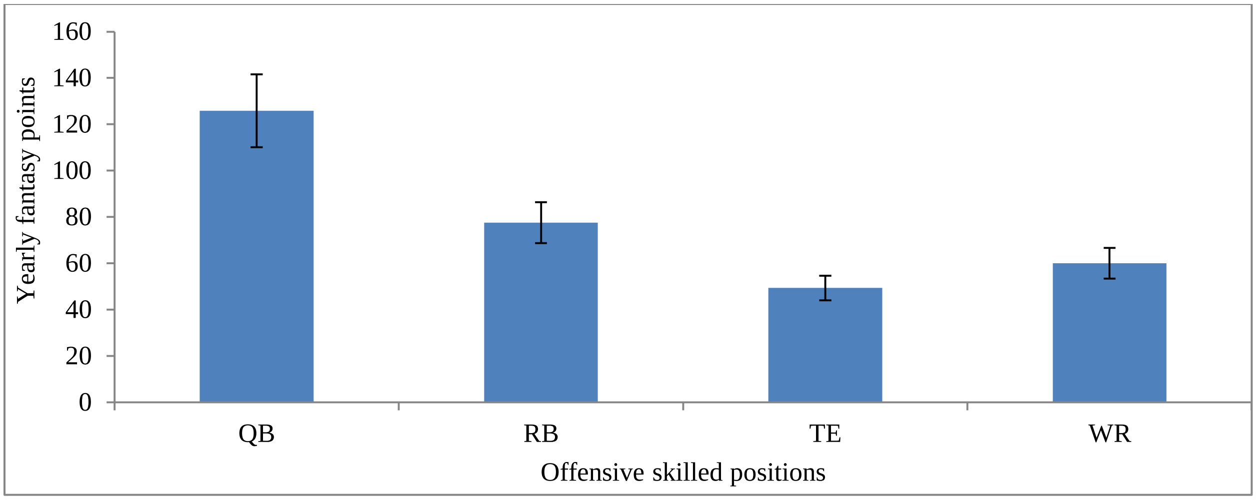

Figure 26 Fantasy points during TBI for offensive skilled positions

Injury severity and yearly fantasy points of TBI offensive skilled players

Pearson r and spearman rho correlational analysis exploring games missed due to TBI by yearly fantasy points indicates weak negative correlation between the variables (Figure 27) ($r_{(206)}$= - .24, $rho_{(206)}$= -.22).

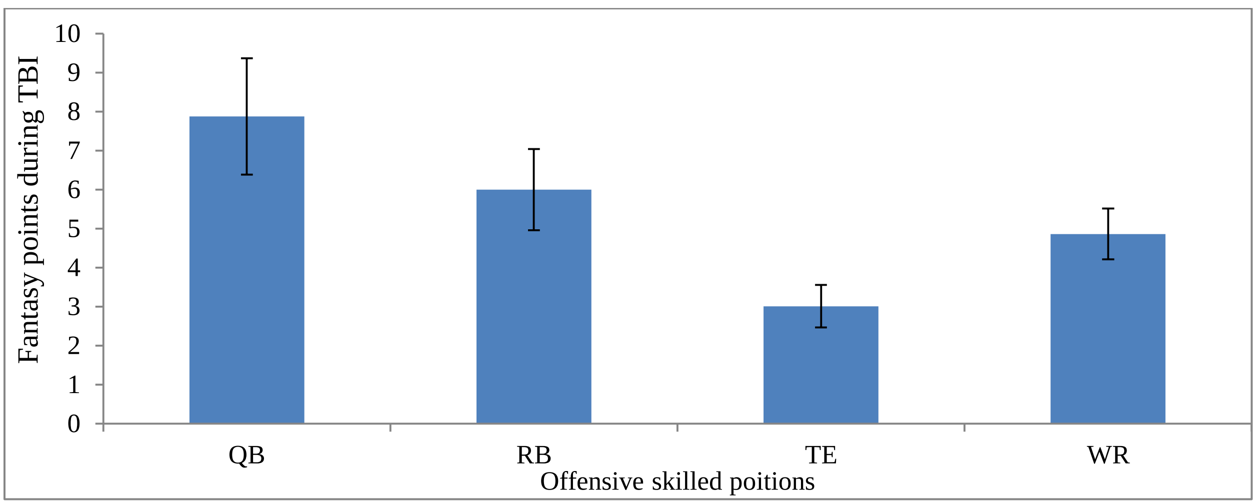

Figure 27 Games missed due to TBI by Yearly fantasy points

NFL play calling trends

Changing trends in play calling are a potential influence on TBI rates. The passing attack for example - which includes passing plays conducted through the air – increased from 2010-2015. This reality is reflected in yearly averages for (1) passing plays (%), (2) passing attempts,

(3) passes completed (%), (4) passing yards per game, (5) passing touchdowns per game, and (6) total yards per game, all of which have trended upward over the aforementioned 6-year period. This shift in play calling philosophy is also represented inversely in yearly rushing attack variables. These rushing variables include; (1) rushing plays (%), (2) rushing attempts, (3) yards per rushing attempt, and (4) rushing yards per game, all of which have decreased from 2010-2015. The yearly averages for the aforementioned aerial and ground attack trends by year can be observed in Table 25.

Table 25 NFL play calling philosophy from 2010-2015

Statistic	2010	2011	2012	2013	2014	2015
Passing Plays (%)	53.40%	53.50%	54.10%	54.50%	54.50%	55.50%
Passing Attempts	18394	18590	18951	19424	19086	19480
Passes Completed (%)	60.80%	60.10%	60.90%	61.20%	62.60%	63%
Passing Yards Per Game	443.09	459.38	462.57	471.22	473.62	487.64
Passing Touchdowns Per Game	2.93	2.91	2.96	3.14	3.15	3.29
Total Yards Per Game	672.03	693.67	694.4	696.98	696.29	705.31
Rushing Plays (%)	43.10%	42.90%	42.30%	41.70%	41.80%	40.90%
Rushing Attempts	13920	13971	13925	13871	13688	13488
Yards Per Rushing Attempt	4.21	4.29	4.26	4.17	4.16	4.13
Rushing Yards Per Game	228.93	234.29	231.83	225.76	222.66	217.67

League wide NFL passing statistic trends by year

When the pass attack variables are z-score transformed and plotted over time, the results can be observed in Figure 28.

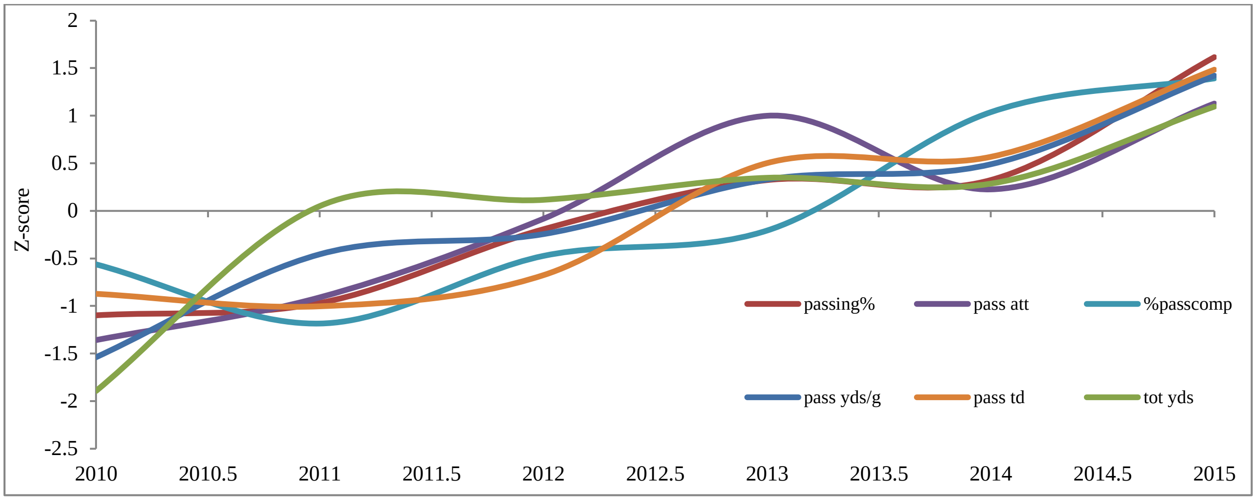

Figure 28 Z-score transform: NFL league wide aerial statistics by year including; passing percent, pass attempt, percent pass complete, pass yards per game, pass touchdowns, total passing yards

League wide NFL running statistic trends by year

The Z-scored transformed rush variables include yards per rushing attempt, percent of rushing plays, rushing attempts, and rushing yards per game. A plot of these variables over time appears as Figure 29.

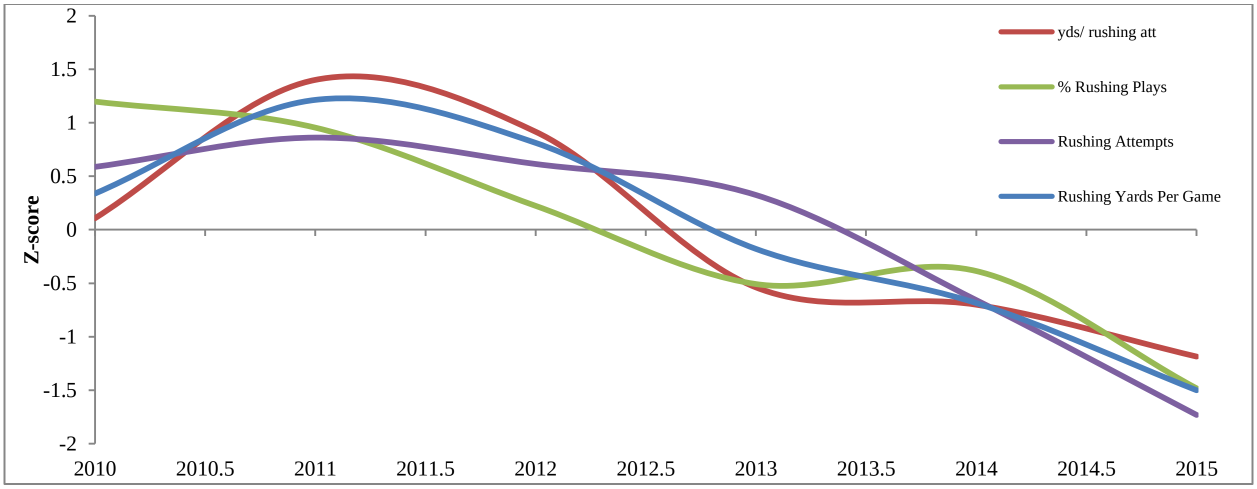

Figure 29 Z-score transform: NFL league wide ground play calling statistics by year including; yards per rush attempt, percent of rushing plays, rushing attempts, rushing yards per game

TBI history

The 'Quigley rule', created in 1945 by Dr. Quigley, is in reference to a three-strike rule with regard to returning to play after repeated acquired Traumatic Brain Injuries. The original rule stated that if an athlete suffers 3 concussions in 1 season, that they are to be ruled out of competition for the remainder of that year (McCrory, 2001). This policy was revised by several scholars, including Thorndike who suggested that players who suffer 3 concussions in a career should retire. Players with a concussion history are more likely to have future injuries and previous concussions may be associated with slower recovery of neurological function (Guskiewicz et al, 2003).

Career weighted approximate value by TBI history

Career weighted approximate value also significantly differed by career TBI history [$F_{(5,639)}$=3.13, r^2=.02, p<.001].

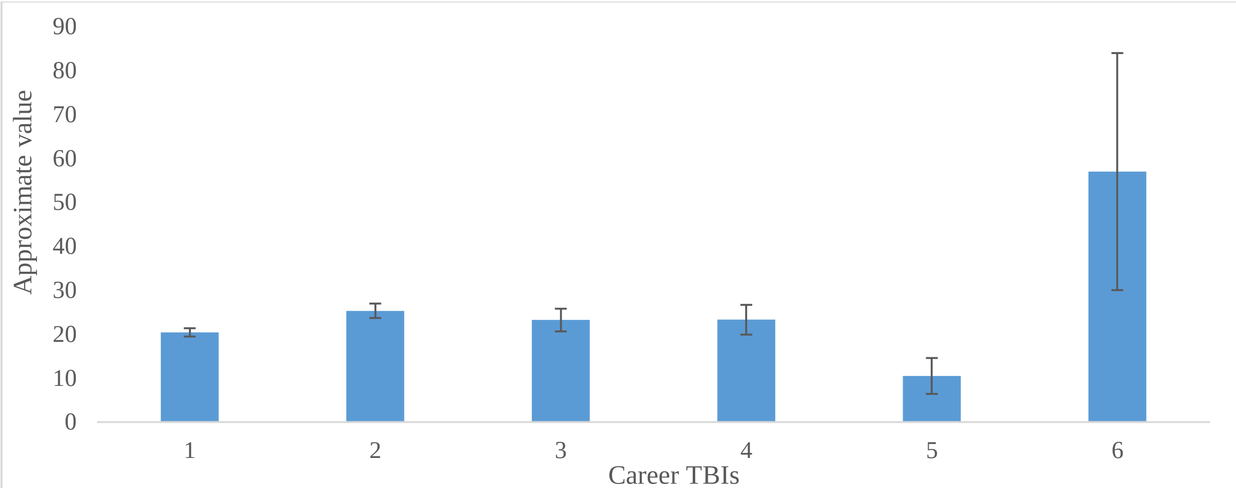

Figure 30 Career weighted approximate value by career head trauma

Injury severity by TBI history

One-way analysis of variance exploring games missed due to injury by career concussion total revealed significant differences between the means [$F_{(5,606)}$=6.08, r^2=.05, p<.001].

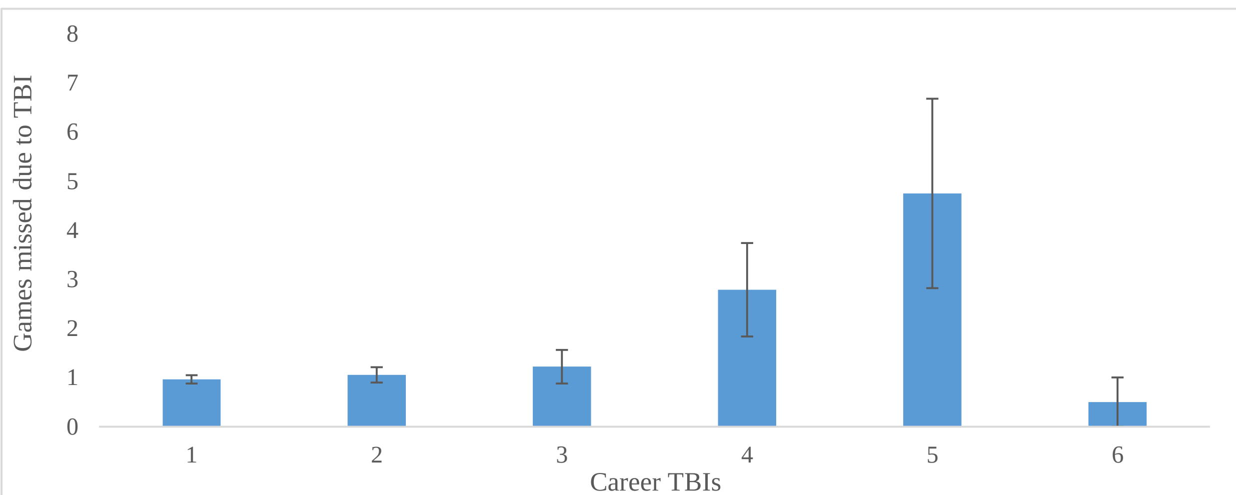

Figure 31 Games missed due to TBI by career head trauma history

Injury severity and BMI for players with a documented TBI history

Chi-square analysis was conducted exploring injury severity and BMI cluster classifications within players with a history of head trauma. The results indicate that players who have acquired multiple head injuries and who were smaller than average at their position, missed more time per injury then players who were bigger than average and had sustained multiple TBI's [$\chi_{(1)}$=10.24, lambda=.19, phi=-.22].

Table 26 Games missed due to injury clusters by league and position referenced BMI clusters for players with head trauma history

			Games missed due to TBI		Total
			0	1+	
Individuals with reported Head trauma history	BMI+/-	BMI-	37	64	101
		%	18%	30%	48%
		BMI+	64	45	109
		%	30%	21%	52%
	Total		101	109	210
	%		48%	52%	100%

Injury severity for players with a TBI history by organization

Split file in SPSS was employed in order to isolate the multiple head injury group. A One-way analysis of variance exploring games missed due to injury by team illustrates that 12 NFL teams showed an average of less than one game missed following subsequent TBI for players in the repeated head trauma cluster [$F_{(31,178)}$=1.64, r^2=.22, p<.03].

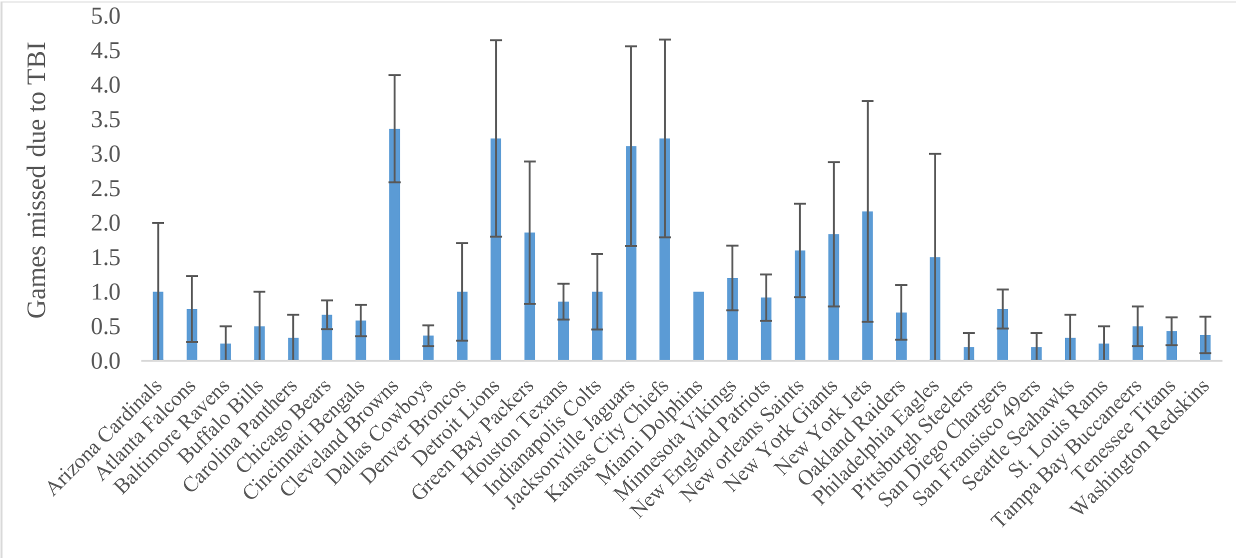

Figure 32 Games missed due to injury for players who have a history of repeated head trauma by team doctors

TBI History and team role

Chi-square analysis was conducted exploring TBI history with team role cluster classifications, wherein a discrepancy was demonstrated between observed and expected values [χ^2=3.51, p<.04]. The data indicates that players on offense acquired more repeated head trauma in comparison to players who acquired a TBI on defense.

Table 27 Head trauma history by team role of injured player

		Team role		Total
		Offense	Defense	
TBI History	First	208	213	421
	%	32%	33%	65%
	Repeated	128	96	224
	%	20%	15%	35%
Total		336	309	645
%		52%	48%	100%

Career related predictors of TBI history

The concussion history of 645 TBI injured players in the NFL between 2012 and 2015 were collected from *frontline.org* as well as from *kffl.com*. The results indicate that 40% of TBI injured players between 2012 and 2015 in the NFL had suffered at least their 2^{nd} career TBI (N=213), and 8% (N=50) had suffered at least their 3^{rd} career TBI. Total career TBI count positively correlated with several career related features including: average athletic exposure before injury ($r_{(569)}$=.09, $rho_{(569)}$=.09); career weighted approximate value ($r_{(645)}$=.09, $rho_{(645)}$=.14); ($r_{(632)}$=.08, $rho_{(632)}$=.10); athletic exposure after return from injury ($r_{(390)}$=.11, $rho_{(390)}$=.14); and the number of years the player has played professional football ($r_{(644)}$=.16, $rho_{(644)}$=.19). When these variables are simultaneously entered into multiple regression analysis in order to predict the player's career concussion total, number of years pro entered as the lone predictor [$F_{(1,643)}$=15.78, r^2=.02] yielding the following predictive equation: **careerTBI#= 1.18 + .045*(#of years pro)**. The correlation between the documented career TBI's sustained with the number of years the player has played professional football is presented in Figure 33.

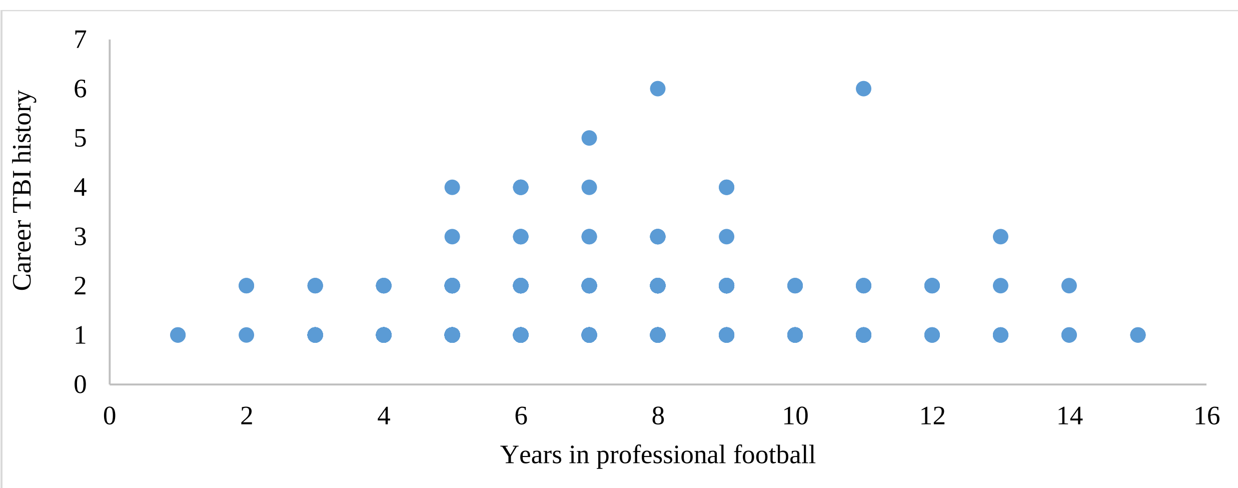

Figure 33 Career TBI's by number of years pro

Temporal and spatial contributions to TBI acquirement

There were 271 diagnosed concussions during preseason and season games as well as practices in the 2015 season from the start of training camp until the final snap. This was an increase in the total number of concussions after there had been a downward trend in 2013 (229) and 2014 (206) from 2012 (261), when the league implemented its enhanced concussion protocol. This is evident when quantifying the number of concussions per team, and comparing the averages of the 32 franchises by year [$F_{(3, 124)}$=4.85, r^2=.11, p=.0031] (Figure 34).

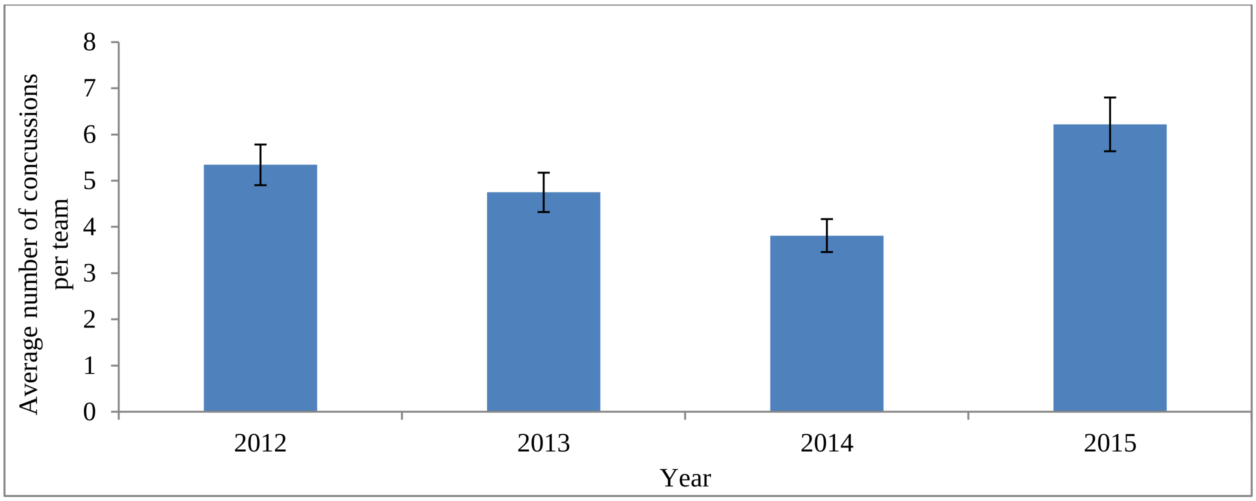

Figure 34 Average number of concussions per team by year

TBI rates by field type

Analysis of variance showed no significant difference in concussions per year by field type ($F_{(19, 12)}$=1.17, r^2=.64, p=.4) (Figure 36). A paired samples t-test did reveal differences between outliers such as Voyageur Bermuda grass and Field Turf Revolution [$t_{(10)}$=-3.13, p=.011]. The results indicated lower rates for the Voyageur Bermuda grass (M=2.5, SEM=.87) in comparison to the Field Turf revolution (M=7.00, SEM=1.15).

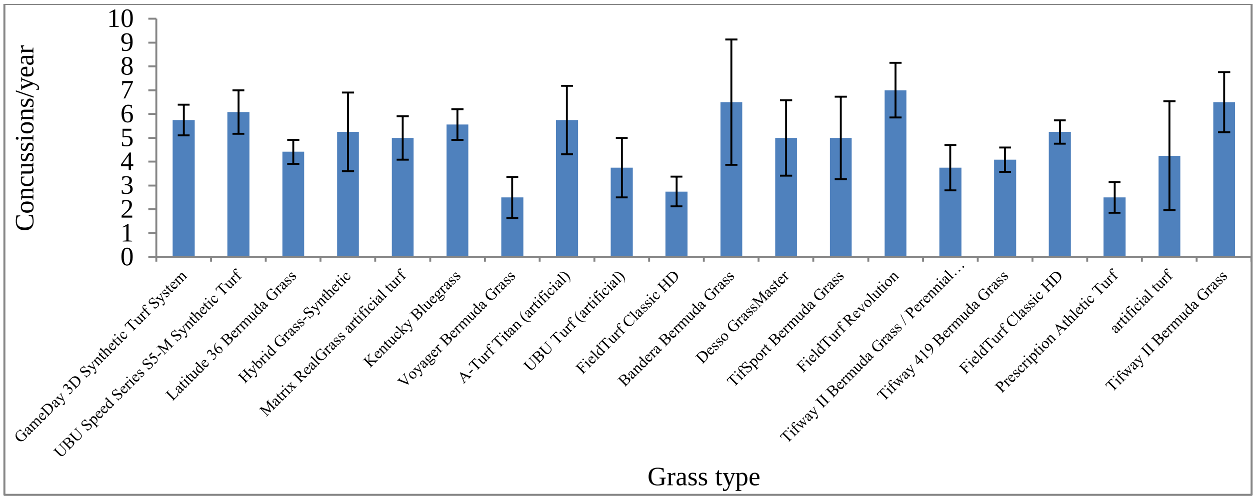

Figure 35 Average number of concussions per year by field type

TBI rates by field type clusters

Field types were manually clustered into turfs, grasses or bluegrasses, and an independent samples t-test of annual TBI rates indicated that grass fields had significantly lower (M=4.62, SD=1.18) TBI rates then did Bluegrass (M=5.56, SD=.47) fields ($t_{(13)}$=-2.35, p=.035).

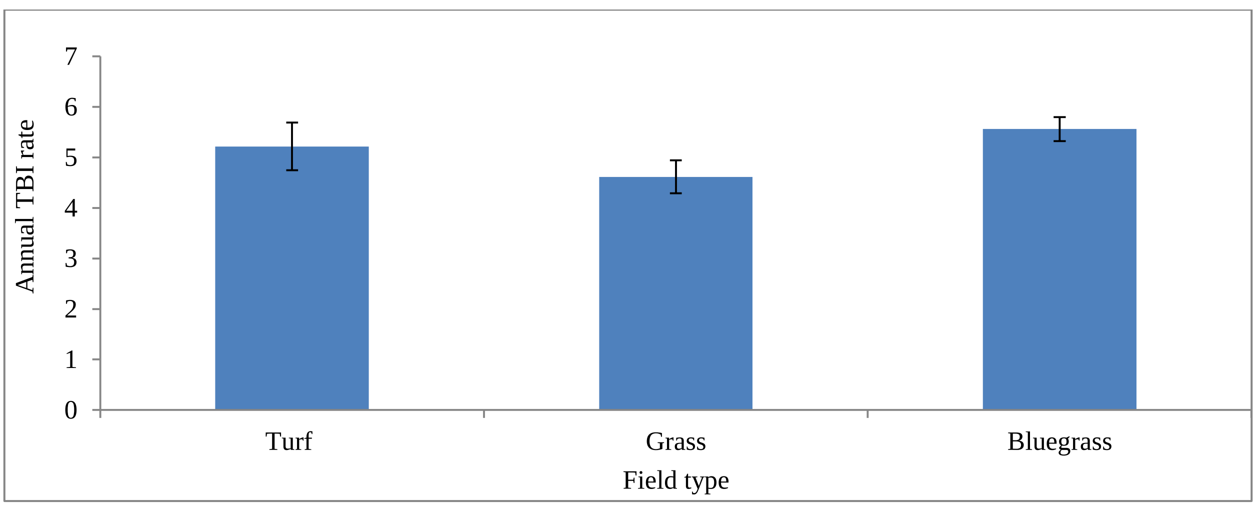

Figure 36 Concussions per year by field type: Turf, grass, and Bluegrass

TBI rates by stadium type

A one-way ANOVA explored annual concussion rates by roof type. The results indicate that TBI incidence rates were not significantly different in fixed, open or retractable stadiums.

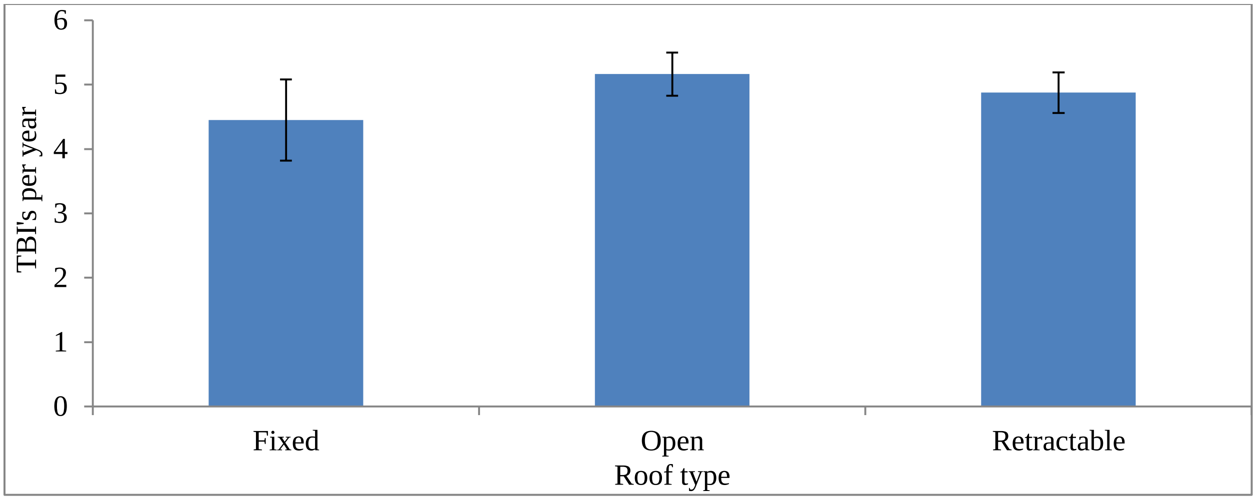

Figure 37 TBI's per year in fixed, open, and retractable Roof type stadiums

Humidity and temperature during TBI acquirement by stadium design

A one-way ANOVA exploring temperature during TBI by stadium design indicated significant differences between the means. Retractable roof stadiums were significantly warmer at time of TBI acquisition [$F_{(2,587)}$=8.32, r^2=.03].

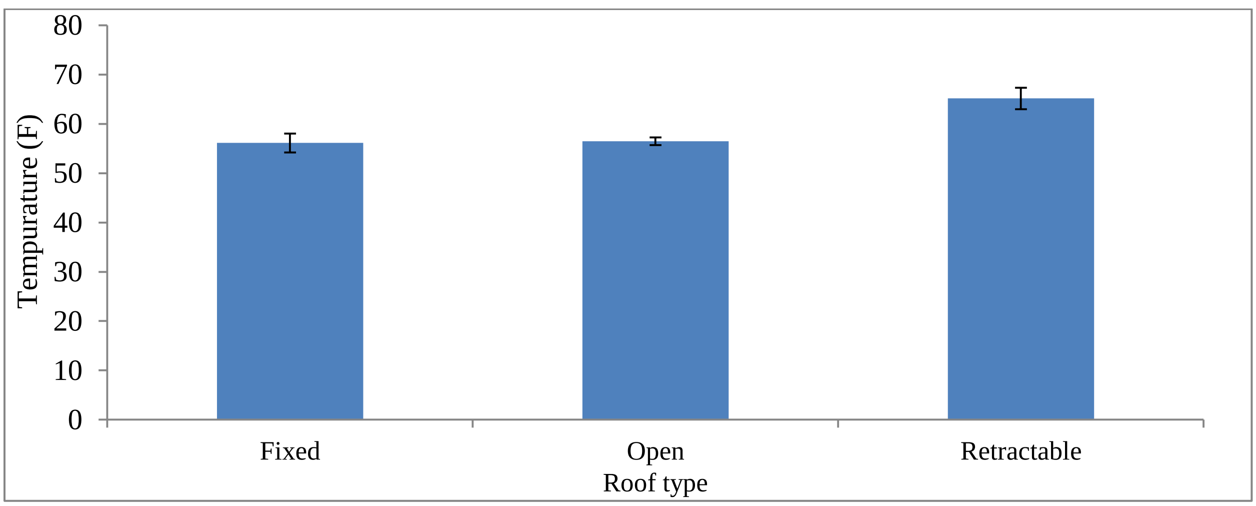

Figure 38 Game time temperature of city in which TBI occurred by roof type

A one-way analysis indicated humidity was significantly lower in retractable roof stadiums at time of TBI acquisition relative to fixed and open stadium design [$F_{(2,587)}$=7.08, r^2=.02].

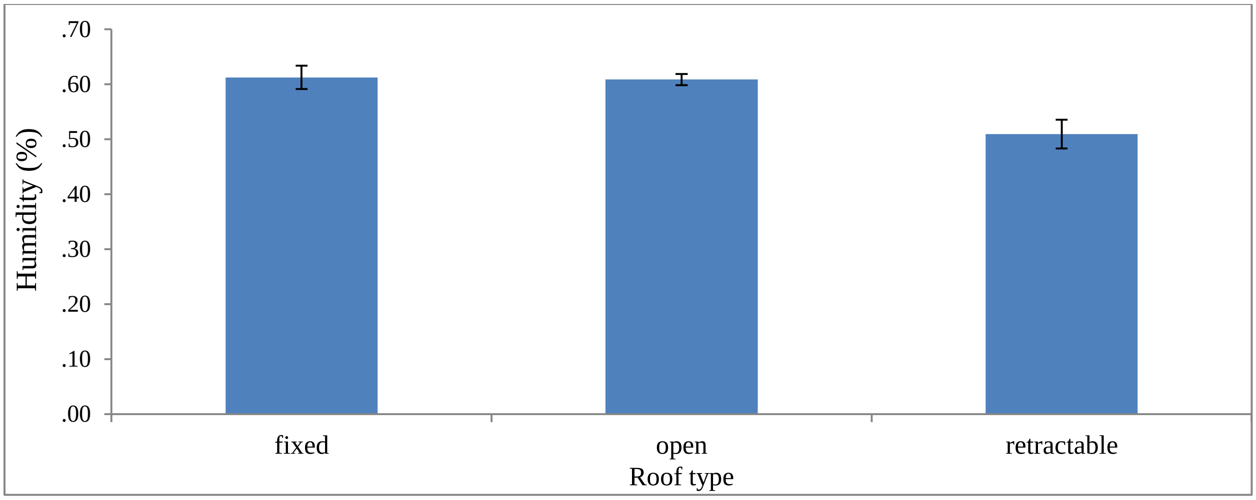

Figure 39 Humidity during TBI acquisition by roof type

Environmental ratios of TBI severity and change in athletic exposure

Environmental factors promoted the relationship between injury severity and change in athletic exposure classifications. In specific, this effect was promoted during mostly cloudy weather [$\chi^2_{(1)}$=9.47], Southwesterly winds [$\chi^2_{(1)}$=6.72], and during high humidity [$\chi^2_{(1)}$=15.66; $\chi^2_{(1)}$=5.65].

Table 28 Chi-square results: Weather related contributions to discrepancies in the relationship between games missed due to TBI and change in athletic exposure after injury

			Athletic exposure		Total
			Decrease	Increase	
Cloudy weather	Games missed	0	27	34	61
		%	25%	31%	55%
		1+	36	13	49
		%	33%	12%	45%
	Total		63	47	110
	%		57%	43%	100%
Southwesterly winds	Games missed	0	9	10	19
		%	24%	26%	50%
		1+	15	4	19
		%	39%	11%	50%
	Total		24	14	38
	%		63%	37%	100%
60-80% Humidity	Games missed	0	30	43	73
		%	21%	30%	50%
		1+	53	19	72
		%	37%	13%	50%
	Total		83	62	145
	%		57%	43%	100%
80-100% Humidity	Games missed	0	29	28	57
		%	25%	24%	50%
		1+	42	16	58
		%	37%	14%	50%
	Total		71	44	115
	%		62%	38%	100%

Stadium contributions to TBI severity and change in athletic exposure as a result of TBI

Chi-square analysis was conducted in order to identify relationships between TBI severity and change in athletic exposure cluster classifications by Stadium type. The results indicated that injury severity and change in athletic exposure had a significant relationship within fixed [$\chi^2_{(2)=}$15.89, tau=.20] and open roofs [$\chi^2_{(2)=}$14.45, tau=.04].

Table 29 Change in athletic exposure by injury severity cluster classifications during stadium considerations

roof type			Athletic Exposure		Total
			Decrease	Increase	
Fixed Roof	Games missed due to TBI	0	18	24	42
		%	23%	31%	54%
		1	26	6	36
		%	33%	8%	46%
	Total		44	30	78
	%		56%	38%	100%
Open Stadiums	Games missed due to TBI	0	87	102	204
		%	20%	24%	47%
		1	137	74	228
		%	32%	17%	53%
	Total		224	176	432
	%		52%	41%	100%

TBI rates by city

A one-way ANOVA exploring annual TBI rates-per-team by stadium in which the injury occurred, yielded insignificant differences between the means [$F_{(31, 96)}$=1.40, r^2=.31, p=.10]. A paired samples t-test was employed to determine if rates significantly varied by the outlier cities in the Southeast and Northwest U.S. which had significantly elevated rates from those cities which were had lower annual rates. The results indicate significantly lower annual TBI rates [$t_{(6)}$=-3.20, p=019] in Carolina (M=2.5, SEM=.87) in comparison to Seattle (M=8.75, SEM=1.75).

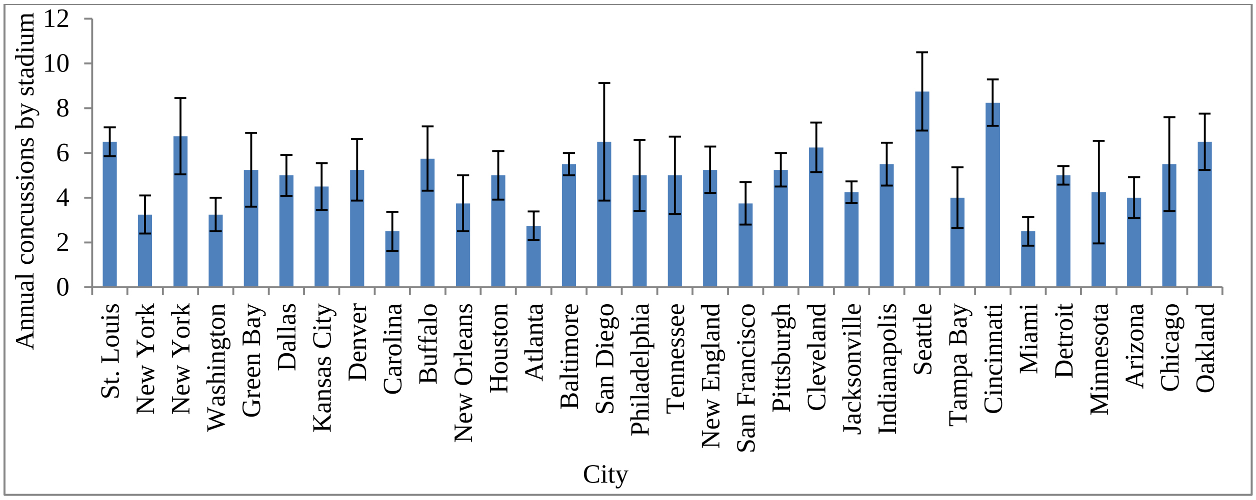

Figure 40 Number of concussions per year by city

Temperature during TBI by city in which the injury occurred

A one-way analysis of variance was conducted exploring *temperature* at the time of injury by *stadium* in which the injury revealed significant differences between the means [$F_{(30,563)}$=8.80, r^2=.32, p<.001].

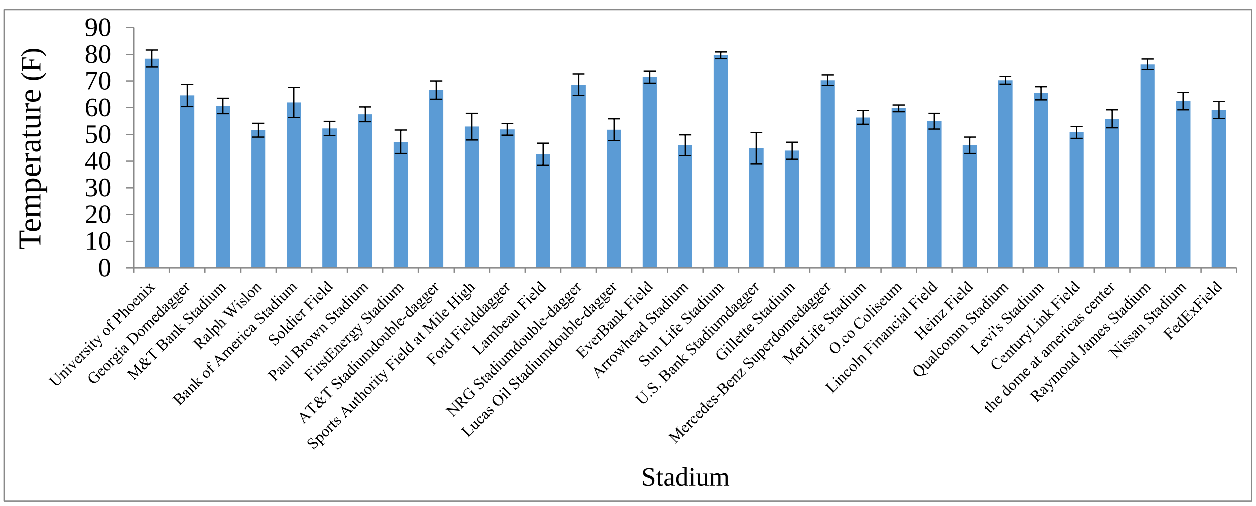

Figure 41 Temperature of city at game time during which TBI occurred

Local ratios of TBI severity and change in athletic exposure

A chi-square analysis was conducted exploring TBI severity and change in athletic exposure cluster classifications. Spatially this relationship was evident for injuries which occurred in the Western U.S. [$\chi^2_{(1)}$=18.94], in specific those injuries which occurred in San Diego [$\chi^2_{(1)}$=5.06] or St. Louis [$\chi^2_{(1)}$=8.42] stadiums.

Table 30 Change in athletic exposure by games missed due to injury in specific cities

			Change in athletic exposure		Total
			Decrease	Increase	
San Diego Stadium	Games missed	0	3	10	13
		%	13%	43%	57%
		1+	7	3	10
		%	30%	13%	43%
	Total		10	13	23
	%		43%	57%	100%
St. Louis stadium	Games missed	0	3	9	12
		%	14%	43%	57%
		1+	8	1	9
		%	38%	5%	43%
	Total		11	10	21
	%		52%	48%	100%

TBI rates by NFL conference

An independent sample t-test compared the average number of concussions per team per year by the NFL conferences including the American Football Conference (AFL) and National Football conference (NFC). The results indicate that more concussions were diagnosed in the AFC (M=5.62, SD=3.22) than in the NFC (M=4.44, SD=1.94) [$t_{(126)}$=2.53, p<.01].

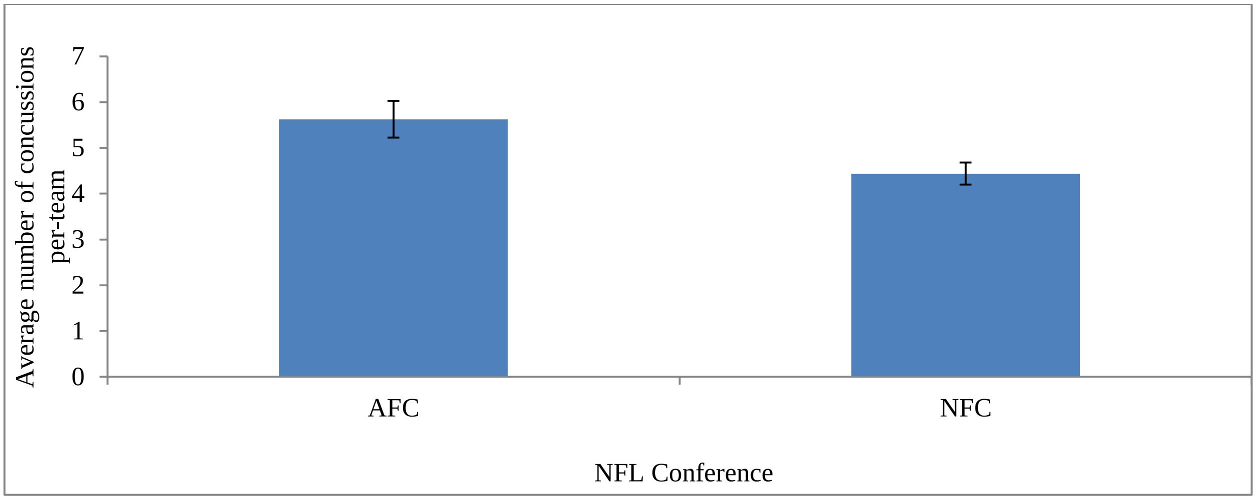

Figure 42 T-test results: Average number of concussions per team by NFL conference: AFC/NFC

TBI rates by NFL Division

A one-way ANOVA exploring number of concussions per team by the divisions in each conference (North, South, East, and West) indicated significant differences between these groups [$F_{(7,120)}$=3.05, r^2=.15, p=.005], suggesting that localized regions within the U.S. may have characteristics that contribute to injury susceptibility.

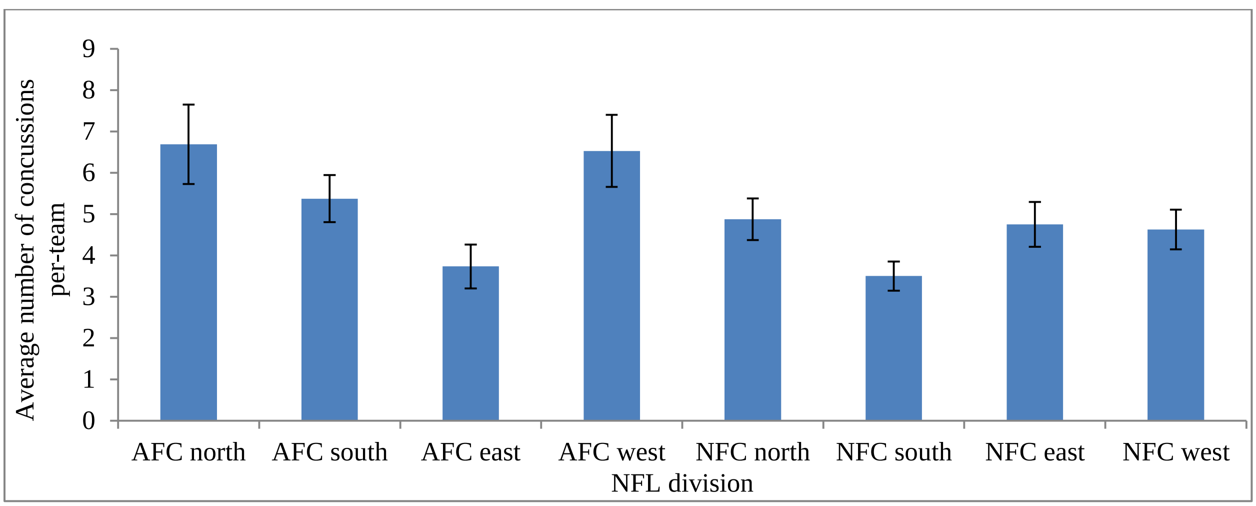

Figure 43 Average number of concussions per team by division

TBI rates by the cardinal directions in the NFL

When divisions from each conference were grouped together by cardinal direction, and entered into a one-way ANOVA, a significant difference between means was observed [$F_{(1,126)}$=7.49, r^2=.06, p=.007]. The data indicates that teams that are within divisions in the North and West report a higher number of concussions than teams in the South and East.

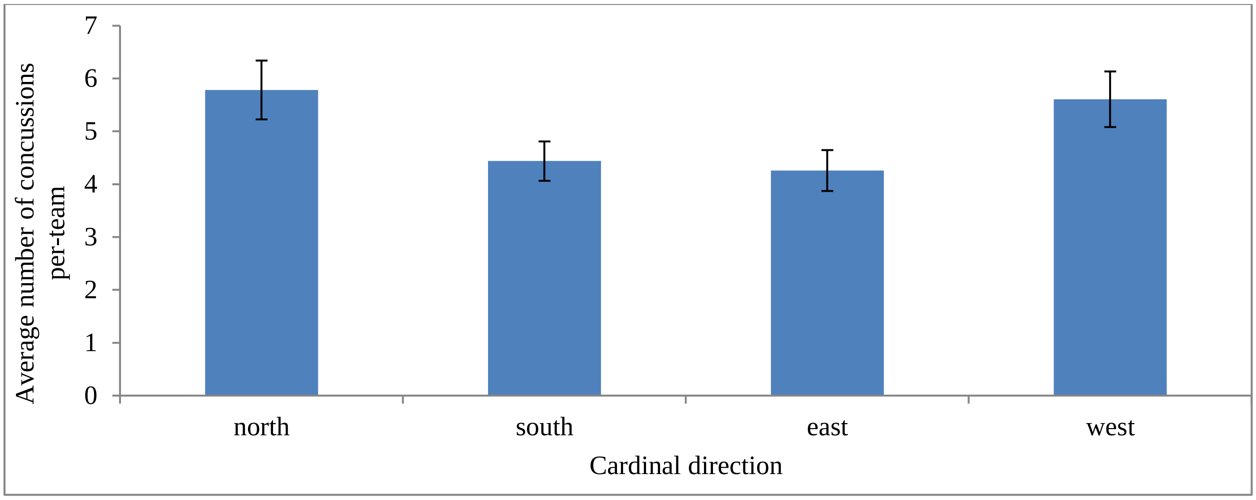

Figure 44 Average number of concussions per team by cardinal direction in the National Football League (NFL)

TBI rates by Northwest and Southeastern U.S.

These cardinal direction clusters were manually clustered into Northwest and Southeast groupings. The average annual concussions per team were entered into an independent samples t-test by these geographical cluster classifications. The results indicate that the average number of TBI's per team were higher in Northwest (M=5.67, SD=3.09) NFL divisions, then they were in the Southeast (M=4.39, SD=2.11) divisions ($t_{(126)}$=2.73, p=.03)

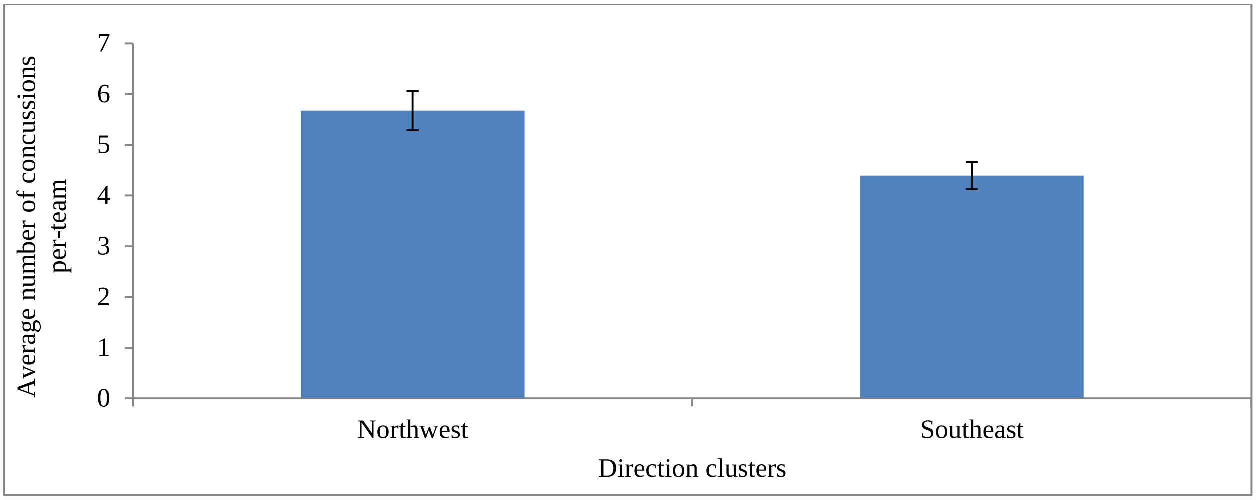

Figure 45 Average number of concussions per team by northwest and Southeast NFL Divisions

Altitude ratios of TBI severity in the North and West U.S.

Chi-square analysis exploring the relationship between games missed and altitude showed relationships dependent upon spatial variation. Northern latitudes (>37.85° North) [$\chi^2_{(1)}$=3.14], and Western longitudes showed a significant relationship (<89.86° West) [$\chi^2_{(1)}$=4.98, tau=.02, φ=.15].

Table 31 Injury severity and altitude within Northwestern regions

			Altitude (meters)		Total
			<159.84	>159.84	
North U.S.; >37.86°	Games missed	0	91	81	172
			24%	21%	45%
		1+	92	118	210
			24%	31%	55%
	Total		183	199	382
			48%	52%	100%
West U.S.; <89.87°	Games missed	0	94	29	123
			41%	13%	54%
		1+	66	39	105
			29%	17%	46%
	Total		160	68	228
			70%	30%	100%
Open stadiums	games missed	0	145	59	204
			34%	14%	47%
		1+	137	91	228
			32%	21%	53%
	Total		282	150	432
			65%	35%	100%

Altitude contributions to TBI severity by player profile

TBI severity and altitude cluster classifications entered into crosstab analysis in order to determine if altitude was associated with variation in TBI severity. The results indicated 57% of TBI's acquired at higher altitude required the player to miss time due to injury, in juxtaposition to only 47% at lower altitudes [$\chi^2_{(1)}$=5.26, tau=.009, φ=.10]. Further investigation identified specific player attributes that enhance this effect. Crosstab analysis revealed that altitude amplifies TBI severity for players with below average BMI relative to their position [$\chi^2_{(1)}$=4.62, tau=.02, φ=.13], and for players drafted in the late rounds (3-7) of the NFL entry draft [$\chi^2_{(1)}$=3.91, tau=.01, φ=.10], including undrafted players [$\chi^2_{(1)}$=3.92, tau=.04, φ=.19]. This effect was present for players who participated in less football than their position-average during year of injury [$\chi^2_{(1)}$=3.89, tau=.02, φ=.13], specifically those players who ranked in the 3rd quartile with regard to annual snap count [$\chi^2_{(1)}$=3.42]. Players on offense were the unit most susceptible to this effect [$\chi^2_{(1)}$=3.72], specifically tight ends [$\chi^2_{(1)}$=4.99, tau=.09, φ=.29].

Table 32 Injury severity by altitude during competitive considerations

			Altitude (meters)		Total
			<159.84	>159.84	
Games missed		0	186	97	283
		%	32%	17%	49%
		1+	167	129	296
		%	29%	22%	51%
Total			353	226	579
%			61%	39%	100%
BMI-	Games missed	0	80	42	122
		%	29%	15%	45%
		1+	79	71	150
		%	29%	26%	55%
	Total		159	113	272
	%		58%	42%	100%
<50% Annual athletic	Games missed	0	69	35	104
		%	28%	14%	42%

exposure		1+	77	66	143
		%	31%	27%	58%
	Total		146	101	247
	%		59%	41%	100%
3rd Quartile annual snaps	Games missed	0	52	26	78
		%	30%	15%	46%
		1+	49	44	93
		%	29%	26%	54%
	Total		101	70	171
	%		59%	41%	100%
Offense	Games missed	0	85	42	127
		%	29%	14%	43%
		1+	95	75	170
		%	32%	25%	57%
	Total		180	117	297
	%		61%	39%	100%
Tight End	Games missed	0	18	4	22
		%	31%	7%	38%
		1+	19	17	36
		%	33%	29%	62%
	Total		37	21	58
	%		64%	36%	100%

Altitude and the Earth's Geomagnetic field during TBI acquirement

Correlational analysis indicated that *Altitude* (meters) of TBI acquirement was associated with features associated with weather as well as the Earth's magnetic field during TBI acquirement. Pearson r and spearman rho analysis indicated that *altitude* was positively correlated with the *total intensity* $(F=\sqrt{X^2+Y^2+Z^2})$ [$r_{(596)}$=.20, rho=.46], the *orthogonal component* *(Z)* [$r_{(596)}$=.19, rho=.45], and the *magnetic inclination* $(I= \tan^{-1}[Y/X])$ [$r_{(596)}$=.17, rho=.41] of the Earth's magnetic field. Altitude was also positively associated with *visibility (miles)* [$r_{(593)}$=.55, rho=.13]. Altitude was inversely related with the *horizontal intensity* $(H=\sqrt{X^2+Y^2})$ [$r_{(596)}$= -.14, rho= -.35], and *north component* $(X=H \cos[D])$ [$r_{(596)}$= -.11, rho= -.26] of the Earth's magnetic field. Other negative correlates of altitude include; *dew point* [$r_{(593)}$= -.34, rho= -.34], *humidity* [$r_{(594)}$= -.26, rho= -.13], and *temperature* [$r_{(594)}$= -.11, rho= -.21]. Each TBI injury was recoded into hi (+) or low (-) altitude cluster classifications in reference to the aforementioned league average.

Discriminant analysis determined whether the altitude correlates of the Earth's geomagnetic field could accommodate hi/lo altitude group membership. The results indicated that the *total intensity (F)* and the *orthogonal component (Z)* of the Earth's magnetic field, entered as independent variables within the analysis [$\chi^2_{(2)}$=228.57, $F_{(2,589)}$=139.93, λ=.68, CCA=.57], which correctly classified 76.3% of the cross-validated grouped cases, and produced the following discriminant function:

+/-Altitude= -157.05 -.005*(Z) + .007*(F)

Overall intensity of the Earths' magnetic field by cardinal direction during TBI

Overall intensity of the Earth's magnetic field was then entered into a one-way analysis of variance by the 4 cardinal directions the 8 NFL divisions are clustered into. The results indicated that the overall intensity of the Earth's magnetic field was strongest in the North-East, and weakest in South-Western U.S. [$F_{(3,592)}$=105.18, r^2=.35] (Figure 48).

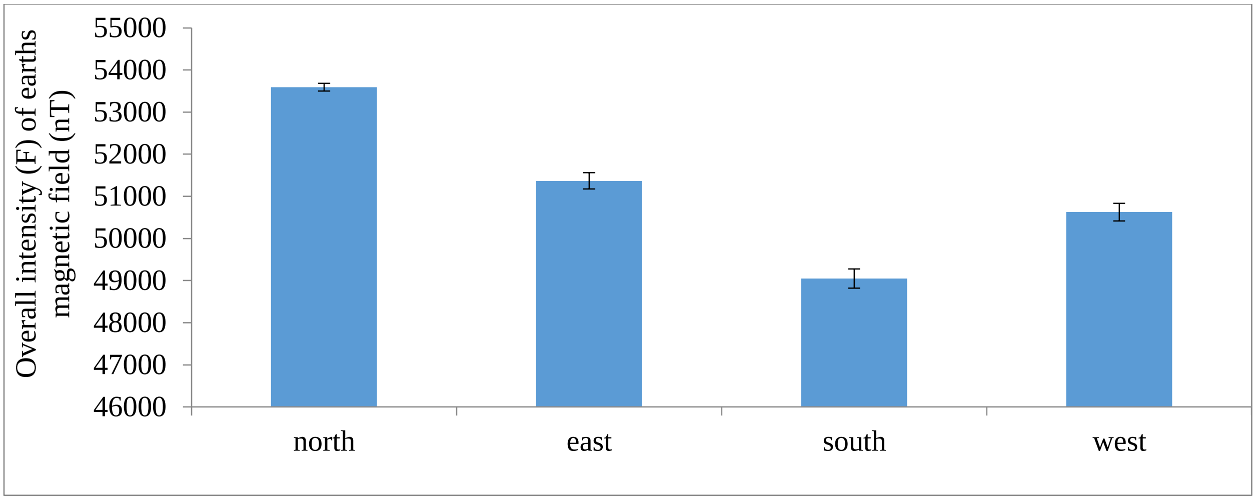

Figure 46 Overall intensity of the Earth's EMF by cardinal direction regarding the 8 NFL divisions

Overall intensity of the Earth's magnetic field and TBI severity

Total intensity of the Earth's magnetic field was then entered into an independent t-test by games missed due to injury cluster classifications; none or 1 or more, wherein significance was observed [$t_{(577)}$=-2.23, p=.026]. The results of the analysis indicated that the overall intensity of the Earth's magnetic field was reduced (M=51093.81, SEM=168.65) during injuries which did not require time to recover, in comparison to those TBI injuries that did (M=51604.06, SEM=155.21).

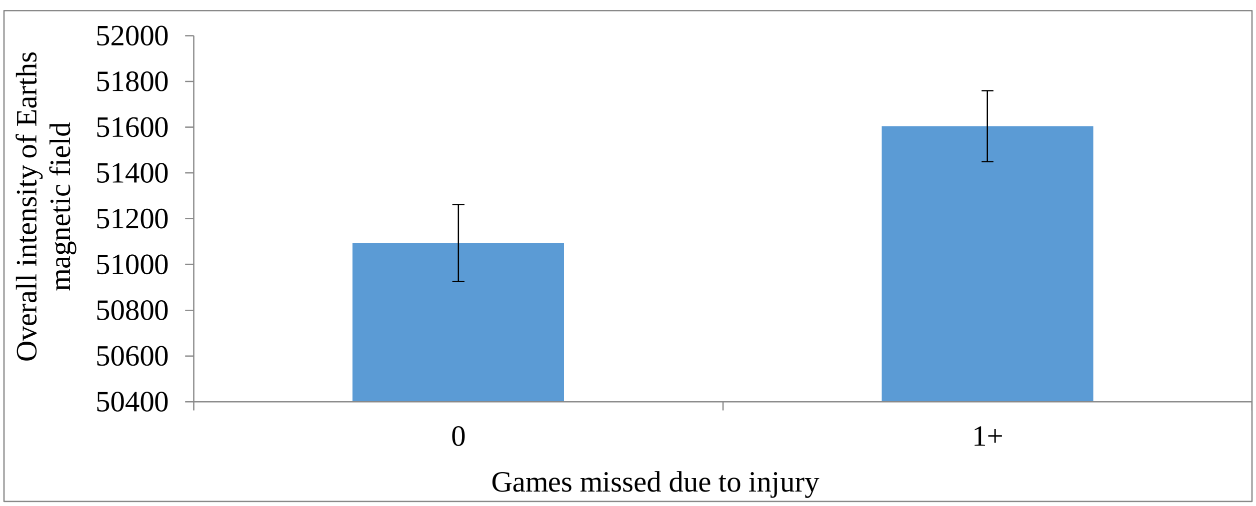

Figure 47 Overall intensity of the Earth's magnetic field by games missed due to injury clusters

The Earths Geomagnetic field and latitude during TBI

Correlational analysis was conducted in order to explore the relationship between total intensity of the Earth's magnetic field during TBI acquisition by latitude of injury acquisition. The results revealed that the Earths total intensity was positively correlated with latitude ($r_{(596)}$=.92, $rho_{(596)}$=.89), indicating that the total intensity of the Earth's magnetic field was greater as the location of the injury increased in latitude.

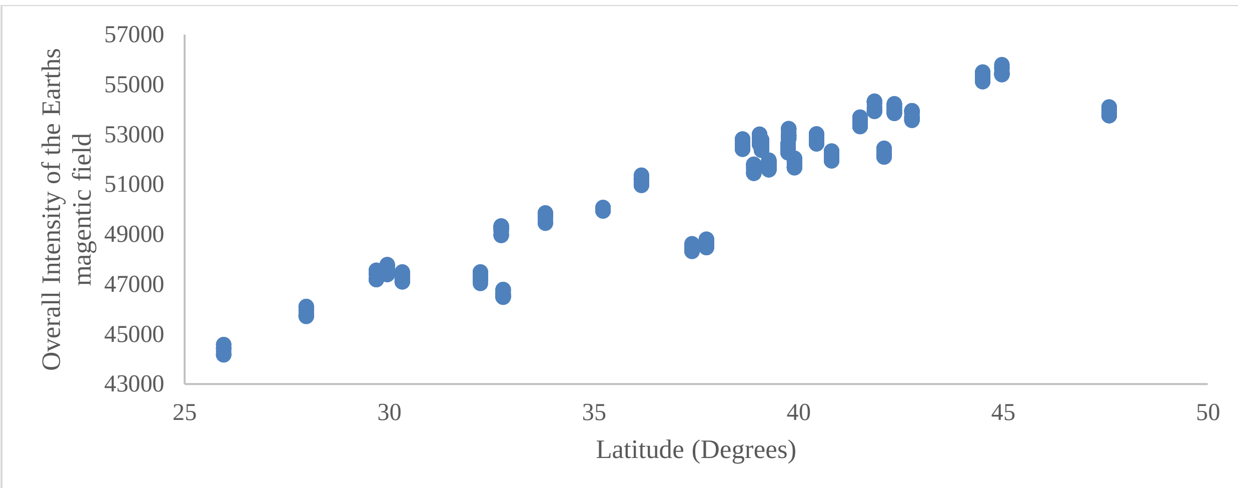

Figure 48 Earths overall intensity during TBI acquirement by latitude of stadium in which injury occurred

When stadium latitude cluster classifications were then entered into discriminate analysis with the overall intensity of the Earth's magnetic field (F) as the IV, significance was observed [λ=.41,Rao's V=868.18, eigenvalue=1.46, CCA=.77, χ^2=534.63], producing the following discriminant function: **Hi/Lo Latitude= -29.21 + .001*(F)**, which correctly classified 88.3% of the cross-validated group cases (Table 33).

Table 33 Discriminant analysis: discriminating latitude clusters with the Earth's overall intensity of its magnetic field

			Predicted latitude group membership		Total
			Low	High	
Original	Count	Lo	188	70	58
		Hi	0	338	38
	Percent	Lo	72.9	27.1	100
		Hi	0	100	100
Cross-validated	Count	Lo	188	70	58
		Hi	0	338	38
	Percent	Lo	72.9	27.1	100
		Hi	0	100	100

Latitude contributions to TBI severity

Chi-square analysis exploring hi/lo latitude clusters by games missed due to TBI cluster classifications was conducted. The results indicated that a relationship existed between latitude and time missed due to injury. Injuries acquired at higher latitudes resulted in more missed games [$\chi^2_{(1)}$=5.88, lambda=.05, phi=.103] (Table 34).

Table 34 Chi-square analysis: Hi/Lo Latitude cluster classifications by games missed due to injury cluster classifications

		Games missed due to TBI		Total
		0	1+	
Latitude clusters	25.96 - 39.05 (Degrees)	136	115	251
	%	23%	20%	43%
	39.10 - 47.60 (Degrees)	147	181	328
	%	25%	31%	57%
Total		283	296	579
%		49%	51%	100%

Latitude and lunar considerations to injury severity

Chi-square analysis indicated a significant relationship between TBI severity and latitude+/- clusters during lunar transit. The data indicates that when the Moon was moving closer to the Earth during time of TBI acquirement, 65% of those injuries which required recovery time occurred at higher latitudes, while 53% of less severe TBI's occurred at lower latitude [$\chi^2_{(1)}$=11.34, lambda=.11, phi=.19]. The effect of altitude on TBI severity was also prevalent when the Moon was leading the Sun in the observer's sky, wherein 60% of TBI's which required recovery occurred at higher latitude while 51% of the less severe injuries occurred at lower latitude [$\chi^2_{(1)}$=4.18, lambda=.06, phi=.12].

Table 35 Injury severity by latitude during lunar orientation

			Games missed due to TBI		Total
			0	1+	
Moon moving closer to Earth	Latitude clusters	25.96-39.05	79	56	135
		%	25%	18%	43%
		39.10-47.60	70	108	178
		%	22%	35%	57%
	Total		149	164	313
	%		48%	52%	100%
Moon leading Sun in observer sky	Latitude clusters	25.96-39.05	75	61	136
		%	25%	20%	45%
		39.10-47.60	71	93	164
		%	24%	31%	55%
	Total		146	154	300
	%		49%	51%	100%

Lunar data

Date of injury was available for 594 TBI's, which allowed for analysis of TBI acquisition in relation to the Moon. The lunar variables of interest include; lunar phase (new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter, and waning crescent), Moon visibility (0-100%), as well as Moon age.

Distance of Moon during lunar transit

The range of the Moon's center with respect to an Earth-bound observer, was cyclical during TBI observations, with the smallest distance recorded during the 1st quarter Moon phase, and the greatest distance observed during the last quarter moon phase [$F_{(7,598)}$=20.03, r=.19].

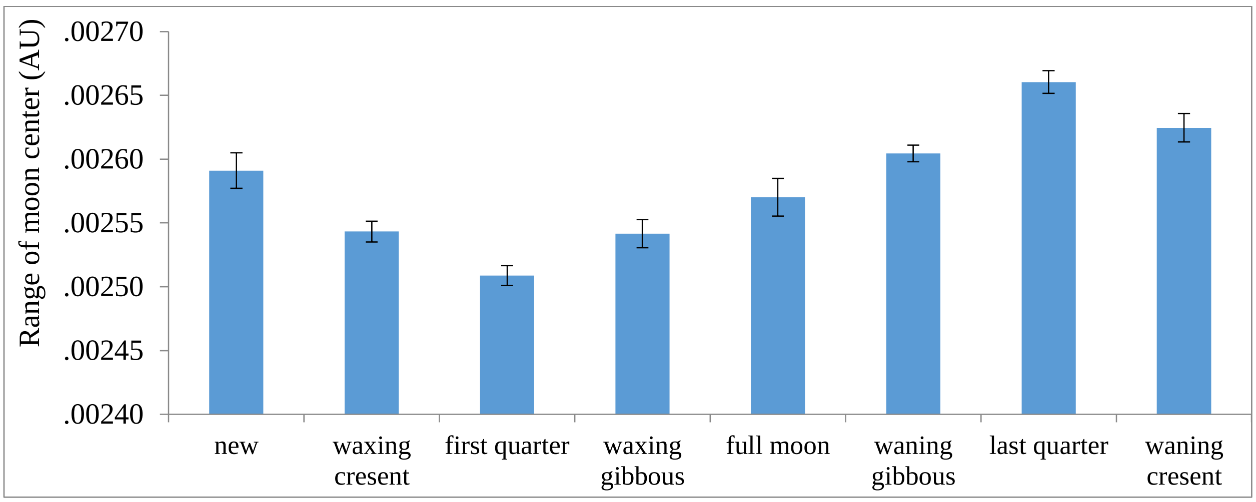

Figure 49 Range of Moon center by lunar phase during TBI acquirement

Spatial relationship between TBI rates and lunar phase

When the stadium in which a concussion occurred is coded by cardinal direction via the division in which the home team is a part of (i.e. NFC North and AFC North=North, NFC East and AFC East =East, etc.), and then entered into chi-square analysis with *Moon phase*, a relationship is observed [$\chi^2_{(21)}$=36.71, λ=.045, Φ=.25, p=.018].

Table 36 Lunar phase by cardinal direction within the U.S. during TBI acquirement

		Location of stadium				Total
		North	East	South	West	
Lunar phase	new moon	8	22	8	20	58
		1%	4%	1%	3%	10%
	waxing crescent	29	21	14	15	79
		5%	4%	2%	3%	13%
	first quarter	15	9	16	13	53
		3%	2%	3%	2%	9%
	waxing gibbous	29	30	21	23	103
		5%	5%	4%	4%	17%
	full moon	14	12	13	13	52
		2%	2%	2%	2%	9%
	waning gibbous	32	15	21	41	109
		5%	3%	4%	7%	18%
	last quarter	15	11	11	16	53
		3%	2%	2%	3%	9%
	waning crescent	30	17	11	29	87
		5%	3%	2%	5%	15%
Total		172	137	115	170	594
		29%	23%	19%	29%	100%

Temporal relationship between TBI rates and lunar phase

Critical temporal features were collected for 581 Traumatic Brain Injuries (TBI's) which occurred in the NFL between 2012 and 2015. Month of injury and the lunar phase in which the injury occurred were entered into cross-tab analysis to investigate whether the injuries which occurred between September through January of The NFL season were affected by the lunar cycles naturally occurring during the same period [$\chi_{(28)}$=91.01, Λ=.06, Φ=.40].

Table 37 Chi-square analysis: Month of season and lunar phase in which TBI's occurred from 2012-2015

		Lunar phase								Total
		new moon	waxing crescent	first quarter	waxing gibbous	full moon	waning gibbous	last quarter	waning crescent	
Month of season	Sept	20	10	12	10	15	15	9	15	106
		19%	10%	11%	10%	14%	14%	8%	14%	18%
	Oct	13	21	6	22	12	13	21	10	118
		11%	18%	5%	19%	10%	11%	18%	8%	20%
	Nov	17	22	17	40	10	33	13	30	182
		9%	12%	9%	22%	6%	18%	7%	17%	32%
	Dec	6	20	18	31	9	46	4	29	163
		4%	12%	11%	19%	6%	28%	2%	18%	28%
	Jan	2	2	0	1	3	0	4	0	12
		17%	17%	0%	8%	25%	0%	33%	0%	2%
Total		58	75	53	104	49	107	51	84	581
		10%	13%	9%	18%	8%	18%	9%	14%	100%

TBI severity ratios during the Waxing Crescent lunar phase

Games missed due to injury were entered into a series of independent sample t-tests by the position-relative BMI+/- cluster classification during each lunar phase. The results indicate that players who had below average BMI scores (M=1.67, SEM=.36) missed more time due to TBI then did BMI+ players (M=.63, SEM=.22) during the *waxing crescent* [$t_{(73)}$=2.55, p=.013].

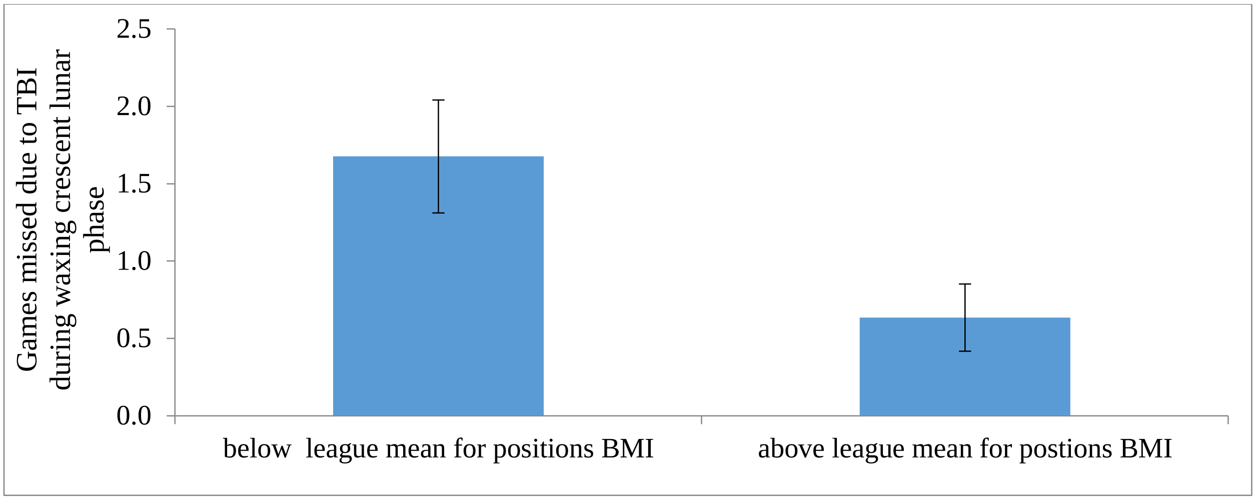

Figure 50 Increased games missed due to TBI for players below the league mean for their positions BMI during the waxing crescent Moon phase

Chi-square analysis was conducted in order to explore possible relationships between altitude and injury severity during the waxing crescent lunar phase [$\chi^2_{(1)}$=4.60, tau=.06, φ=.25]. Split file cross tab analysis was employed by lunar phase in order to further explore BMI. The results indicate a relationship such that during the waxing crescent Moon phase, proportionately more BMI+ players acquired more TBI's but missed fewer games, while BMI- players acquired fewer injuries but missed proportionately more games [$\chi_{(1)}$=11.00, Λ=.33]. Furthermore, this effect was strengthened in open stadium designs [$F_{(1,52)}$=6.30, r^2=.21, $\chi^2_{(1)}$=8.24] and within the eastern U.S. [$\chi^2_{(1)}$=5.50] during the waxing crescent lunar phase.

Table 38 Injury severity and altitude cluster classifications during the waxing crescent lunar phase

				Games missed due to TBI		Total
				0	1+	
Waxing Crescent	Altitude (meters)		<159.84	27	15	42
			%	36%	20%	56%
			>159.84	13	20	33
			%	17%	27%	44%
	Total			40	35	75
	%			53%	47%	100%
	Open roof	BMI+/-	BMI-	8	20	28
			%	15%	38%	53%
			BMI+	17	8	25
			%	32%	15%	47%
		Total		25	28	53
		%		47%	53%	100%
	Eastern U.S.	BMI+/-	BMI-	4	13	17
			%	15%	48%	63%
			BMI+	6	4	10
			%	22%	15%	37%
		Total		10	17	27
		%		37%	63%	100%
	Overall	BMI+/-	BMI-	11	23	34
			%	15%	31%	45%
			BMI+	29	12	41
			%	39%	16%	55%
		Total		40	35	75
		%		53%	47%	100%

TBI ratios Waxing Gibbous lunar phase

Significant differences between the observed and expected values for BMI and games missed due to TBI cluster classifications were also found within the Eastern U.S. during the waxing gibbous lunar phase [$\chi^2_{(1)}$=4.60]. Injury severity and change in athletic exposure clusters were entered into a chi-square analysis during the waxing gibbous lunar phase, upon which a significant relationship was observed [$\chi^2_{(1)}$=4.60, tau=.06, φ=.25].

Table 39 Injury severity and BMI cluster classifications during the waxing gibbous lunar phase

				Games missed due to TBI		Total
				0	1+	
Waxing gibbous	Eastern U.S.	BMI+/-	BMI-	1	10	11
			%	3%	33%	37%
			BMI+	9	10	19
			%	30%	33%	63%
		Total		10	20	30
		%		33%	67%	100%
	Athletic exposure		Decrease	15	42	57
			%	15%	42%	56%
			Increase	27	17	44
			%	27%	17%	44%
	Total			42	59	101
	%			42%	58%	100%

TBI severity and change in athletic exposure ratios during the Waning Gibbous lunar phase

A chi-square analysis suggested the relationship between games missed due to TBI and change in athletic exposure might have a lunar phase component. The results indicate that the relationship can be observed between these categorical clusters during both the waxing [$\chi^2_{(1)=}$12.56] and waning gibbous [$\chi^2_{(1)=}$14.03] lunar phases.

Table 40 Injury severity and change in athletic exposure cluster classifications during the waning gibbous lunar phase

			Games missed due to TBI		Total
			0	1+	
Waning gibbous	Change in Athletic exposure	Decrease	21	48	69
		%	21%	47%	68%
		Increase	23	10	33
		%	23%	10%	32%
	Total		44	58	102
	%		43%	57%	100%

TBI ratios during the last quarter lunar phase

An independent sample t-test compared games missed due to TBI by position specific BMI+/- cluster classifications. The results indicate that TBI injured players who were below the league average for their position missed more games (M=1.53, SD=1.68) than players who were above the league-wide average BMI (M=.47, SD=.61) during the last quarter [$t_{(1,47)}$=17.15, p<.01] Moon phase.

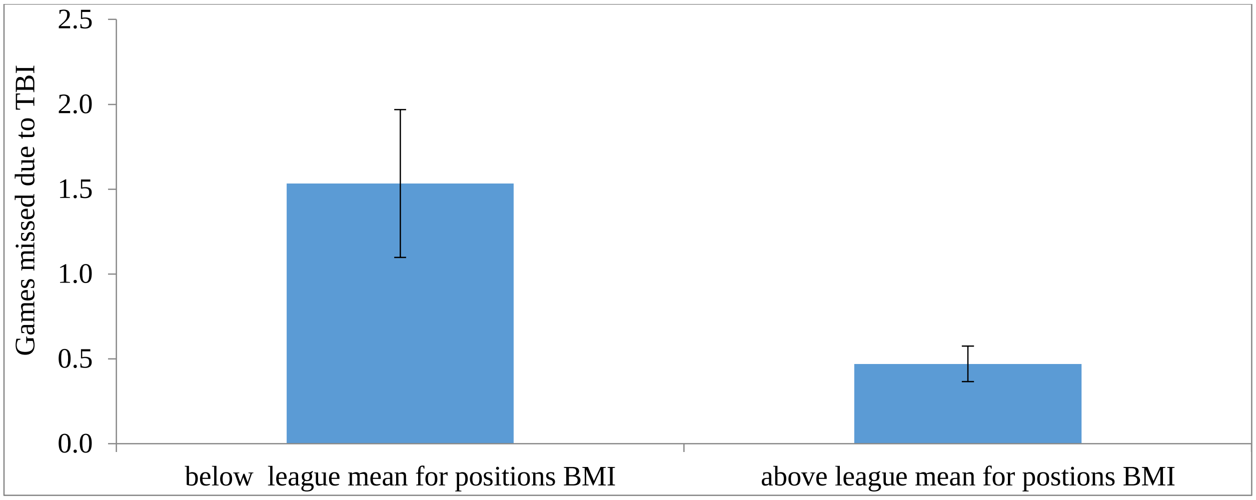

Figure 51 Increased games missed due to TBI for players who were below the league average for their position during the last quarter Moon phase

Open stadium types also differentiated between BMI and games missed cluster classifications in open roof type during the third quarter lunar phase [$\chi^2_{(1)}$=6.72], specifically in the Western U.S. [$\chi^2_{(1)}$=7.2, $p<.05$]. Chi-square analysis exploring the contributions of altitude on injury severity during the last quarter lunar phase also produced revealed significant differences between observed and expected values [$\chi^2_{(1)}$=3.93, tau=.08, φ=.28].

Table 40 discrepancies in observed and expected values in injury severity and BMI cluster classifications by lunar phase considerations

				Games missed due to TBI		Total
				0	1+	
3rd quarter	Open roof	BMI+/-	BMI-	2	9	11
			%	5%	23%	28%
			BMI+	18	10	28
			%	46%	26%	72%
		total		20	19	39
		%		51%	49%	100%
	Open roof/western U.S.	BMI+/-	BMI-	0	2	2
			%	0%	17%	17%
			BMI+	9	1	10
			%	75%	8%	83%
		Total		9	3	12
		%		75%	25%	100%
	Altitude (meters)		<159.84	20	12	32
			%	40%	24%	64%
			>159.84	6	12	18
			%	12%	24%	36%
	Total			26	24	50
	%			52%	48%	100%

TBI severity and BMI ratios during waning crescent lunar phase

A final independent samples t-test indicated differences in games missed due to injury by BMI cluster classifications during the waning crescent [$t_{(82)}=-1.8$, $p<.05$]. Players who had a lower BMI than the league average at their position missed fewer games (M=.54, SEM=.13) due to injury than players with a higher than average BMI (M=1.00, SEM=.22).

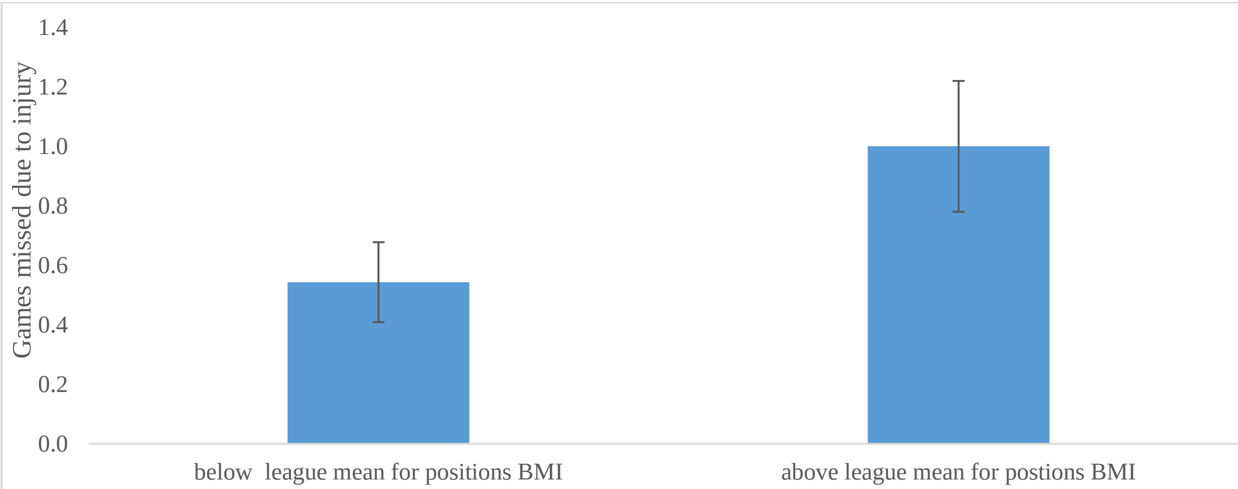

Figure 52 Games missed due to TBI for players who were below or above the league average at their position during the Waning crescent lunar phase

Chi-square analysis explored whether specific factors promoted differences between BMI and injury severity clusters during the waning crescent lunar phase. The results indicated that this was apparent within the Western U.S. [$\chi^2_{(1)}$=7.87, p<.01], specifically in open stadium types [$\chi^2_{(1)}$=7.08, p=.012].

Table 41 Injury severity and BMI cluster classifications during the Waning Crescent lunar phase

				Games missed due to TBI		Total
				0	1+	
Waning crescent	Open roof/Western U.S.	BMI+/-	BMI-	11	3	14
			%	48%	13%	61%
			BMI+	2	7	9
			%	9%	30%	39%
		Total		13	10	23
		%		57%	43%	100%
	Western U.S.	BMI+/-	BMI-	13	3	16
			%	48%	11%	59%
			BMI+	3	8	11
			%	11%	30%	41%
		Total		16	11	27
		%		59%	41%	100%

Sunspot activity by lunar phase during TBI acquirement

Daily averaged global sunspots (S) were entered into a one-way ANOVA by lunar phase (L), in order to identify the temporal signature of S during TBI acquisition. The results indicate significant differences in S across L [$F_{(7,599)}$=4.45, r^2=.05], with minimum S observed after a full moon, namely from waning gibbous to last quarter L.

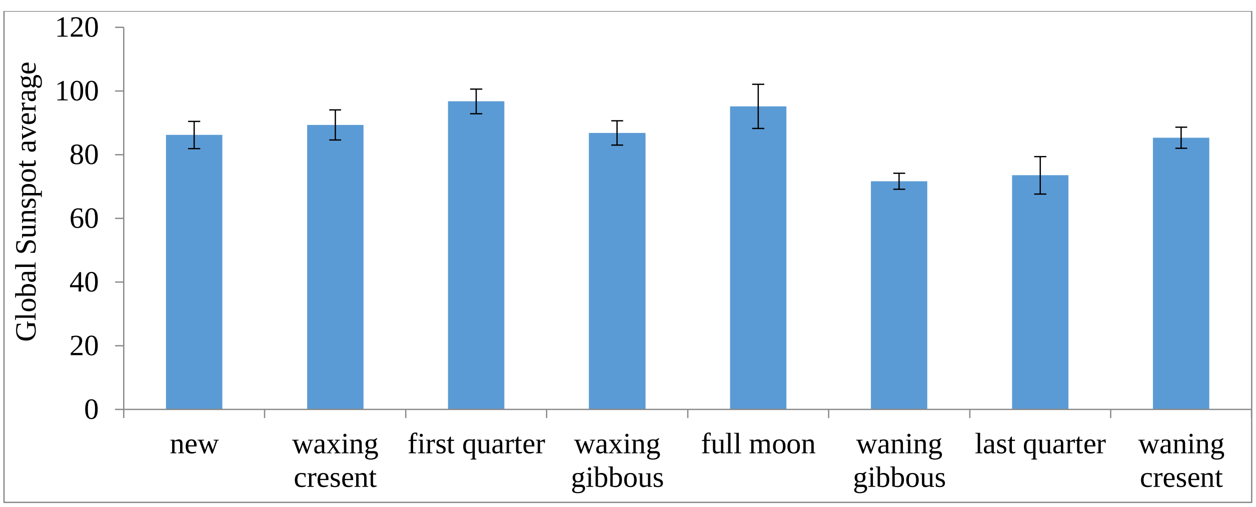

Figure 53 Daily Global Sunspot average during TBI by lunar phase

Change in Sunspot activity by lunar phase during TBI acquirement

This data was de-trended by subtracting the average S during the week (7 days) prior to TBI acquirement, from the S during day of injury (Δ; post-pre). The ΔS by L indicate that the greatest increases in S were observed from waning to waxing crescent L [$F_{(7,599)}$=13.48, r^2=.14] (Figure 54).

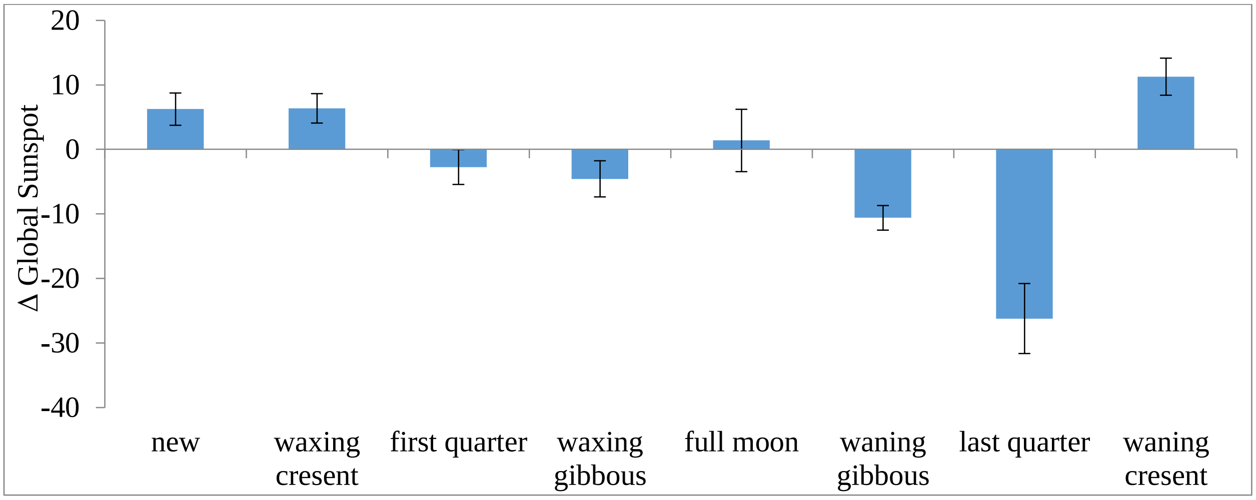

Figure 54 Change in global sunspot on day of TBI acquirement from the previous week by lunar phase

Solar activity as a precondition of TBI severity during: New Moon, 1st quarter and Waxing Gibbous lunar phase

The preinjury sunspot activity was classified into 'quiet' or 'noisy' clusters - contingent upon whether the preinjury S were above or below Bauer and colleagues (2013) average of 66 S from an investigation between 1920-1989 (Economics and Human Biology). Cross-tab analysis revealed differences between the observed and expected frequencies for quiet and noisy S as the precondition of TBI severity clusters (games missed; 0/1), during; new Moon [$\chi^2_{(1)}$=3.66, φ=-.25], 1st quarter [$\chi^2_{(1)}$=6.39, λ=.17, φ=.34], and waxing gibbous [$\chi^2_{(1)}$=5.08, tau=.05, φ=-.22] L. The results indicate quiet preinjury S actually increased TBI severity during the new Moon L, in juxtaposition to 91% and 63% of TBI's which occurred following noisy preinjury S during 1st quarter and waxing gibbous L, respectively.

Table 42 Pre-injury Sunspot activity clusters by games missed due to TBI clusters by lunar phase

			Sunspot activity pre-injury		Total
			Quiet	Noisy	
new moon	Games missed	0	7 (12%)	22 (38%)	29 (50%)
		1+	14 (24%)	15 (26%)	29 (50%)
	Total		21 (36%)	37 (64%)	58 (100%)
first quarter	Games missed	0	5 (9%	20 (37%)	25 (46%)
		1+	0 (0%)	29 (54%)	29 (54%)
	Total		5 (9%)	49 (91%)	54 (100%)
waxing gibbous	Games missed	0	11 (10%)	33 (32%)	44 (42%
		1+	28 (26%)	32 (31%)	60 (57%)
	Total		39 (37%)	65 (63%)	104 (100%)

Accommodating TBI player mass, height and injury severity during the full moon

Multiple regression analysis confirmed TBI player mass (kg) relationships with geomagnetic contributions during the full moon. The results indicated that increased change in the Inclination (I) [$F_{(1,49)}$=7.62, r^2=.14], as well as increased annual change in the horizontal intensity (H) [$F_{(2,48)}$=7.77, r^2=.25] of the Earth's magnetic field, collectively explained 25% of the variance in the mass of injured TBI players during the Full moon.

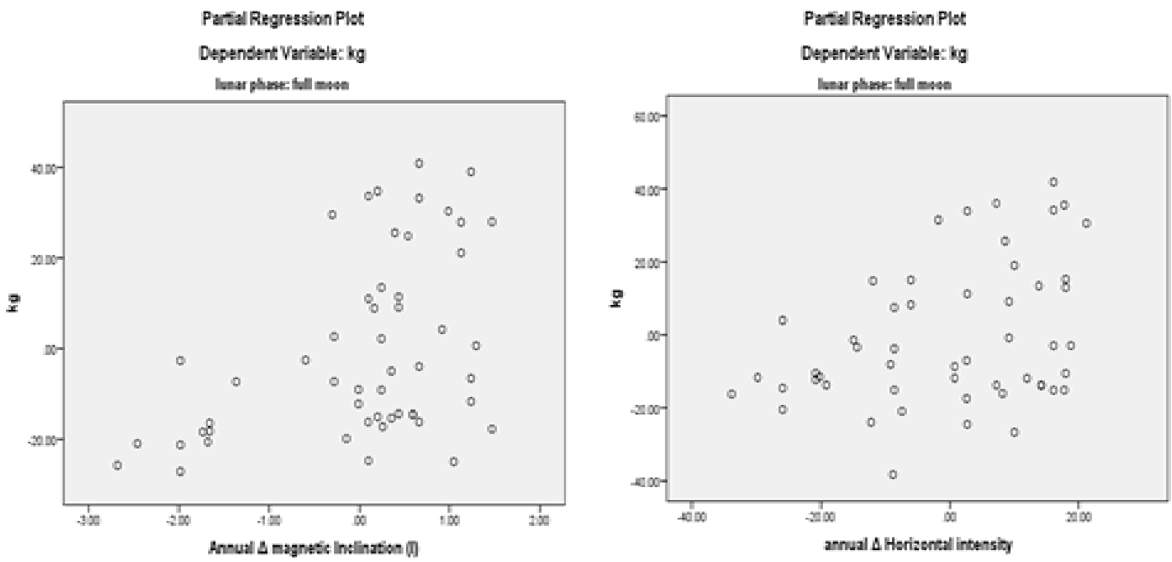

Figure 55 Increased annual change in the inclination, and increased annual change in the horizontal intensity of the Earth's EMF predict Mass of TBI player during the full moon lunar phase

Multiple regression analysis exploring predictive models within latitude clusters indicated that increased east-component (Y) [$F_{(1,21)}$=22.53, r^2=.52] as well as increased annual change in the North component (X) [$F_{(2,20)}$=16.11, r^2=.62] of the Earth's magnetic field collectively explained 62% of the mass of the injured players during the full moon L within the south U.S. regions

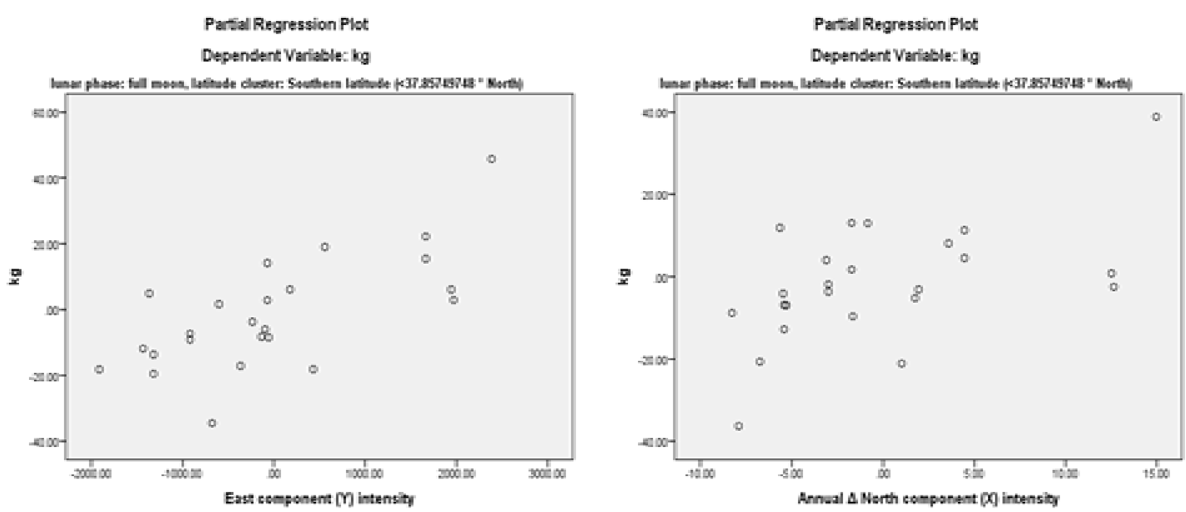

Figure 56 Increased intensity of the Y component of the Earth's EMF, and increased annual change in the X component of the Earth's EMF predict mass of the TBI player during Full moon lunar phase in the Southern half of The U.S.

Mass of injured TBI players was predicted during the full moon lunar phase (L) by increased annual change in the Earths geomagnetic field (G), namely in (1) the magnetic Inclination ($I=\tan^{-1}[Z/H]$) and the horizontal intensity ($H=\sqrt{X^2+Y^2}$) [$F_{(2,48)}=7.77$, $r^2=.24$]. Subsequent analysis indicated that the predictive models of increased annual change in inclination and increased horizontal intensity on mass, were most accurate at lower altitudes (<159.84 meters) [$F_{(2,29)}=6.69$, $r^2=.32$].

Multiple regression (MR) analysis also revealed significant predictors of TBI player height (meters) during the full moon L. Full moon TBI player height was accommodated by ↑Δ (annual) in both the orthogonal and east [$Y= H \sin(D)$] components of the Earth's *G* [$F_{(2,48)}=8.29$, $r^2=.26$], specifically at lower altitudes [$F_{(2,29)}=7.70$, $r^2=.35$].

Full moon TBI player Height was also predicted by (1) increased annual change in Inclination within Southern latitudes [$F_{(1,21)}=24.05$, $r^2=.53$], (2) *increased* Moon age within Northern latitudes [$F_{(1,26)}=5.01$, $r^2=.16$] and Western longitudes [$F_{(1,18)}=5.01$, $r^2=.22$] and (3) increased change in the North component ($X=H \cos[D]$) intensity within Eastern longitudes [$F_{(1,29)}=11.79$, $r^2=.29$].

Multiple regression analysis confirmed daily averaged global sunspots (S), geomagnetic [G] (F, H, Z, X, Y, D and I) and lunar variables accommodative capacity of injury severity during the full moon. The results revealed that increased daily average global sunspots (S) [$F_{(1,49)}=5.65$, $r^2=.10$], as well as decreased S standard deviation (SD) [$F_{(2,48)}=5.93$, $r^2=.20$] during the day of TBI acquirement, collectively explained 20% of the variance in games missed due to injury during the full moon lunar phase, which can be observed in the figures below.

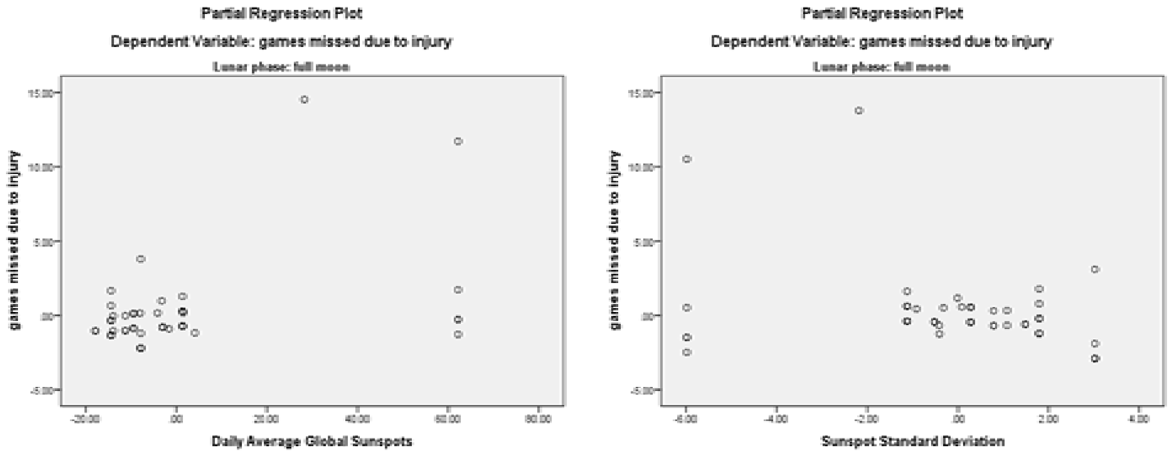

Figure 57 Multiple regression results: Increased daily global Sunspots, and decreased Sunspot standard deviation predict games missed due to TBI during full moon lunar phase

Further analysis indicated that this model was most accurate in Eastern longitudes [$F_{(2,28)}$=8.38, r^2=.37]. Full moon TBI severity was also predicted by *increased change* in the orthogonal (Z) intensity of the Earth's G at higher altitudes [$F_{(1,17)}$=13.76, r^2=.45].

Injury severity was predicted by spatial considerations in the Southern U.S. during the full moon. The results indicated that decreased range between the Earth and Moon [$F_{(1,21)}$=6.24, r^2=.23], and increased altitude (meters) of injury origin [$F_{(2,20)}$=8.17, r^2=.45] collectively explained 45% of the variance in TBI severity during the full moon L in the Southern U.S.

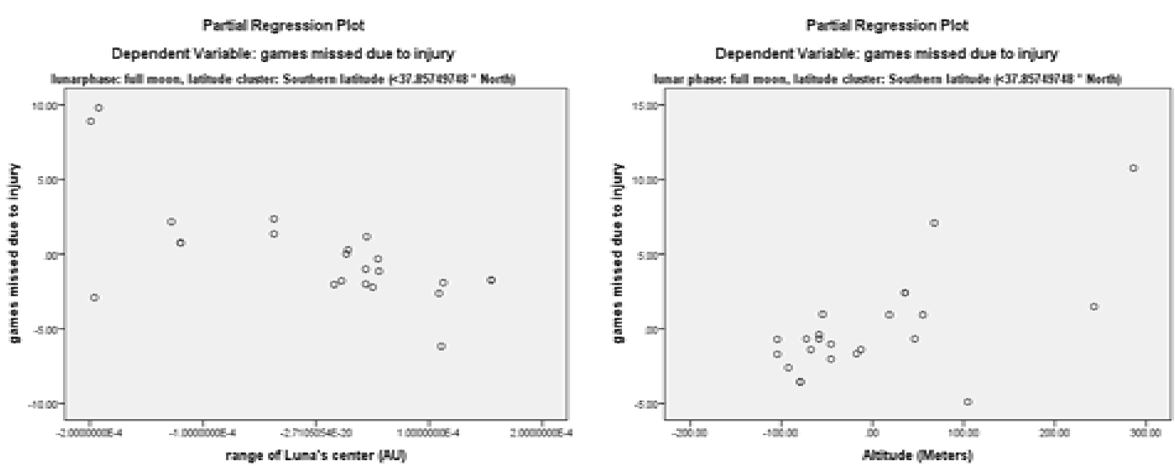

Figure 58 Multiple regression results: decreased range of Moons center, and altitude predict games missed due to TBI during full moon lunar phase

The predictive equations of TBI player mass, height and injury severity during the full moon lunar phase by variations in latitude, longitude and altitude can be observed in the table below.

Table 43 Geomagnetic, sunspot and lunar coefficients of mass, height and TBI severity with and without spatial clustering

VOI	*Full moon* coefficients	*Δ Latitude* coefficients	*Δ Longitude* coefficients	*Δ Altitude* coefficients
Mass	$Full_{kg}$=145.70 [+] 9.05*(*ΔI*) [+] .43*(*ΔH*)	$South_{kg}$=123.39 [+] .009*(*Y*) [+] 1.02*(*ΔX*)	N/A	Lo_{kg}=146.27 [+] 9.08*(*ΔI*) [+] .48*(*ΔH*)
Height	$Full_{h}$=2.25 [+] .002*(*ΔZ*) [+] .002*(*ΔY*)	$South_{h}$=1.96 [+] .02*(*ΔI*) $North_{h}$=1.45 [+] .03*(*Moon age*)	$West_{h}$=1.43 [+] .04*(*Moon age*) $East_{h}$=1.84 [+] .002*(*ΔX*)	Lo_{h}=2.28 [+] .002*(*ΔZ*) [+] .002*(*ΔY*)
TBI severity	$Full_{gm}$= [-] 1.31 [+] .06*(*S*) [-] .37*(*S-SD*)	$South_{gm}$=47.20 [-] 18312.78*(*Moon distance*) [+] .02*(*Altitude*)	$East_{gm}$= [-] 2.06 [-] .57*(*S-sd*) [+] .08*(*S*)	Hi_{gm}=21.87 [+] .16*(*ΔZ*)

Discussion

Player profile

The data indicates that the position an NFL athlete plays, explains 78% of the variance in annual TBI's over the four-year period with cornerbacks and wide receivers being most susceptible. NFL play calling philosophies however, do allow for the number of athletes who assume these positions at any given time to vary considerably by game flow dynamics and coaching style. Exploration of the physical attributes of TBI players does indicate that certain positions display a particular physique, which may make them susceptible to TBI acquisition. Players on offense are bigger then defensive players for example, however they do acquire more annual TBI's which may reflect the competitive reality associated with the collision sport of football, wherein strategies to slow down bigger offensive players may be to knock them out of the game. Another possible explanation for this effect could be that athletic trainers and spotters might be able to identify injuries on offense more easily insofar as they are in large part dictating the events during gameplay due to the fact that they control the football. The Center position was among the positions on offense that had the least severe injuries on average, which could be because they handle the football on every play and therefore largely dictate game flow.

Body Mass Index

Fifty-nine percent of players who sustained a TBI and had higher BMI values not only missed time due to injury but had a reduction in athletic exposure in comparison to only 38% of players who were smaller than average, suggesting that increased aggression may have been a means of slowing down bigger players. TBI players on offense also had higher BMI scores and more severe injuries then TBI players on defense. Team success measured in wins and losses, was more likely if the injured player was on defense. Fifty-five percent of TBI's to players below the league average BMI for their respective position missed 1 or more games due to injury in comparison to only 47% for players who have a larger BMI than the league average at their position, this feature was most apparent during the waxing crescent of the Moon.

Athletic exposure

Comparisons of athletic exposure before, during and after TBI acquisition by the position specific league average snap count quartile ranks, indicates that, on average, players resumed their pre-injury contributions after returning from injury. However, players who sustained a TBI that required at least a month of recovery time were unable to finish within the top 25% of snap leaders. This ultimately reduced the value of the injured players' contributions, since players who finished within the top quartile with regard to annual snap counts were most valuable, ranked highest in comparison to all other NFL players since 1950, and had the highest annual salaries. A majority of players who sustained a concussion but still managed to finish in the top quartile with regard to annual gameplay, likely did so because they did not miss any time due to TBI acquisition, which may suggest that their contributions were significant and that the coaches wanted to get them back on the field as quickly as possible. The inverse relationship between games missed due to injury and annual athletic exposure supports this hypothesis, which suggests that increased diagnosed TBI severity inhibits the potential contributions of the player in question.

Players who had the highest contributions before TBI acquisition also managed to finish the season with increased gameplay. NFL quarterbacks for example, one of the most important positions with regard to team success, had the highest offensive athletic exposure of any skill position on offense. Furthermore, this position also had the highest fantasy point contributions during the game in which the injury occurred, suggesting that these players may have attempted to remain in the game longer then they should have. A majority of players who were not required to miss time due to TBI acquisition actually returned to an increased role upon return from injury, while players who did require recovery time, experienced a decrease in athletic exposure of roughly 5 snaps per week lost in recovery.

Subtracting the athletic exposure after return from injury from the average athletic exposure before injury provided an indication of change in athletic exposure from TBI acquirement. The results indicate a total reduction in snap count in return game from injury of -3423 snaps, or -6.05 snaps per TBI case from their pre-injury average snap counts. There was a weak to moderate negative association between number of games missed due to injury and change in athletic exposure, demonstrating collaboration between team doctors and coaching staffs, such that as a player misses more time due to injury, they are more likely to see a reduction in snap count upon return from injury. Comparing change in athletic exposure of players who miss no time at all and players who miss one or more games due to injury supports this finding. The results indicate that players who miss one or more games due to injury have an average change in athletic exposure of -11.94 snaps; whereas players who did not miss any time play the same amount as before the injury (.23 snaps). Lunar variations magnify this effect under specific circumstance, insofar as this feature was specifically apparent during waxing and waning gibbous lunar phases and for the Cleveland Browns, Detroit Lions, and Kansas City Chiefs.

TBI Severity

Exploration of games missed due to injury by team role indicated that 57% of injured offensive players missed time due to injury in comparison to only 45% of injured defensive players. Analysis of annual athletic exposure relative to all players who played in the NFL between 2012 and 2015 indicated that time needed to recover from a TBI severely hindered players' ability to finish within the top quartile of their peers during the year of injury. Measures of annual athletic exposure drastically reduced as injury severity increased. Analysis of athletic exposure before, during, and after TBI acquisition indicated that despite league relative snap counts, players from all four athletic exposure quartile ranks returned on average to the level of play they had been participating in prior to TBI acquisition.

This has implications with regard to a player's approximate value, as players who finished in the top quartile with regard to participation in football were valued, ranked and paid the highest among their colleagues. The relationship between athletic exposure prior to injury with annual statistics of offensive and defensive players is of interest because it indicates that players finished the year with participation in football equivalent to that prior to injury. These players may have been plugged back into their respective roles upon return, despite the fact that players had an average reduction in play of approximately 12 athletic exposures for every game missed due to injury. While 59% of players who missed time due to a TBI had decreased athletic exposure after returning, 57% of players who did not miss time due to TBI acquisition actually had increased athletic exposure upon returning from injury.

Injury label

The analysis of injury labels suggests that the NFL began to take TBI's seriously during the study. After the year 2012, in which 90% of head injuries were diagnosed, the frequency of this diagnosis dropped sharply. The more accurate label of concussion was used more frequently beginning in 2013. Noting that 57% of head injuries resulted in no games missed due to injury, compared to only 43% of injuries labelled as concussions does raise some questions about the team doctors' diagnosis, and may suggest possible collusion between doctors and coaches in order to facilitate a quicker return to gameplay. There did appear to be significant collaboration between doctors and coaches with regard to injury management, as athletic exposure decreased significantly following injuries that required the player to miss time. Analysis of injury severity and change in athletic exposure by injury label indicates that 36% of concussion labels resulted in the player not only missing time, but also seeing a reduction in athletic exposure upon return, in comparison to only 27% of head injuries.

NFL Reference groups

Comparison of annual athletic exposure counts of the TBI players during year of injury to league wide –averages suggests that brain injuries severely dampen players' ability to finish in the snap leaders at their respective positions. None of the injured quarterbacks for example, was able to finish in the top league wide athletic exposure quartile. This has career related implications, as an individuals' position rank relative to all players who played in the NFL since 1950 was highest in players who were able to finish in the top athletic exposure quartile. Athletic exposure counts before, during and after TBI acquisition suggests that on average, players from all four quartiles eventually returned to the level of athletic exposure counts prior to injury. Injury severity was highest in players who fell in the bottom half of the athletic exposure quartiles and 87% percent of players who fell below the top athletic exposure quartile, had decreased participation in football after injury. Annual player salary was also highest in players who finished in the top quartile, as was their approximate value

Draft profiles

Comparisons of players who sustained a TBI to those who have been inducted into the football Hall of Fame (HoF) suggests that these types of injuries can severely reduce the players' potential to be regarded as one of the best players at his position. This is to say, that the average career weighted approximate value scores were able to accommodate the differences between these groups. This is an important distinction insofar as career weighted average value is elevated in players who were drafted early, suggesting that NFL teams are able to identify this potential. The overall rank of players who sustained a TBI was also highest for players drafted early. Annual athletic exposure was highest in players drafted in the early rounds suggesting that teams chose these players to fill holes within the roster, and subsequently expected them to have large contributions very early on. Notably, only 2% of players drafted in the first two rounds of their NFL entry draft had a TBI that required them to miss at least a month due to injury.

Competitive considerations

With regard to the 579 TBI's that occurred in games, 537 of them allowed for comparisons of injury severity and change in athletic exposure, as these players actually returned to action. Thirty-four percent of in game TBI's resulted in this type of injury, which may be a marker of TBI severity. While only 32% of these serious injuries occurred during home games, 38% occurred during away games suggesting that unfamiliarity may have facilitated greater injury susceptibility. Thirty-seven percent of these severe injuries occurred during losses in comparison to only 32% during wins. Sixty-seven percent of TBI's diagnosed by the Cleveland Browns followed this trend, which was only slightly higher than the Kansas City Chiefs (65%), and considerably so in comparison to the Detroit Lions (42%). Interestingly, a higher proportion (34%) of TBI's that occurred at lower altitudes, within open stadium types, and during losses (32%) did not require forced recovery time. Fifty-five percent of in game injuries to offensive players occurred during a loss, while 55% of in game injuries to defensive players occurred when their team won the game.

Yearly fantasy points for offensively skilled positions indicated that quarterbacks have a tremendous impact with regard to offensive production in comparison to other skilled positions. This was even evident during the game in which the injury occurred, suggesting that they were in the gameplay longer due to their contributions to the team. Yearly fantasy production however drastically declined as injury severity increased. The fantasy production of NFL quarterbacks, who throw the football, could be due to trends in the NFL over the duration of the study, as passing plays were significantly increasing over this period in relation to running plays.

Naturally occurring competitive considerations that are intrinsic to the sport of football at the professional level appear to have had a significant impact on TBI incidence rates. For instance, TBI rates by NFL conference suggest that AFC doctors diagnose more TBI's than NFC doctors, or there may be differences in the style of play between these groupings. Differences in TBI rates by NFL divisions when coded by cardinal direction, suggests that geospatial considerations associated with variations in meteorological stability existed. There were differences in annual TBI rates in games played in cities within the Northwest versus the Southeast regions, such as reduced incidence in Carolina in comparison to Seattle. Other factors such as field type appeared to contribute to observed differences as fewer annual concussions were acquired on natural grass in comparison to bluegrass.

TBI History

Injury severity varied substantially by TBI history suggesting a trend in return to play guidelines that is in consideration of the player's injury history. Players who had acquired more brain injuries missed more time than those who suffered fewer. The average snap count after return from injury demonstrates that the four players, who had received their fifth career TBI diagnosis, did not participate in football after return from injury. This could be attributed to the career weighted approximate value of the career TBI clusters, as the players who had sustained five career TBI's had the lowest career weighted AV of the clusters. These players may not have had adequate value to their team. In juxtaposition, the cluster with the most career TBI's had the highest approximate value, suggesting that their value to their team could be the reason they missed fewer games due to injury and their participation in football post-injury was highest.

The data regarding the treatment of head trauma versus repeated head trauma was comparable, and differences were minute which might reflect the NFL's attitude towards brain injuries. The differences in rest accommodation wherein repeated cases of head trauma appeared to receive more rest following injury, appeared to be amplified by only a few team doctors league wide.

Temporal and spatial dynamics of TBI's

TBI ratios appeared to decline from 2012 to 2014 only to significantly increase during the 2015 season, possibly due to increased vigilance by league doctors. Analysis of stadium features however, does suggest that certain designs may facilitate TBI acquisition. For example, fewer annual TBI's occurred on natural grass in comparison to artificial bluegrass field types. The data indicate that 37% of TBI's acquired during humid conditions (60-100%) resulted in increased injury severity and forced recovery time. This effect was evident in fixed and open stadiums which are typically located in humid regions, however 54% of TBI's acquired in stadiums with fixed roofs were not severe enough to require rest, while 32% of TBI's in open stadiums were more severe and resulted in time off.

Longitude/latitude

TBI rates across NFL cities indicated differences across U.S. regions where cities clustered together. Surprisingly, 43% of injuries which occurred in San Diego and St. Louis (cities which are no longer a part of the NFL) had lower injury severity and increased athletic exposure. TBI rates differed by conference play within the NFL, such that AFC doctors were found to diagnose more concussions than did the NFC, which could be the result of the more physical nature of the teams within it. Rates by NFL divisions however, indicate that geo-coordinates may play a significant role since divisions in the Northwest displayed higher rates then did divisions in the Southeast.

Earth's magnetic field

The pervasive influence that altitude has on TBI severity may be the product of variation in geophysical manifestation, and its role as a precondition of the neuro-metabolic cascade that follows a concussion. The results that indicate significant variation in the intensity of the Earth's local magnetic field because of spatial clustering and temporal sequences over time such as lunar phase might reflect the signature interaction between the Earth's magnetic field and its geographical composition. It also appears as if specific spatial preconditions exist which facilitate a higher degree of time missed due to TBI injuries, specifically playing football in an NFL stadium North of Kansas City. This effect was enhanced by the appropriate temporal lunar features namely when the Moons apparent position is coming closer to the Earth, and when the Moons position is leading the Sun in the Earth oriented observers sky. This may suggest human behavior is influenced by these cyclical patterns, more so in the northern latitudes in comparison to the Southern U.S.A.

Altitude

Seventy percent of in game TBI's occurred within western longitudes in cities of elevated height. Altitude appeared to play a role in injury severity within the Northwest, such that 59% of injuries at higher elevation in northern latitudes resulted in time missed due to injury. Altitude also contributed to TBI susceptibility insofar as 61% of time stamped TBI's occurred at lower altitude, with 58% of TBI's acquired by smaller than average players sustaining the injury. Low elevation also contributed to higher (59%) rates for players who play less football than the league average at their position. Players on offense were more likely to sustain a TBI at lower altitudes, specifically tight ends. The discrepancies in TBI ratios regarding doctor diagnosis and coaching decisions with regard to returning to play by altitude may be because the cluster classifications of the NFL stadiums are associated with the overall intensity of the Earth's magnetic field. The geomagnetic field strength also varies by cardinal direction, with maximum intensities observed in the North, and minimum intensities in the South. This could suggest that the higher TBI rates (57%) in Northern latitudes could be due to electromagnetic dynamics produced by the Earth, such that increased geomagnetic field strength was also persistent during more severe TBI's.

Lunar considerations

Extra-terrestrial influence also contributed to the effect of latitude on injury severity, insofar as a higher proportion (66%) of severe injuries occurred at higher latitudes when the Moon was moving closer to the Earth, suggesting gravitational influence. When the Moon was leading the Sun in an Earth-bound observer's sky 60% of severe injuries occurred at increased latitude.

Analysis of lunar phase during injury acquisition by cardinal direction indicated that 38% of TBI's occurred during the gibbous moon regardless of direction, however lunar phase contributions to TBI acquirement also differentiated by latitude and longitude considerations. 72% of TBI's that occurred during the new moon were in Eastern and Western regions. 63% of the TBI's during the waxing crescent lunar phase occurred in the Northeast. This directional effect on increased TBI rates shifted to the Northern and Southern regions during the first quarter lunar phase, such that 58% of injuries during this phase occurred in these regions. This spatial degree of high susceptibility transitioned to the Northeast during waxing gibbous Moon wherein 57% of TBI's occurred during this period. Full moon ratios were consistent across the country, however during waxing lunar conditions 64% of injuries occurred within the Northwest.

The month with the highest injury frequency, regardless of lunar phase, was November. This could be a function of the number of games played and meteorological instability. The lunar phase with the highest rate-of-injury however, appears to change as a function of the month in season. The new moon had the highest ratio (18%) of injury acquisition during September, but the waxing gibbous moon had the highest rate of injury during November through December wherein 68% of TBI's occurred. This moving average was apparent within waning gibbous and last quarter moon phases, wherein the highest TBI rates were observed in December and January, respectively.

Lunar effects on Body mass of TBI players

Lunar contributions influenced TBI severity in relation to BMI considerations. Injury severity was greater for players who were smaller than average at their position during the waxing crescent lunar phase wherein these players required a week and a half of recovery on average, in comparison to players who were bigger than average who had reduced injury severity during this phase and did not even require a week of recovery. This was evident in the ratio of injury severity and BMI cluster classifications during the waxing crescent lunar phase wherein

73% of less severe injuries occurred to players with a larger then average BMI, while 66% of the more severe injuries occurred to smaller players. This effect amplified in stadiums with open roof designs, and within the Eastern U.S. where 76% of the more severe TBI's occurred to smaller players. This mass dependant model of injury severity amplified during the waxing gibbous lunar phase wherein 90% of the less severe injuries within eastern longitudes occurred in players who were bigger, even though 67% of these injuries within this region during this phase had increased injury severity. Smaller than average players were also more susceptible to increased injury severity during last quarter lunar phase, specifically in open roof stadiums wherein 90% of less severe injuries occurred to players who were bigger than average. Within the Western U.S, all of the less severe TBI's that occurred in these types of stadiums happened to bigger players. Bigger players were most susceptible to injury severity during the waning crescent phase, specifically in open roof stadiums, specifically in the Western U.S. While smaller players made up 60% of all TBI's under these circumstances, 72% of the more severe injuries happened to bigger players.

TBI's that resulted in increased injury severity and reduced athletic exposure were prevalent during the gibbous moon, such that they entailed 45% of all injuries during the waxing and waning gibbous lunar phases. This could be the result of the interaction between the lunar and solar cycles, such that sunspot activity significantly varied by lunar phase and systemically decreased during these phases in addition to the last quarter lunar phase. Noisy solar conditions the week prior to injury actually promoted reduced severity during the new Moon wherein 59% of TBI's resulted in no time missed due to injury, in comparison to quiet solar preconditions which promoted increased injury severity in 66% of the injuries during these conditions during this phase. This effect was flipped during the first quarter lunar phase, wherein 54% of TBI's acquired after noisy solar preconditions resulted in increased injury severity. Quiet solar activity prior to the waxing gibbous lunar phase resulted in a higher proportion (78%) of more severe injuries.

Solar and lunar contributions of mass of player who sustained a TBI

The specific solar and gravitational models pertaining to TBI severity (games missed) and mass of injured players during the full moon L may be due to gravitational (g) contributions. Given that human composition can be metaphorically attributed to that of ‘2 Parts Sea and 1-part land’, tidal theory dynamics are considered here. Tides vary in relation to the g pull on the Earth due to change in phase, declination, and distance of the Moon in relation to the Earth during lunar orbit. The g potential increases linearly with mass, but decreases with the distance between two bodies. The distance between the Earth-Moon couplet changes by roughly 11% during lunar transit. The systemic mass-dependent TBI severity model occurred when lunar and solar pull was maximum (spring), insofar as there was alignment (syzygy) among the Moon, Earth, and Sun (new/full moon) (Mazumder and Arima, 2005). The observed amplification of these effects in the South regions of the U.S. could be due to the equatorial bulge on centripetal and g forces, insofar as, the bulge exerts substantial torque (Bell et al., 1991; Volland, 1996), and the dynamics of its atmosphere are void of centrifugal acceleration (Egger and Hoinka, 1999). This is important because centripetal force is generally different in location and greater in magnitude than g force. The exception to this phenomenon exists at two points in a line connecting them to the center of the Moon, and on opposite ends of the Earth - wherein the centripetal and g forces are in the same direction, and the difference between these forces create tidal bulges (Coughenour et al., 2009), and may amplify mass dependant variation in TBI severity during The full moon lunar phase.

The findings that height was the most predictive physical attribute of players who acquired a TBI during the full moon lunar phase is of interest. Predictive models of height were generated in all four cardinal directions (N, S, E and W) of the NFL U.S., as well as for higher altitudes. The accuracy of overall height and mass within full moon TBI models were greatest at lower altitudes, whereas the accuracy of models predicting TBI severity during the full moon, were greatest in Southern latitudes. In specific, it was predicted by solar maximum, which would act in juxtaposition within North and South regions due to large solar wind variability (Smith et al. 2001) and slower solar wind flows (McComas et al., 2003) observed at high latitudes, which would likely dampen the effect of S on TBI severity under such circumstance.

Full moon TBI height was accommodated by increased change in the Earth's magnetic field is of particular interest, insofar as there is force associated with magnetic fields. The increased annual change in orthogonal force, associated with increased change in Z component intensity, along with increased change in horizontal force, namely increased East-West force, associated with increased change in Y component intensity, may have enhanced player-to-ground and player-to-player collisions, specifically when the gravitational pull from the Moon was maximum (spring; Syzygy), and further exclusive to a Moon-Earth-Sun alignment. In summary, these findings confirm temporal-spatial dependent models of environmental accommodation of player composition (weight/height) and degradation (games missed due to injury) during full moon TBI acquirement. Amplified TBI player mass, height and TBI severity were observed during gravitational, magnetic and solar maximums, respectively.

Conclusion

In summary, the dynamics of TBI acquirement are extensive and the factors that might influence injury susceptibility are plentiful. The nature of professional football indicates that players who have a specific role have certain profiles such as clustered height and weight signatures. Cornerbacks for example are required to stay lean and fast in order to cover the much bigger wide receivers, which could leave them in vulnerable in matchups, and may explain why this position displays the highest TBI rates among positions in the NFL. They are also among the positions that perform the most cardiovascular activity which may serve as a predisposition of enhanced injury acquisition. Smaller players experienced more TBI's on average than players with a larger BMI, however bigger players experienced greater injury severity. Relationships between Body Mass Index (BMI) and injury severity were enhanced during variation in meteorological phenomena including the altitude, longitude latitude of injury origin as well as lunar transit. The degree to which an injured player's height and weight were predicted by geomagnetic and solar contributions during the full moon lunar phase, suggests a direct link by which environmental influences can enhance injury susceptibility during naturally occurring background cycles.

Increased athletic exposure is a primary TBI risk factor. Injury severity accommodated changes in athletic exposure due to TBI acquisition. Predictive equations suggest that, on average, players have a consistent reduction in football participation of approximately five athletic exposures per game missed due to injury. The primary relationship between these measures indicates that the possibility of a type 2 error was most prevalent wherein doctors and coaches may have agreed that there was a significant injury when there may have not been, however the 2012 and 2013 NFL seasons actually contained a majority of TBI's that did not require recovery time. Lunar contributions in association with measures of longitude and latitude also displayed variations in changes in athletic exposure suggesting that this data could be used in order schedule games in regions that do not align with phases of the Moon that promote more severe injuries.

Other measures of TBI players such as draft statistics and comparisons to HOF inductees as well as NFL players' league wide give indications of how TBI's affect a player's career. Environmental considerations however, such as geo-coordination, geomagnetic field intensities, as well as lunar and solar contributions indicate that TBI acquisition displays variation by these factors. This type of interdisciplinary approach is of assistance in identifying interactions between factors that promote and inhibit injury severity, and can be of assistance in the scheduling of games. In summary, Traumatic Brain Injuries (TBI's) are an epidemic in collision sports, future research in association with this data should be used to keep football as safe as possible insofar as the youth of today are the leaders of tomorrow and their health should not be compromised due to participation in sport.

Chapter 3 Geomagnetic Variables and Market Descriptors as Predictors of the Frequency of Use of Google Search Terms *Anxiety, Depression,* and *Dow Jones*

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Contributions: Marco G. Di Feo collected the Google trend data, Stan Koren transformed the data into weekly time intervals for analysis, Lyndon Juden-Kelly collected the geomagnetic data from sgo.fi, Dr. Cynthia Whissell wrote this article and did the analysis.

In addition to exploring the effects of environmental stimulation during injury acquisition during sporting events, this chapter is intended to explore possible meteorological contributions to aggregate global human behaviors to determine whether or not the influences of the natural world are a real phenomenon or the product of a confounding variable.

Introduction

Researchers have provided convincing evidence of relationships between changes in the Earth's geomagnetic field and human behaviour. Weekly geomagnetic variability is associated with an increase in first aid mining accidents (Persinger & Nolan, 1984) and geomagnetic storm activity with an increase in suicide rates (Gordon & Berk, 2003). Artificial magnetic fields can affect emotional states (Tsang, Koren, & Persinger, 2009) and increased geomagnetic storm activity predicts increases in psychiatric admissions (Friedman, Becker & Bachman, 1963). Krivelyova & Robotti (2003) demonstrate that the behaviour of the stock markets is related to the presence of geomagnetic storms, and suggest that relationship between geomagnetic activity and market behaviour is likely mediated by changes in people's moods. The mechanisms by which geomagnetic variables have their effects is not entirely known, but dysregulation of melanin and the pineal gland, with ensuing changes in the autonomic nervous system, have been thought to be involved (Krivelyova & Robotti, 2003; Gordon & Berk, 2003).

Stock market trends and suicidal depression are, respectively, large-scale and grave events. As well, geomagnetic storms do not occur daily. Since prediction is possible at these extremes, it would be logical to question whether normal variations in geomagnetic activity can be used to predict less expansive or extreme behaviors. In this research, weekly geomagnetic variables are employed to predict the world-wide frequency of use for search terms on Google. Google search data have been applied to the study of both mental health phenomena (Nuti et al, 2014) and market behaviours (Preis, Moat, & Stanley, 2013). Because of the demonstrated relationship of geomagnetic activity to mood, *Anxiety* and *Depression* were two of the search terms examined, and because of the relationship of geomagnetism to stock market behaviours, the search term *Dow Jones* was also included. Weekly frequency of Google searches for these three terms, provided by Google Trends, was predicted from several variables reflecting the ongoing levels of geomagnetic activity and from two market variables – the Dow Jones Index and Dow Jones trading volume.

Method

Weekly worldwide data for Google search frequencies were obtained from Google Trends[1] for 261weeks beginning May 27th, 2012 to May 21st, 2017. Google Trends publishes relative rather than absolute values. These were the data employed for three search terms entered simultaneously: *Depression*, *Anxiety*, and *Dow Jones*. Initially, the search term *Suicide* was also included, but its frequencies were extremely low (in comparison to the other terms), and

[1] https://trends.google.com/trends/?geo=US

markedly skewed (beyond the point of correction by transformation), making it an inappropriate variable for correlational analyses. Because the terms *Depression, Anxiety*, and *Dow Jones* were all assumed to reflect negative mood, the search term *Peace* was included as a comparative term: it was expected to show evidence of dissimilar relationships to geomagnetic activity.

Weekly electromagnetic data for the Earth were obtained from a site in Finland.[2] Data were available for strength of activity in three dimensions, X (South to North), Y (West to East) and Z (up to down),[3] as were estimates of r (overall activity) and phi (measure of the Earth's magnetic dipole), and an estimate of the variability of each of these over the week, resulting in 10 measures of electromagnetic activity (Table 1). Weekly Dow Jones data were obtained reflecting price (the Index) and trading volume.[4] Time was represented by a variable indicating the number of the week (1 to 261).

Variables that were extremely skewed (frequency of searches for *Anxiety*, *Dow Jones*, and *Peace*, and the Dow Jones trading volume) were submitted to a Log_{10} transformation to correct the skew. There was a considerable time effect in the data. For example field strength along the Y axis and weekly anxiety search frequencies were both strongly correlated with time. These values represent long-term trends that dominate the data but are not the focus of the research. In the first case the trend might be due the Sun spot cycles that influence magnetic activity; Sunspots were on the rise in the years studied. The second trend is likely the outcome of the increased availability of computers and a rising use of Google searches worldwide between 2012 and 2017. All terms were corrected for time by predicting each variable from time and retaining the residual. After correction, search frequencies for *Depression* and *Anxiety* were

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[2] http://www.sgo.fi/Data/Magnetometer/magnData.php (Finland)
[3] http://www.geomag.nrcan.gc.ca/mag_fld/comp-en.php
[4] https://www.investing.com/indices/us-30-historical-data

correlated (*r*=.65, *p*<.001), and search frequencies for *Anxiety* and *Dow Jones* were correlated (*r*=.18, *p*<.05). There was no relationship between search frequencies for the terms *Depression* and *Dow Jones*. The frequency of searches for *Peace* was moderately correlated with that for all other search terms (*Depression*, *r*= .38; *Anxiety*, *r*=.32; *Dow Jones*, *r*=.28, *p*<.001).

Results

Relationships between electromagnetic and market variables and search frequencies are reported in Table 44. Dow Jones volume, which reflects the level of trading activity, was positively related to all four search frequencies; as the trading volume rose, searches for the terms *Anxiety*, *Depression*, *Dow Jones* and *Peace* also rose (independently of time). The Dow Jones Index, on the other hand, was negatively correlated to frequency of searches for *Anxiety*, *Dow Jones* and *Peace*; as prices rose, searches for these terms, but not for *Depression*, declined. Searches for the term *Dow Jones* were weakly but consistently related to all measures reflecting the variability of the Earth's magnetic field; greater variability was associated with more frequent searches.

Table 44 Significant relationships among search, market and electromagnetic variables (p<.001, variables corrected for time)

Geomagnetic and Market variables	Depression	Anxiety	Dow Jones	Peace
DJ Volume	.31	.43	.28	.19
DJ Price	---	-.27	-.38	-.38
X	-.17	-.26	---	---
Y	---	.21	---	---
Z	---	.15	---	---
R	---	---	---	---

Phi	.13	.25	---	---
sdX	---	---	.12	---
sdY	---	---	.12	---
sdZ	---	---	.14	---
Sdr	---	---	.14	---
sdPhi	---	---	.13	---

There were several significant relationships among magnetic variables. To allow for simpler predictive equations, all potential predictors (10 magnetic variables and two market variables) were entered into a principal components analysis with a varimax rotation. The analysis yielded four components that explained 84% of the total variance. The first component had high loadings for all the variability measures and was labeled *Magnetic Variability*. The second component included high loadings for phi and Y activity, a high negative loading for X activity, and a moderately high loading for trade volume. It was labeled *West-East Activity and Trade*. The third component had high loadings for Z activity and r (overall activity), and the final component represented only the Dow Jones Index. These two components were labeled *Up-Down Activity* and *Prices*. Component scores were then employed as predictors of search frequencies in linear regressions with simultaneous entry of all four variables (Table-45).

Table 45 Standardized regression formulas for the prediction of the frequency of Google searches for four component scores representing geomagnetic and market activity

	Criteria (Search Terms)			
Predictive Components	Depression	Anxiety	Dow Jones	Peace
Magnetic Variability	-.15*	-.12*	.07	-.08

West-East Activity/ Trade Volume	.26*	.38*	.06	.17*
Up-Down Activity	.05	.12*	.09	.04
Prices	.03	-.19*	-.28*	-.32*
R (p<.001)	.31	.46	.31	.37

*p<.05

Prediction was moderately successful in every case and each resulting formula was unique in terms of its significant contributors. Search frequencies for *Anxiety* were best predicted, and they tended to be high when *Magnetic Variability* and *Price* were low, and when *West-East Activity/Trade* and *Up-Down Activity* were high. The only significant predictor of searches for *Dow Jones* was the *Price* component, which was negatively related to it. As stock prices fell, there were more searches for the term *Dow Jones*. Searches for *Peace* increased when *West-East Activity/Trade* was high and when *Price* was low. Searches for *Depression* were highest when *West-East Activity/Trade* was high and *Magnetic Variability* was low. The components employed in prediction were orthogonal to one another (totally unrelated), so the standardized weights in Table 45 also represent the correlations between components and search term frequencies.

Discussion

Data reported and discussed in this paper point to the fact that common day-to-day behaviours such as Google searches are correlated with week to week changes in levels of geomagnetic activity and can be predicted from such activity and from the behaviours of the markets. Distinct predictive formulas suggest that different processes underlie the use of each of the search terms. All the components representing market and geomagnetic predictors entered significantly into one or another predictive formula. *West-East Activity/Trade* and *Price* were the components making the strongest contributions to prediction. High *West-East Activity and Trade* predicted more searches for *Depression, Anxiety,* and *Peace*. This might be the result of the destabilizing influence of high geomagnetic activity in this dimension. High *Price* predicted fewer searches for *Anxiety, Dow Jones,* and *Peace*, which could suggest a greater reassurance (and a lesser need to search) in times of a high Dow Jones Index.

Chapter 4 - Biometeorological Contributions to Cryptocurrency popularity and its market behaviour

The influence of ambient background conditions on specific and collective behaviors regarding finance have been well documented. This investigation was designed to discern whether or not the relatively novel digital currency market of cryptocurrency is susceptible to these affects as well. This investigation also aims to determine if the relationship between traditional finance and meteorological considerations are conducive to the literature on environmental influence regarding economic activities or whether or not novel models for predicting price index movement

Introduction

Aristotle proposed criteria that represent the composition of 'good money', which include: durability, portability, divisibility, and intrinsic value (Lee, 2009). Gold was originally considered to have fulfilled these components. The growing need for currencies that could be used as a medium of exchange however, led to the creation of fiat, which could be controlled and regulated by governments. Alternative currencies include: currencies with intrinsic utility, tokens, centralized digital currencies, and distributed digital currencies. Currencies with intrinsic utility are not dependent upon governance to be considered monetary instruments and include items such as cigarettes, ramen noodles, metals, and even prepaid phone cards. Tokens refer to currencies that that do not necessarily have intrinsic value, but are bounded by social contracts and agreements such as Salt Spring dollars or casino chips. Centralized digital currencies involve a single administrative body and include historical examples such as the Linden Dollar, which was essentially a closed system with transactions between specified entities (Nian & Chuen, 2015). Distributed digital currencies can be considered an alternative economic option that includes cryptocurrencies such as Bitcoin (BTC) and Ethereum (ETH). These have been considered financial market disrupters due to the associated shift of power from legally regulated institutions such as banks and governments to an unregulated, decentralized network of anonymous users (Salman, 2019). Alternative currencies are being considered for use globally due to: localism, technological consideration, anonymity, the political economy, environmentalism, inefficiencies, financial freedom, and speculation.

Digital currencies

Cryptocurrencies are digital in nature and can be used as a medium of exchange, unit of account, and store of value (Salman & Razzaq, 2018). BTC, however, has been criticized with regard to these features. As medium of exchange, BTC does not have intrinsic value: its utility is dependent upon its usefulness in the consumer market. Furthermore, if an individual is unsuccessful as a miner of new coins, they must purchase coins on online exchanges, which typically have low liquidity, significant spreads between bids and ask prices and currently have a considerable amount of risk. While a transaction on the BTC blockchain can have numerous payments within it, there is a currently an associated delay time which lasts ten minutes on average. A connection on the Internet of Things (IoT) is also required for transactions on its blockchain.

With regard to being a unit of account, the extreme volatility associated with BTC means that price comparisons between it and other cryptocurrencies change drastically from day to day. This requires that retailers frequently recalculate rates, which can be costly and confusing for buyers. If one cryptocurrency were to rise to the top of the market and be used as a primary payment method this problem would be solved, but this has not manifested despite BTC’s current market dominance. Differences in BTC price amongst varying exchanges also violate the classical law of one price. This leaves it exposed to arbitrage, wherein traders purchase BTC at deflated lower prices, and sell them in exchanges where the prices are inflated. The fractional prices associated with BTC, which are expressed by extended decimal places, are also contrary to the high inflation associated with traditional finance and the rounding methods that have been adopted in the U.S. and Canada (where one cent coins have been removed from circulation).

As a store of value, currencies are purchased at a certain price and later exchanged for goods and services of equal economic value. If cryptocurrencies are truly purchased as a store of value, methods for keeping them safe have been considered limited. They may be kept in digital wallets, often provided by third parties, but these are prone to security threats. Cold storage wallets (physical hardware for offline storage) are another option, but this method limits time sensitive access to funds (Yermack, 2015).

The technology

Blockchain technology preserves historical records for the validation and safeguarding of entries (Crosby et al., 2016) on a shared digital ledger that provides a permanent record between two independent parties (Sulman & Razzaq, 2018). The blockchain primarily structures data in a decentralized and distributed manner that is not controlled by tertiary entities (Hackett, 2016). The components of blockchain technology include: peer-to-peer networking, messaging, consensus, state machine, cryptographic security, incentive (Antonopoulos & Wood, 2018).

The blockchain ledger can be defined as a state transition system, wherein the state is the ownership status of all of the specific cryptocurrency in existence, while the state transition function refers to the transaction of these coins from senders to receivers resulting in the output of a new state (Buterin, 2014). Cryptographic hashing determines transactions on the blockchain by identifying the appropriate inputs and outputs. Outputs of a transaction are only used once in the blockchain, assuring only one recipient of each payment (Tschorsch, & Scheuermann, 2016).

Quorum systems in digital currencies assume that false information and malicious attacks are a natural by-product of a decentralized network, therefore consensus is expected to prevent this behavior. If the majority of nodes agree about the state of the system, they have control of the network and the information is considered valid. As such, every node within the peer-to-peer network records a copy of the transactions within it. This limits double spending but does not prevent it, because a sender could attempt to transmit the same coin to multiple receivers and could validate these transactions by controlling the necessary number of nodes within the network that are required to do so. It is the Proof-of-Work (PoW) algorithm that ultimately deters double spending through necessitating energy intensive computations from the nodes in order to validate transactions. As long as the computational power of honest nodes is greater than 51% within the network, dishonest payments are not validated (Vujičić & colleagues, 2018).

Ethereum

The creation of Ethereum was an attempt at a general technology upon which all transaction based state machines could be built, with the purpose of facilitating economic transactions between individuals on a trustful object messaging framework (Wood, 2014). BTC has an explicit niche, limited range of practicality, and leverages innovation. Ethereum is similar to BTC insofar as they are both cryptocurrencies that allow users to remain anonymous, and are systems that do not require trust. Blocks are mined on both of these cryptocurrencies blockchains with increasing difficulty. Ethereum, however, has a built in Turing-complete programming language which allows the Ethereum Virtual Machine (EVM) to compute any algorithm that can be computed by a Turing machine. This allows individuals to create unique ownership rules and transaction formats through smart contracts which can be written on the Ethereum blockchain. This allows for the execution of cryptographic rules given that specified conditions are met (Buterin, 2014). The only limitations are those associated with finite memory (D'Alfonso et al., 2016), but smart contracts are designed to store digital currency and when they are stolen they are gone forever.

Technical analysis

Effective and profitable trading requires an understanding of market trends. The objective of technical analysis is to forecast price movement by quantitative interpretation of historical data, and it is an important tool for making trading decisions (Saacke, 2002). Technical analysis has been considered profitable when it can represent variations in market psychology (Menkoff & Taylor, 2007).

The Heiken Ashi (HA, Japanese: 'average bar') is a smooth moving average of market movement and reflects the most likely trend direction and momentum. HA charts are a series of bars, or 'candles,' with lighter 'shadow' extensions. HA candles are bigger with long shadows in strong up or down trends (Roy Trivedi, 2018). Average True Range (ATR) is a measure of price volatility. The true range is the greatest distance between one day's high and low, one day's high and the previous day's close, or one day's low and the previous day's close. While the ATR does not predict anything per se, higher can indicate that a stock is trending, while lower can indicate consolidation (as cited in Yamanaka, 2012). Aroon translates from Sanskrit into English as 'dawn's early light' and is a trend indicator that assesses trend strength of stock price movement. The Aroon operates on the hypothesis that a stock is trending up when it is near the top of its price range relative to its previous bottom price, and is trending down when the stock is closer to the bottom of its price range relative to its previous high (Canegrati, 2008).

Popularity

The Internet of Things (IoT) allows for big data analytics regarding mass human behaviors, and can be used to measure price action regarding cryptocurrency. Studies have indicated that daily Wikipedia traffic and weekly Google search volume were correlates of BTC price (Kristoufek, 2013). Positive relationships between BTC price was also found with internet search volume and Wikipedia activity (Phillips & Gorse, 2018). Investor sentiment from news articles (Karalevicius et al., 2018) and Twitter (Kaminski, 2014) was also positively correlated with the BTC price index. Other social media activity such as posts in internet forums (Mai et al., 2018), and user activity within cryptocurrency communities (Kim et al., 2016) were found to have greater predictive power then tweets. Messages within BTC-themed Telegram groups also predicted the direction of cryptocurrency price (Smuts, 2018). Big data and social media analytics have been applied chiefly to BTC rather than the Ethereum price index.

Methodology

The aim of this study is to determine what independent variables, if any, can predict cryptocurrency price indices; this includes intrinsic characteristics of blockchain technology, traditional technical analysis price indicators, global internet search frequencies, or naturally occurring background activity such as lunar and solar periodicities or electromagnetic activity that is intrinsically produced by the Earth. This project also strives to ascertain whether or not there are intercorrelations between these measures.

Cryptocurrency market movement

Historical daily market features were collected for ETH from *coinmarketcap.com*, which is an online database that tracks cryptocurrency prices. Data was also collected for BTC for reference purposes. The market features collected include; (1) daily opening price, (2) daily high,

(3) daily low, (4) daily closing price, (5) daily volume, and (6) daily market cap. These variables were collected as dependant variables in order to have an accurate measure of cryptocurrency price movement.

Blockchain characteristics

Daily measures of cryptocurrency blockchain characteristics collected from *coinmetrics.io* were: transaction volume (USD), transaction count, exchange volume (USD), coins generated, fees, active addresses, transaction value (USD), average mining difficulty, payment count, block-size and block-count. These measures were collected in order to determine whether they correspond with price movement and could be predicted by environmental factors.

Traditional Price indicators

Several price indicators were calculated, including Average True Range (ATR), Aroon up and down, and Heiken Ashi (HA). While these measures are not necessarily among the most widely accepted price indicators, each has its own purpose in identifying the direction, strength and speed associated with market trends.

Average True Range

ATR is a technical analysis indicator used in foreign exchange (forex) trading, to measure the volatility of an asset over a given period. ATR is a smooth moving average which takes the mean score of a commodity's high minus its low. James Welles Wilder Jr., who originally developed the formula in 1942, suggested that using the true ranges over a 14-day period is optimal, and that period was used for this analysis.

Aroon up and down

The Aroon up and down was developed in 1995 by Tushar Chande, and is an indicator in which two lines cross each other, and is intended to reveal when new trends develop, giving a signal to either go long or short. The Aroon indicator measures the number of days since an asset's price has recorded a 25-day high or low, and does this through two measures: the Aroon up, and the Aroon down. When the Aroon up is above the Aroon down, the indicator is giving a buy signal, and vice versa. This makes the Aroon up and down a unique indicator which focuses on price relative to time, which allows it to identify trends, consolidations, correction periods, and reversals. This indicator is represented as a percentage which fluctuates from 0-100. The calculations for Aroon up is ((25-[days since 25-day high])/25) *100. Aroon down is calculated by: ((25-[days since 25-day low])/25) *100.

Heiken Ashi (HA)

The HA is a technical indicator used to measure trend direction. It is considered a means of quieting down noise that is intrinsic with the natural volatility associated with the normal fluctuation of an asset's parameters. There are five components of the HA: the HA open; HA high; HA low; HA close; and the HA pivot point. The HA open is calculated by adding the previous HA open to the previous HA close, and then dividing by two. The HA high is equal to the maximum value of either the high, HA open, or HA close. The HA low is the minimum value of the low, HA open, or HA close. The HA close equals the resultant of the open, high, low and close divided by four. The HA pivot point is equal to the sum of the HA open, HA high, HA low, and HA close divided by four.

Popularity

ETH Popularity was collected from *trends.google.com* for each day of the 13 months between March 1st 2017 and March 31st 2018. Popularity data collection occurred independently for each month. This implies that each day received a ratio score out of 100 in relation to the volume of Ethereum Google search interest on the most popular day of the month. The sub-regions which enquired about ETH the most each month was consulted within Google trends, such that the top 5 major cities which most frequently searched for ETH per month were documented (Table 46).

Table 46 Major cities which searched for Ethereum the most each month

year	month	Major cities which searched for Ethereum the most on Google				
2017	March	San Francisco	Amsterdam	Singapore	Yonkers	San Jose
	April	San Francisco	Seoul	New York	Los Angeles	Toronto
	May	San Francisco	Seoul	Vancouver	Amsterdam	Seattle
	June	San Francisco	Seoul	Amsterdam	Seattle	Singapore
	July	San Francisco	Seoul	Singapore	Toronto	Seattle
	August	San Francisco	Singapore	Vancouver	Toronto	Seoul
	September	San Francisco	Singapore	Vancouver	Toronto	Toronto
	October	Yonkers	San Francisco	Singapore	Zurich	Amsterdam
	November	San Francisco	Cape Town	Singapore	Yonkers	Toronto
	December	San Francisco	Toronto	Singapore	New York	Perth
2018	January	San Francisco	Toronto	Yonkers	San Jose	Singapore
	February	San Francisco	Singapore	Toronto	Seoul	Austin
	March	San Francisco	Seoul	Singapore	Toronto	San Jose

Geographic coordinate system and The Earth's geomagnetic field

The longitude and latitude of each of these cities was obtained from *latlong.com*. This was accomplished so that their geographical coordinates could be entered in an online magnetic field calculator (*geomag.nrcan.gc.ca*), in order to calculate the local daily variation with regard to several of the Earth's magnetic field (EMF) components from these specific locations. The geomagnetic field components of interest include; declination (D), inclination (I), horizontal intensity (H), orthogonal intensity (Z), the North component of the magnetic field vector (X), The East component of the magnetic field (Y), as well as the total intensity of the magnetic field vector (F). The calculated magnetic field indices were then averaged into monthly mean values.

Solar and lunar data

Daily solar Sunspot (average) data was collected from an online database (*sidc.be/silso/datafiles*) for the time period between March 1st, 2017 and March 31st, 2018. Daily lunar variables of interest collected from *calendar-12.com* for the same period included lunar phase, Moon visibility, and Moon age. The phases of the Moon were new moon, waxing crescent, 1st quarter, waxing gibbous, full moon, waning gibbous, 3rd quarter, waning crescent. Moon visibility measured the surface brightness of the Moon and ranged from 0-100. Moon-age documented where the day fell in the 31-day lunar cycle.

Analysis

SPSS software was used for the analysis, which explored environmental effects on participation in the cryptocurrency market. Correlational analysis was used as a preliminary method by which to explore the intrinsic relationship between independent and dependent variables of interest. One-way analysis of variance was used to explore relationships across various conditions including lunar phase. Multiple regression analysis was used in order to determine whether market conditions could be predicted by biometeorological considerations. Chi-square analysis was implemented in order to observe differences between observed and expected values across a number of various environmental conditions. Z-score transformations were used to compare the variance in specified variables of interest.

Data cleaning and analysis used

Smooth moving averages were used in this chapter. Interval data was also used with regard to Google trend statistics. Z-score transformations were used to compare variables of interest that had differentiating scales of measurement. Manual clustering was also applicable in order to perform chi-square and discriminant analysis. Analysis used in this chapter include one-way analysis of variance (ANOVA), Pearson r, spearman rho & partial correlations, lag/lead analysis, multiple regression analysis, chi-square analysis, in addition to split file analysis.

Results

Blockchain characteristics

ETH's blockchain features were entered into multiple regression in order to predict its market cap over the total duration of its existence from August 2015 to February 2019, the results indicate that its daily payment count entered as the lone predictor, explaining 85% of the variance in its market cap movement [$F_{(1,1249)}$ =6825.09, r^2=.85]. When ETH's market cap and daily payments are z-score transformed and plotted over time, the results can be observed below.

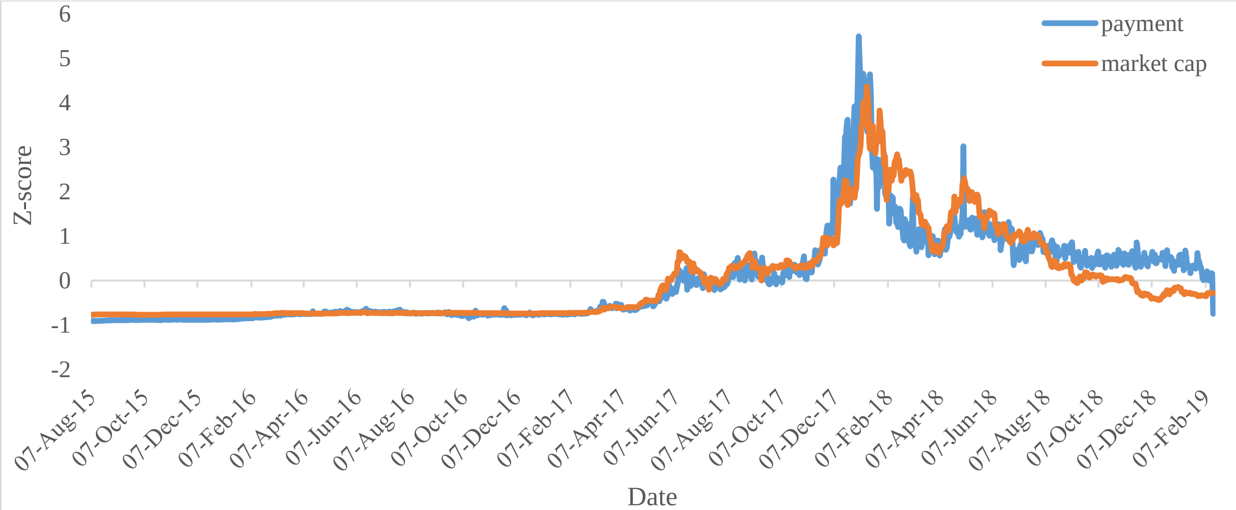

Figure 59 Z-score transform: ETH's market cap and daily payments ($) over time

ETH daily fees by lunar phase

A one-way analysis of variance explored ETH daily fees ($) by lunar phase to determine if they significantly vary by lunar transit, which was observed [$F_{(7,388)}$ =2.40, r^2=.04, p=.02]. The results indicate lower fees from the 1^{st} quarter to full moon lunar phase.

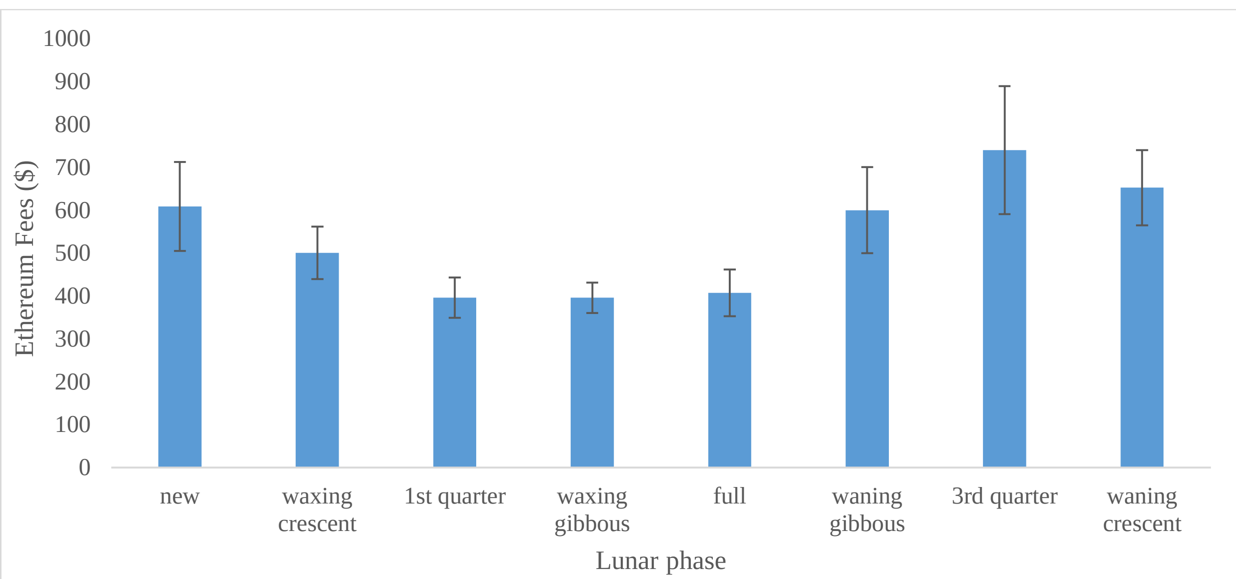

Figure 60 ETH daily fees by lunar phase

ETH's Average True Range

Correlational analysis indicated that the ATR value was significantly associated with ETH's open ($r_{(382)}$=.88, rho=.83), close ($r_{(382)}$=.88, rho=.82), volume ($r_{(382)}$=.77, rho=.86), and market cap ($r_{(382)}$=.88, rho=.82). Partial correlations accounting for time still yielded significant results for ETH's ATR and its open (r=.88), close (r=.88), volume (r=.78) and market cap (.88). When ATR was lagged up to 7 days, it still displayed correlative success with ETH's aforementioned market features with correlations ranging between .78-.81.

To verify that these results were not due to the fact that ETH was trending up during this period, a subsequent dataset was created which included the daily market behavior of ETH from April 1st, 2018 to January 14th, 2019. Analysis indicated that the correlative and predictive models of ATR on ETH's market features were even stronger during ETH's downtrend. ETH's market cap, for example, was found to be correlated ($r_{(275)}$=.93, rho=.89) and accommodated [$F_{(1,268)}$=1602, r^2=.86] by the ATR. These effects were consistent when ATR was lagged up to 5 days prior to price.

ETH's Average True Range (ATR) was able to predict its market cap [$F_{(1,380)}$ =1306.6, r^2=.78] with 78% accuracy from March 1st 2017 to March 31st 2018, which yielded the following equation: **ETHMarketcap= 13180031468.16 + 659865670.461*(ATR)**. When this analysis is flipped, the equation is: **ETHATR= -6.367 + 1.174*(Market cap).** Partial correlations between ATR and market cap also remained significant in this dataset ($r_{(272)}$=.59) when controlling for time. When ETH's daily ATR and market cap are z-score transformed and plotted over time the results can be observed below.

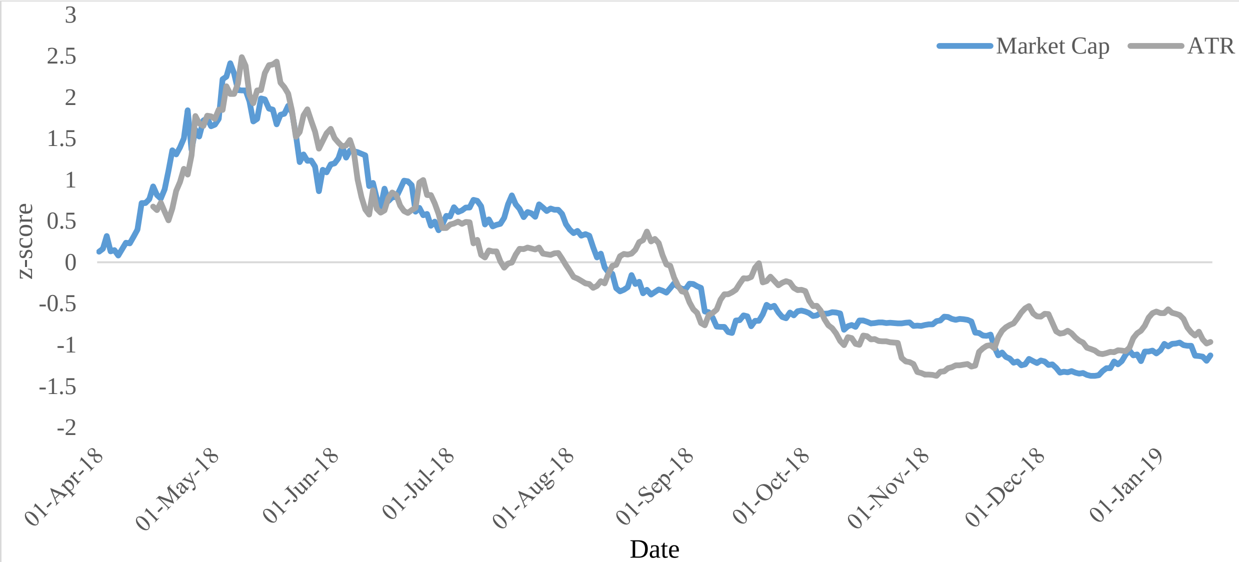

Figure 61 Z-score transform: ETH's Market cap and ATR from April 1, 2018 through January 31, 2019

ETH's Average True Range 14-day moving average by temporal, lunar and solar activity

Pearson and Spearman rho correlational analysis indicated that ATR was correlated with daily solar flare average ($r_{(382)}$= -.25, rho= -.29), the horizontal component of the Earths EM field ($r_{(382)}$=.43, rho=.61), as well as the X ($r_{(382)}$=.43, rho=.62) and Z ($r_{(382)}$=-.24, rho=-.46) components. When these and other measures of the Earths EM field were entered into multiple regression analysis as IV's in order to predict ATR, the results indicate that the horizontal component [$F_{(1,380)}$=84.7, r^2=.18, SEE=37.27], the daily solar flare average ($F_{(2.379)}$=53.5, r^2=.22, SEE=36.45) and Y component of the Earths EM field ($F_{(3,379)}$=37.42, r^2=.23, SEE=36.29) collectively explain 23% of ATR's variance, and gave the following equation:

ETHATR=-207.94 + .01*(H component) - .35*(daily solar flare) -.004*(Y component)

The residual scores from the regression analysis were saved for split file analysis. The model was able to predict ATR in 11 out of 13 months, with effect sizes ranging from .14-.99. Split file by lunar phase indicated that the model successfully predicted ATR in all 8 lunar phases; however variance explained ranged from 88-94% before the full moon to only 76-84% after.

Table 47 Predictive models of ETH's Average True Range with geomagnetic and solar variables of interest

Month	**R^2**	**Lunar phase**	**R^2**
March '17	$F_{(1,15)}$=18.75, r^2=.56	new moon	$F_{(1,29)}$=226.26, r^2=.87
April '17	$F_{(1,28)}$=4.41, r^2=.14	waxing crescent	$F_{(1,47)}$=382.93, r^2=.89
May '17	$F_{(1,30)}$=58.07, r^2=.67	1st quarter	$F_{(1,33)}$=164.5, r^2=.83
June '17	$F_{(1,28)}$=183.80, r^2=.87	waxing gibbous	$F_{(1,47)}$=60.14, r^2=.58
August '17	$F_{(1,29)}$=6.33, r^2=.18	full moon	$F_{(1,30)}$=62.61, r^2=.68
October '17	$F_{(1,29)}$=68.53, r^2=.70	waning gibbous	$F_{(1,44)}$=60.14, r^2=.58
November '17	$F_{(1,28)}$=285.21, r^2=.91	3rd quarter	$F_{(1,32)}$=45.84, r^2=.59
December '17	$F_{(1,29)}$=2680.67, r^2=.99	waning crescent	$F_{(1,45)}$=103.95, r^2=.70
January '18	$F_{(1,29)}$=7606, r^2=.99	**Solar flare**	**R^2**
February'18	$F_{(1,26)}$=2712.33, r^2=.99	quiet	$F_{(1,128)}$=755.65, r^2=.86
March '18	$F_{(1,29)}$=403.14, r^2=.93	noisy	$F_{(1,250)}$=767.08, r^2=.75

BTC Average True Range and its Market cap

BTC's market features were collected over the aforementioned period. Multiple regression analysis indicated that BTC's ATR was able to predict its own market cap with 88% accuracy ($F_{(1,380)}$=2851, r^2=.88), yielding the following equation: **BTCMarketcap= 31827885858.34 + 131826260.65*(ATR).** When BTC's market cap is used to predict its ATR, the equation reads as follows: **BTCATR= -150.67 + 6.69*(market cap).**

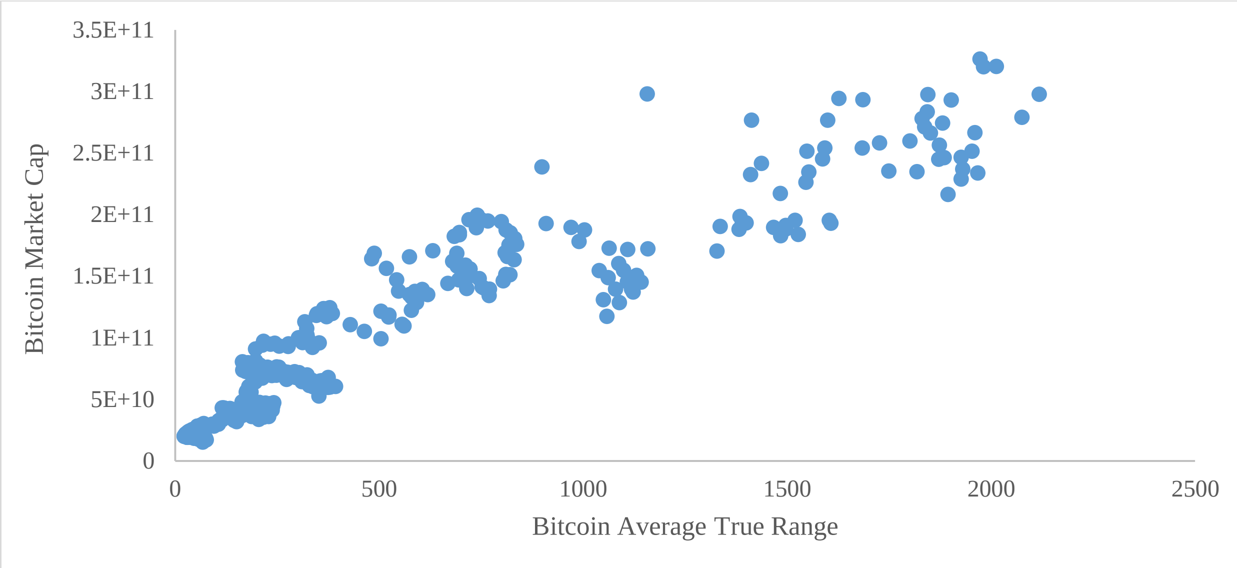

Figure 62 BTCs Average True Range and its Market Cap

BTCs Aroon up and down by lunar phase

The Aroon up and down was calculated for BTC from March 1st 2017 through to March 31st 2018, and entered into a one-way analysis of variance with lunar phase to identify any possible intrinsic temporal sequences. The results indicated that the number of days since last high [$F_{(7,388)}$=2.33, r^2=.04] and low [$F_{(7, 388)}$=2.74, r^2=.05] significantly varied by lunar phase.

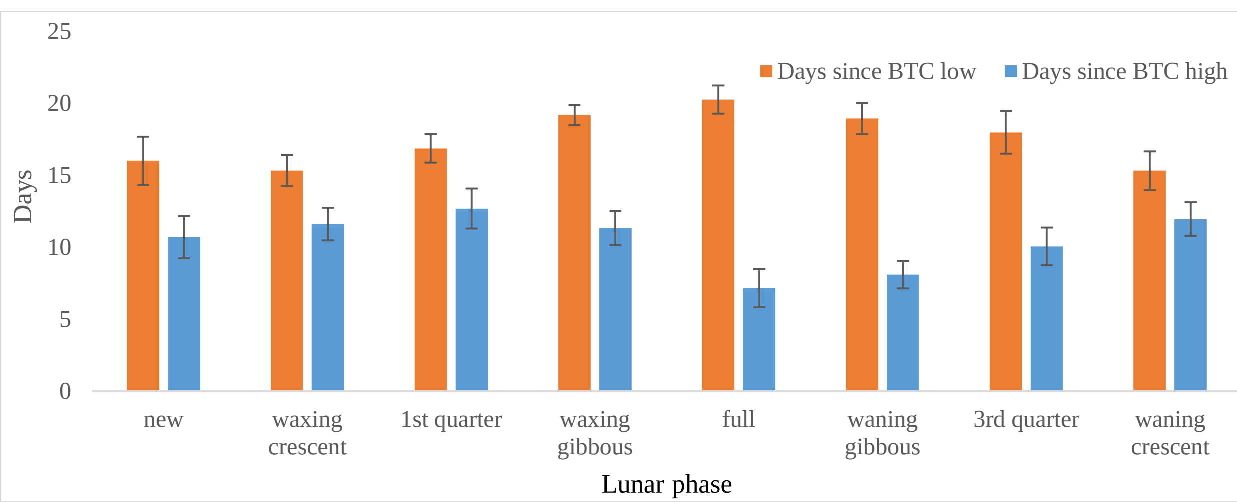

Figure 63 *Days since BTC high and low by lunar phase from March 1, 2017 through to March 31, 2018*

Further analysis indicated that BTC's Aroon up [$F_{(7, 388)}$=2.33, r^2=.04] and Aroon down [$F_{(7,388)}$=2.74, r^2=.05] significantly varied over lunar phase over this period.

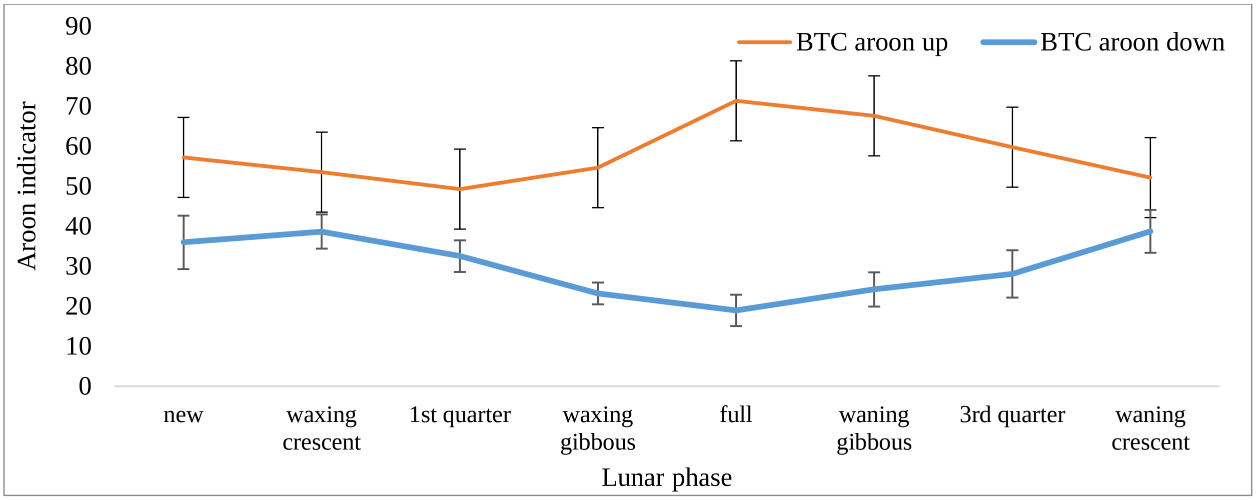

Figure 64 BTC Aroon up and down by lunar phase

ETH's Heiken Ashi pivot point and its market cap

Pearson r and Spearman rho correlational analysis indicated a strong positive correlation between ETH's HA pivot point, and its market cap ($r_{(396)}$=.99, rho=.99). When ETH's market cap and HA pivot point are z-score transformed and plotted over time, the results can be observed below.

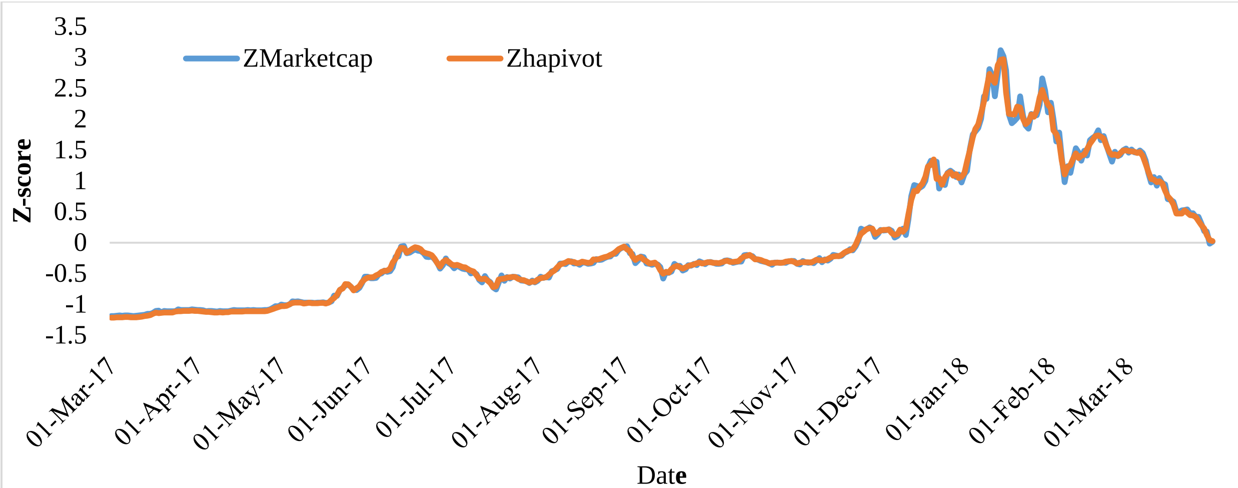

Figure 65 *Z-score transform: ETH's market cap and Heiken Ashi pivot point from March 1st 2017 to March 31st 2018*

Heiken Ashi pivot indicator with environmental features

ETH's HA pivot indicator was entered into Pearson r and spearman rho correlational analysis with solar and with daily features of the Earth's magnetic field. The results indicate that ETH's HA pivot indicator was positively correlated with the horizontal ($r_{(396)}$=.45, $rho_{(396)}$=.42) and North component intensity of the Earth's magnetic field, and was negatively correlated with the daily solar flare average ($r_{(396)}$=-.28, $rho_{(396)}$=-.28), the overall intensity of the Earth's magnetic field ($r_{(396)}$=-.10, $rho_{(396)}$=-.25), the intensity of the East component ($r_{(396)}$=-.28, $rho_{(396)}$=-.36), and the intensity of the orthogonal component ($r_{(396)}$=-.36, $rho_{(396)}$=-.54) of the Earth's magnetic field.

Heiken Ashi 7- and 21-day moving average by solar activity cluster classifications

Seven and twenty-one-day moving averages were calculated for ETH's HA pivot signal and a HA pivot buy signal was calculated by comparing these moving averages. If the 7-day HA moving average was greater than the 21-day HA moving average then the pivot indicator was coded as a buy signal, if the 21-day HA MA was greater than the 7-day HA Moving Average then the HA pivot was coded as a sell indication. When the recoded HA pivot cluster classifications are entered into chi-square analysis with solar active or quiet days a significant relationship was observed [$\chi^2_{(1)}$=5.6, tau=.014 p=.012], the results of which can be observed in the table below.

Table 48 Chi-square results: Heiken Ashi moving average buy/sell signal cluster classifications by solar quiet and active days

		Heiken Ashi buy/sell signal		Total
		sell	buy	
Daily solar flare	none	61	79	140
	%	15%	20%	35%
	1+	81	175	256
	%	20%	44%	65%
Total		142	254	396
%		36%	64%	100%

ETH popularity clusters and its market features

Pearson and Spearman rho correlations between ETH's popularity and its market features ranged from .14-.40. The 396 days of ETH popularity collected via Google trends however, were clustered into popular or unpopular days, dependent upon on whether the day's popularity value (/100) was above or below 50. ETH's market features were then z-score transformed, and found to systemically vary by its popularity clusters. There was less ETH market movement during unpopular days and enhanced ETH market behavior during popular days.

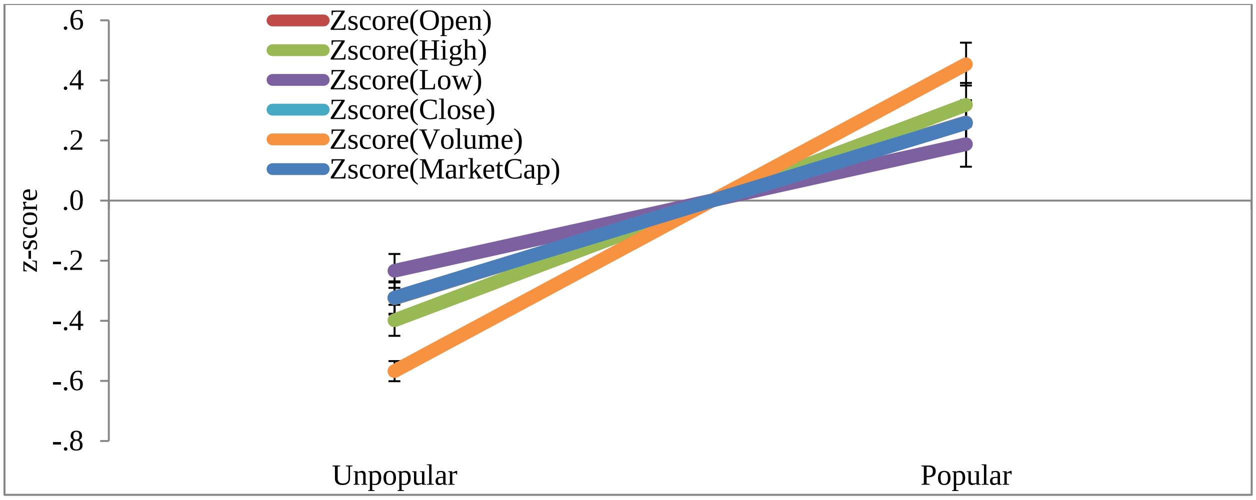

Figure 66 Z-score transform: ETH's market features by ETH's popularity clusters

ETH popularity lunar phase, solar activity, and Earth EMF overall intensity

ETH popularity clusters were entered into a series of cross-tab analyses with environmental signals, including lunar, solar and geomagnetic considerations. Lunar phase and solar active or quiet days were used for models associated with the Moon and Sun. The overall intensity of the Earth's geomagnetic field was manually clustered into quartiles dependent upon the overall intensity measured. The data indicates that ETH popularity cluster classifications were significantly different from random by lunar phase [$\chi^2_{(7)}$=22.99, λ=.10, p=.009], quiet (N=0) or active (N>0) solar disturbance [$\chi^2_{(1)}$=3.45, λ=.01, p=.04], and by EMF overall intensity quartiles [$\chi^2_{(3)}$=34.07, λ=.10, p<.001].

Table 49 in proportional ETH popularity clusters by lunar phase, solar active/quiet days, and by the Earths EMF overall intensity quartile clusters

		ETH Popularity		Total
		↓	↑	
Lunar phase	new moon	13	24	37
	%	3%	6%	9%
	waxing crescent	31	30	61
	%	8%	8%	15%
	1st quarter	28	16	44
	%	7%	4%	11%
	waxing gibbous	36	26	62
	%	9%	7%	16%
	full moon	23	17	40
	%	6%	4%	10%
	waning gibbous	16	39	55
	%	4%	10%	14%
	3rd quarter	12	28	40
	%	3%	7%	10%
	waning crescent	17	40	57
	%	4%	10%	14%
Total		176	220	396
%		44%	56%	100%

		ETH Popularity		Total
		↓	↑	
Sunspot	0	71	69	140
	%	18%	17%	35%
	1+	105	151	256
	%	27%	38%	65%
Total		176	220	396
%		44%	56%	100%

		ETH Popularity		Total
		↓	↑	
Overall intensity of the Earth's magnetic field	<48,000nT	50	42	92
	%	13%	11%	23%
	48,000nT-49,000nT	46	74	120
	%	12%	19%	30%
	49,000nT-50,000nT	22	70	92
	%	6%	18%	23%
	50,000nT+	58	34	92
	%	15%	9%	23%
Total		176	220	396
%		44%	56%	100%

ETH popularity cluster classifications by H Component Intensity cluster classifications

H component intensity clusters were found to demonstrate a significant interaction with daily ETH search frequency on Google [$x^2_{(1)}$=11.69, tau=.03, p<.001]. The results indicate that ETH searches were less frequent during low H component intensity (44.7%) and more frequent (62.3%) during increased horizontal intensity.

Table 50 ETH popularity cluster by H component Intensity cluster classifications

		ETH search frequency		Total
		Low	High	
H component intensity	Low	84	68	152
	%	21%	17%	38%
	High	92	152	244
	%	23%	38%	62%
Total		176	220	396
%		44%	56%	100%

Horizontal component Intensity cluster classifications by solar active or quiet days

The average aggregate intensity of the H component over this period was 25,151.54 gamma (nT). This data was split into high or low H component intensity, dependent upon whether the daily aggregate H component intensity was above or below this mean. Daily sunspot activity was recoded into solar quiet or active days' dependent upon whether or not any Sunspots were observed. Cross-tab analysis exploring Sunspot activity by the aforementioned horizontal intensity clusters revealed a significant relationship [$x^2_{(1)}$=7.58, tau=.019, p=.004], as can be observed below.

Table 51 H component Intensity cluster classifications by solar active or quiet days

		Sunspot activity		Total
		No	Yes	
H component Intensity	Low	41	111	152
	%	10%	28%	38%
	High	99	145	244
	%	25%	37%	62%
Total		140	256	396
%		35%	65%	100%

ETH popularity, Solar Disturbance and the overall intensity of The Earth's electromagnetic field

Measures of (1) ETH popularity, (2) solar disturbance, and (3) EMF overall intensity [$F=\sqrt{X^2+Y^2+Z^2}$] were entered into a partial correlational three-way within SPSS. Initial correlations indicate that ETH popularity was positively correlated with solar disturbance [$r_{(394)}=.17$, $p=.001$] and EMF overall intensity [$r_{(394)}=.11$, $p=.034$]. Partial correlational analysis revealed that the correlation between ETH popularity and EMF overall intensity was no longer significant when controlling for solar disturbance [$r_{(393)}=.07$, $p=.145$]. Furthermore, the correlation between ETH popularity and solar disturbance was still significant when controlling for EMF overall intensity [$r_{(394)}=.15$, $p=.004$].

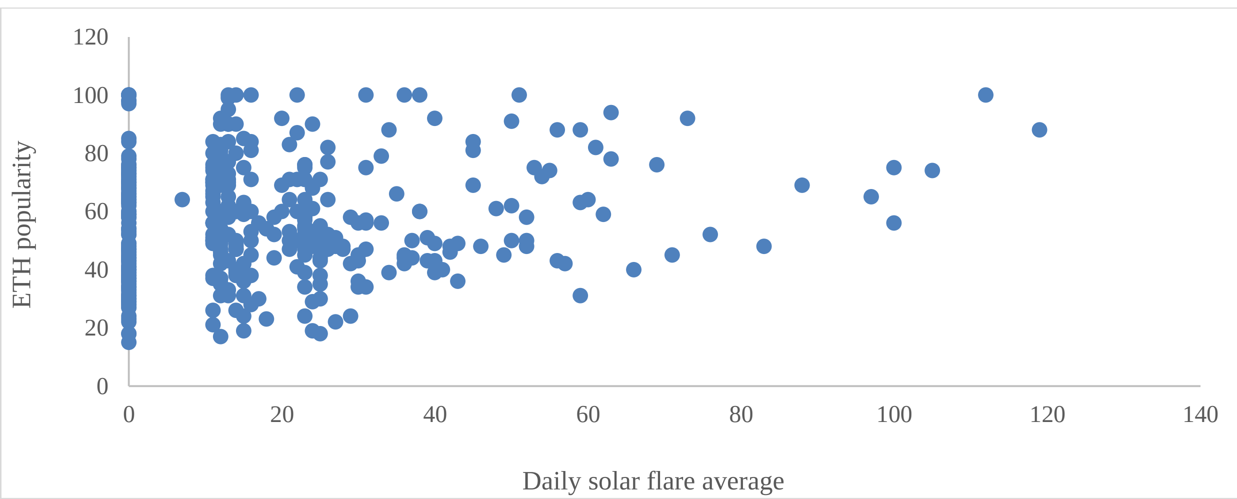

Figure 67 Correlational results: daily solar flare average with ETH popularity

ETH popularity by daily solar flare activity from waxing gibbous to the Full moon

Correlational analysis between ETH popularity and daily solar flare activity within split file by Moon phase revealed that certain lunar orientations enhanced the relationship between ETH popularity and solar flare activity. In specific, the relationship between ETH popularity and solar disturbance was most robust from waxing gibbous [$r_{(62)}$=.40, rho=.25, p=.006] through to the full moon [$r_{(40)}$=.43, rho=.38, p=.001] lunar phase.

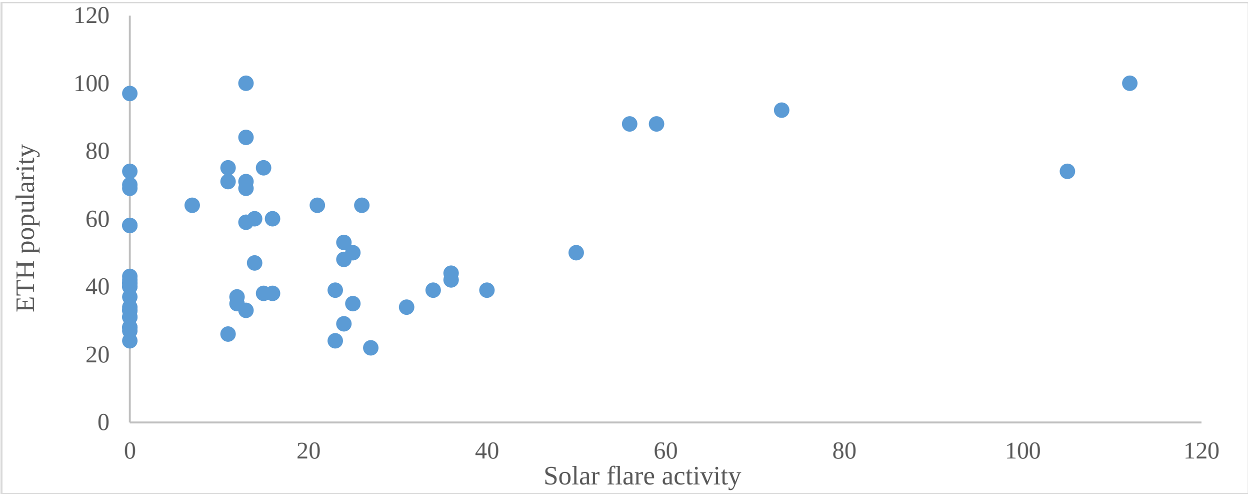

Figure 68 Correlational analysis: daily solar flare average with ETH popularity during the waxing gibbous lunar phase

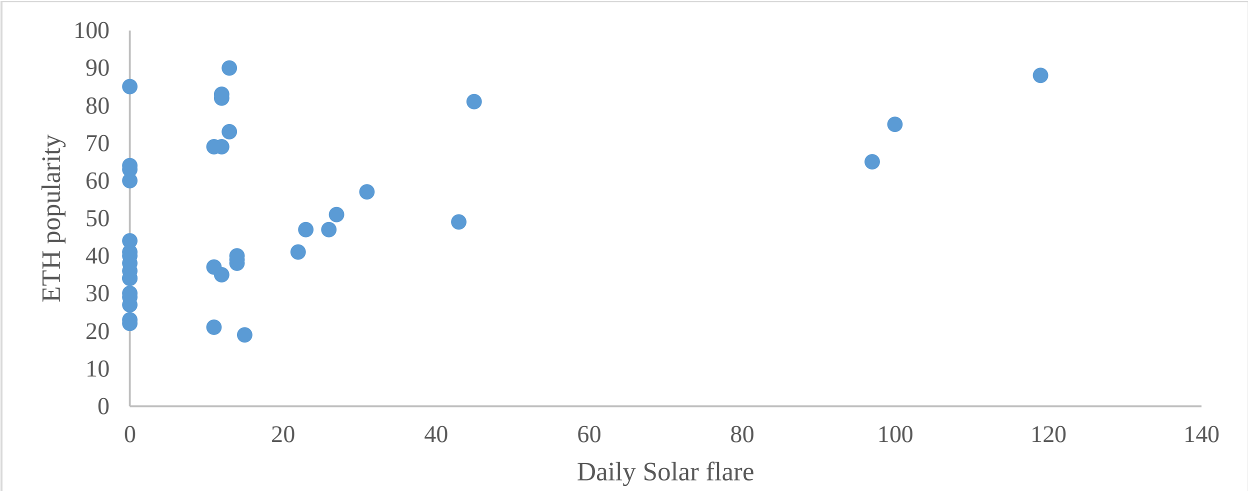

Figure 69 Correlational analysis: daily solar flare average with ETH popularity during the full moon lunar phase

Interaction between ETH popularity and solar activity during the waxing and Waning Gibbous Moon

Split file by lunar phase indicated that the relationship between solar active or quiet days with ETH's popularity clusters was specifically significant during waxing [$\chi^2_{(1)}$=8.12, tau=.15 p=.004] and waning [$\chi^2_{(1)}$=9.02, tau=.19 p=.003] gibbous lunar phases.

Table 52 ETH popularity cluster classifications by solar active and quiet days during waxing gibbous and waning gibbous lunar phases

			ETH Popularity		Total
			No	Yes	
waxing gibbous	Solar flare	0	15	2	17
		%	28%	4%	32%
		1+	17	19	36
		%	32%	36%	68%
	Total		32	21	53
	%		60%	40%	100%
waning gibbous	Solar flare	0	12	9	21
		%	26%	19%	45%
		1+	4	22	26
		%	9%	47%	55%
	Total		16	31	47
	%		34%	66%	100%
Total	Solar flare	0	71	69	140
		%	18%	17%	35%
		1+	105	151	256
		%	27%	38%	65%
	Total		176	220	396
	%		44%	56%	100%

ETH popularity, the overall intensity of the Earth's magnetic field and daily solar flares by lunar phase

Means and standard error of the means of ETH popularity, overall intensity of the Earth's magnetic field and daily solar flare averages by lunar phase can be observed in the table below.

Table 53 Earth's magnetic field overall intensity, daily solar flare activity and Ethereum popularity by lunar phase

		EMF Overall Intensity [$F=\sqrt{X^2+Y^2+Z^2}$]		Daily Solar Flare average		ETH popularity	
		μ	SEM	μ	SEM	μ	SEM
Lunar phase	New moon	48956.34	335.59	21.42	3.68	60.48	3.35
	waxing crescent	48932.93	263.22	24.02	2.77	55.35	2.19
	1st quarter	49074.27	290.79	24.16	3.70	49.45	2.83
	waxing gibbous	48997.53	255.38	20.06	3.37	50.66	2.88
	Full moon	49056.74	312.68	18.91	5.02	47.46	3.35
	waning gibbous	49120.62	244.33	14.77	3.02	60.13	3.29
	3rd quarter	49031.21	320.98	14.74	1.88	58.91	3.78
	waning crescent	48911.12	284.47	17.98	2.49	61.91	2.84

ETH Popularity by lunar phase

One-way analysis of variance was conducted within SPSS with regard to data collected from March, 2017 through March, 2018 exploring daily ETH Google Search frequency by Moon phase. The data indicates significant differences in ETH popularity by lunar phase [$F_{(7,329)}$=3.32, r^2=.07, p=.002], with peak popularity observed during waning gibbous through to the new moon, and declining interest observed from 1st quarter phase to the full moon.

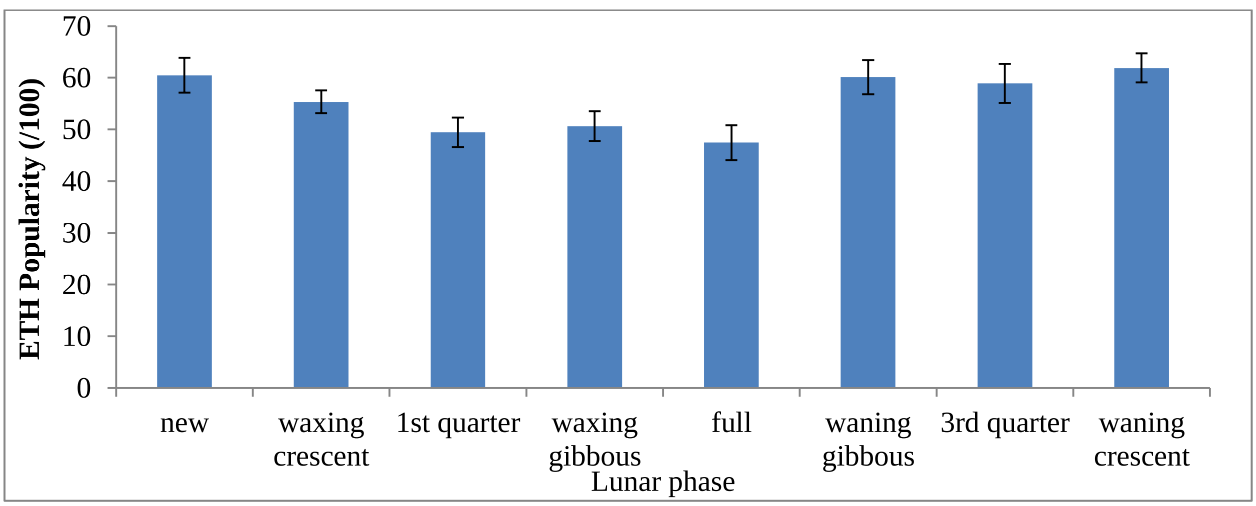

Figure 70 ETH Popularity from March, 2017-March, 2018 by lunar phase

ETH popularity solar activity and Overall intensity of Earth's EMF by lunar phase

Daily EMF, Solar, and ETH popularity values were z-score transformed and entered into a series of individual one-way ANOVA's. The results indicate that all three signals varied significantly by lunar phase, with the EMF maximum significantly amplified during the full moon phase, in contrast to solar activity and ETH popularity scores. The Figure below demonstrates why ETH popularity is correlated EMF and solar contributions, but also why solar activity nullifies the EMF/ETH relationship within partial correlational analysis.

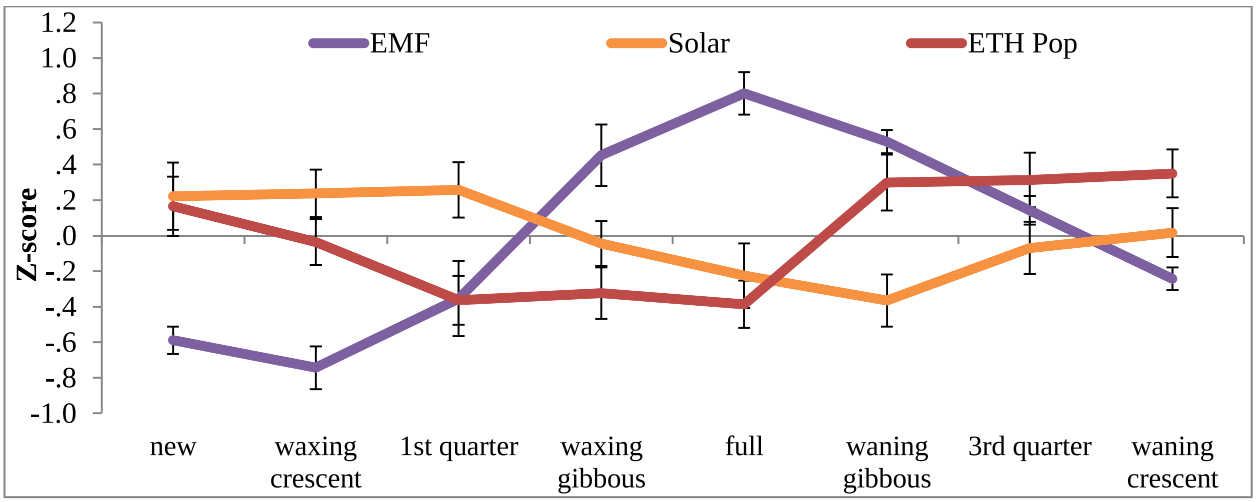

Figure 71 Z-score transform: ETH popularity, EMF overall intensity, and sunspot activity by lunar phase

Summary

ETH and BTC's price were found to be predicted by intrinsic blockchain characteristics, traditional market indicators, and environmental considerations. Not only were blockchain characteristics able to predict price movement, but they were susceptible to environmental influence. Furthermore, predictive models were extracted from traditional price indicators, and these measures also significantly interacted with background meteorological processes. Aggregate global search interest for ETH during its 2017 bull run also mirrored market features and demonstrated departures from random during geomagnetic, solar and lunar variation. These results indicate that variations in cryptocurrency price may be linked to aggregate human behavior which is subtly influenced by meteorological factors.

Discussion

The data indicates that ETH and BTC price action was predicted by numerous independent variables analyzed. Intrinsic blockchain characteristics such as payment count strongly associated with cryptocurrency market movement. Cryptocurrency characteristics such as daily fee count cycled with lunar phase. Traditional indicators were able to track prices consistently, and were even predicted by meteorological events. Non-random patterns in global aggregate search frequencies for ETH under certain biometeorological conditions suggest a direct link between the environment and human behavior

Cryptocurrency as a payment network

A BTC transaction can aggregate thousands of individual economic transfers, and therefore may represent a batched transaction, which has three or more outputs (recipient wallets of payment). It has been demonstrated by *coinmetrics.io*, that batched transactions accounted for only 12% of all transactions on the BTC blockchain between November 2017 and May 2018, however, due to batch adoption amongst major cryptocurrency exchanges, these batched transactions moved between 30-60% of all BTC during this period. It was concluded that ‘transaction count’ has become an unreliable measure of BTC usage due to batching, and therefore the default measure of BTC’s performance should be “payments per day”, which would standardize its ability to transmit economic value across a network of users as a worldwide payment system.

The finding that payments per day were the most accurate predictor of ETH's market cap supports the abovementioned hypothesis. ETH's daily payments closely tracked its market cap through 2014-2017 which was one of the greatest bull events in economic history wherein ETH price grew over 13,000% (Bhosale, Mavale, 2018). Daily payment also followed declining prices during the 'crypto-winter' of 2018. This indicates a direct link between the number of users and price fluctuation.

Average True Range

ETH's Average True Range (ATR) was able to track its market movement closely. This relationship persisted when partial correlations with time were considered. Average True Range 14-day moving averages for ETH were subsequently found to be associated with geomagnetic and solar conditions. Predictive models indicated that specific features including increased horizontal intensity of the Earth's magnetic field decreased solar flare activity and decreased Y component intensity explained over 23% of the variance in ETH's 14-day ATR moving average. This model was consistent in split file analysis as it predicted ETH's ATR moving average in 11 of 13 months with effect sizes ranging from .14 to .99. It was also applicable during lunar transit, and was able to accommodate between 58-89% of the variance during all 8 phases of the Moon, with the strongest predictive capacities observed from the new moon to the 1st quarter lunar phase, wherein between 83-89% of the variance was explained. Predictive models were also related to variations in solar activity; however they were strongest during quiet solar activity when solar flares were absent.

BTC Average True Range and Aroon up and down

BTC's ATR was also able to accommodate a significant amount of variance in its market cap, explaining 88% of the variance in its price action. BTC's Aroon up and down was found to significantly vary by lunar phase and consistently provided a buy signal between the 1st to the 3rd quarter lunar phases from March 2017 through March 2018. This data suggests that trends develop in BTCs market movement in relation to that of lunar cycles.

Heiken Ashi (HA)

The Heiken Ashi (HA) indicator was also a strong predictor of daily price movement as the HA pivot was strongly associated with ETH's market cap. This is important, as ETH's HA pivot indicator was positively associated with the horizontal intensity of the Earth's geomagnetic field. The ETH HA pivot was also negatively associated with environmental features including solar flare activity, the east-west and orthogonal components of the Earth's magnetic field, and its overall intensity. When the buy and sell signals obtained from the 7 and 21 day HA moving averages were analysed, the results indicated that 44% of days within the investigation that provided a buy signal were marked by solar flare activity, whereas only 15% of days that provided a sell signal had no solar flare activity. This suggests that ETH's price action responded to extraterrestrial influence.

ETH popularity

Online search frequency for ETH on Google trends turned out to be a weak to moderate predictor of price action. When ETH popularity was categorized as popular or unpopular, however, the results indicate that these cluster classifications reliably distinguished between high and low market fluctuation. This interaction is of interest because ETH popularity clusters were found to have a relationship with lunar, solar, and geomagnetic conditions.

Solar and EMF contributions

ETH popularity was associated with natural background phenomena such as solar flares and the Earth's geomagnetic field. Sixty-nine percent of popular search days occurred during a day that experienced solar flare activity. Fifty-two percent of days with high interest in ETH occurred at moderate geomagnetic intensities between 48,000-50,000nT, while 61% of unpopular occurred at extreme intensities above and below this threshold. Sixty-nine percent of popular days occurred during increased horizontal component intensity. This component is the most sensitive to solar projections and it was observed that 37% of days experienced increases in both solar and horizontal intensity, while only 10% of days displayed decreases in both phenomena. Partial correlational analysis indicated that it was solar flare activity which was the main correlate of online interest in ETH. The solar influence on global aggregate interest in ETH was enhanced during either gibbous moon: 66% of days during the waning gibbous moon resulted in increased ETH popularity; 71% of which corresponded with increased solar activity.

Solar activity and the Horizontal component of the Earth's magnetic field

Sunspots affect Earth through solar wind; a stream of charged particles which interacts with the Earth's magnetosphere. Such interactions primarily affect the North/South, and East/West components of the geomagnetic field, and are reflected in variations in intensity of the horizontal component at the onset of magnetic storms at mid/low latitudes. These interactions may explain the close association of solar and EMF contributions to cryptocurrency interest

Lunar cycle and The Efficient Markets Hypothesis

The efficient markets hypothesis (EMH) is a rational, efficient-markets principle, which maintains that market prices fully reflect all available data and leaves no room for behavioral and physiological influences in the movements of stock market prices (Lo, 2007). Lunar influences on price volatility, however, would not be a violation of the EMH, but would demonstrate the presence of non-informational, behavioral influences (Herbst, 2007). The systemic differences in ETH daily fees and popularity by lunar phase partially supports findings by Dichev and Janes

(2003) who found strong lunar cycle effects in stock returns, specifically that stock returns are double 15 days surrounding the new moon, then they are 15 days surrounding the full moon. It was reported that this effect was present for nearly all major stock indexes over the last century and for nearly all major stock indexes of 24 other countries over the last 30 years.

Lunar contributions to ETH popularity

Lunar contributions to discrepancies in ETH popularity include the findings that 64% of days during the 1st quarter moon were associated with reduced ETH interest, while 71% of waning gibbous and crescent lunar phase days showed an increase in ETH search frequency. The moon phase was also associated with the effect of solar activity on ETH popularity as it was observed that 88% of days during the waxing gibbous phase that did not experience solar activity also resulted in decreased ETH popularity.

Daily fees and the lunar cycle

It has been postulated that the implementation of transaction fees in cryptocurrency blockchain networks is a crucial step in evolving to a more market-based system that can adapt to changing economic conditions. Without network fees the BTC blockchain would not be viable since the limited number of coins available to be mined requires an alternate incentive for miners to validate transactions (Easley et al., 2019). In ETH, network users pay a variable amount of Ether called 'gas' to the network which provides profit for miners who validate transactions. A higher daily fee count implies more users who are transacting on the network, which require validation from the miners (Wood, 2014).

ETH's daily fees were found to vary systemically with the lunar cycle during its great bull run at the conclusion of the 2017. The results indicated reduced transaction fees from the first quarter phase to the full moon lunar phase, with increased daily fees during waning lunar conditions. This suggests an indirect link between ETH's blockchain features and the environment which could be modulated by possible lunar effects on the psychology of the users within the global network.

Summary

Cryptocurrency is a novel phenomenon that is relatively responsive to a host of predictive models based on its intrinsic organization, its global nature, traditional indicators and even environmental considerations. Intrinsic blockchain characteristics are able to predict cryptocurrency market behavior, and were also associated with background environmental considerations. Market indicators which removed noise within economic signals such as market cap also fluctuated according to meteorological variations. Finally, aggregate group behavior such as search frequency interest in ETH was found to vary systematically with price and environmental conditions. This type of knowledge may reduce the speculation involved and promote a better understanding of this relatively new market. Future research should build on these models in order to quantify the dynamics that influence human activity measurable in collective behaviors such as participation in global networks, and in trading economic signals with each other on the IoT.

Future research

It has been postulated that blockchain-specific information would be the primary components that predict cryptocurrency price movement (Kim et al., 2019), however the persistent environmental components identified here need further verification and acceptance in addition to mainstream adoption in order to truly understand the dynamic implicates associated with the movement of cryptocurrency price. Machine learning techniques have also been applied – insofar as- research has accommodated a cryptocurrency index with machine learning algorithms (Chowdhury et al., 2019). Future research should sharpen and develop the techniques used in these analysis by young thinkers and paradigm shifters in order to maximize mass economic returns.

Conclusion

Biometeorological effects on human behavior are extensive and evident within multiple facets of various human activities such as Traumatic Brain Injury (TBI) acquisition in professional football, and during aggregate participation in traditional and digital finance. Numerous environmental factors can directly influence the physiology of humans, possibly affecting the nervous system and manifesting as susceptibility or anomalous psychological states measureable in global aggregate group behaviors. This data can be used to identify the potential preconditions of the neurometabolic cascade following a concussion, and the environmental conditions which enhance or inhibit it.

Traditional considerations

Phenomena intrinsically associated with the NFL and global digital currency market did appear to have a significant impact on injury acquisition and interest in cryptocurrency. For example, competitive considerations influenced systemic variation in injury rates and severity. For example, injury severity was greater during losses and away games, and was reduced during wins and home game. Furthermore, over the course of the investigation league wide passing plays increased, which may have made positions such as cornerbacks more susceptible, since they cover the wide receivers that catch the ball during passing plays.

Attributes associated with players' profile also exhibited different responses to injury. For example, players who exhibited different body mass characteristics experienced different injury severity levels, with bigger players actually obtaining more severe injuries in comparison to smaller players. Increased athletic exposure was another prominent factor in TBI acquisition, as the number of years playing professional football was the most prominent career related statistic that accommodated head trauma history. With regard to global interest in cryptocurrency, factors such as the number of daily payments on the network were strong predictors of cryptocurrency price. Traditional market indicators also predicted price action, but were found to vary together with natural background signals such as solar geomagnetic and lunar contributions. This suggests that some market patterns could be attributable to the influence of the environment on the humans whose aggregate behavior creates the markets.

Spatial considerations

Variation in the Earth's geomagnetic field may be a factor in spatial clustering and temporal sequences of TBI ratio, insofar as ratios and injury severity was enhanced in the Northwest, and reduced in the Southeast. Among the candidates that might be responsible for this effect are weather related factors such as temperature, humidity and winds. The Northwest coast, along the storm track, is associated with enhanced cognitive capacities, which has been attributed to the region's meteorological instability. Major cities within the U.S. and worldwide which demonstrated the most interest in cryptocurrency during its massive bull run of 2017, were found to display unique geomagnetic tendencies, that changed as a function of latitude and longitude.

Earth's geomagnetic field

Increased intensity of the Earth's geomagnetic field was not only associated with increased TBI severity but was also found to correspond with global aggregate behaviors, which suggests that it could influence decision making and emotional states by interacting with the nervous system. Geomagnetic activity may also be a factor in the spatial clustering of brain injuries since overall geomagnetic intensity changed as a function of latitude and longitudinal considerations. Interest in cryptocurrency was found to correspond positively with moderate global geomagnetic intensities, while unpopular days occurred during extremes of variation in geomagnetic intensity. This is in accordance with research that has indicated that geomagnetic activity exerts a negative influence on returns from the US stock market. In specific, a causal relationship was found between monthly based geomagnetic indices with the S&P 500 over a 20 year period. This study specifically controlled for SAD and therefore it was concluded that this effect was not the cause of semi-annual variation of geomagnetic activity (Peng et al., 2019). Increased intensity of the horizontal component corresponded with enhanced global interest in Ethereum; however horizontal intensity is the component of the geomagnetic field most responsive to solar flare activity. Importantly, the influence of solar activity on economic popularity and injury acquisition was found to be altered during the lunar cycle.

Lunar phase

Lunar phase contributed to increased TBI severity, specifically when the Moon was positioned closer to the Earth, and when the Moon was leading the Sun from an earthbound observer. TBI acquisition at the beginning of the lunar cycle, specifically during the new moon, was most frequent in Eastern and Western regions within the U.S. which suggests that this Moon influences human behavior more as a function of longitude then it does latitude. Injuries during the new moon were also most prevalent during the September lunar phase. The highest proportion of waxing crescent lunar phase TBI's occurred in the Northeast. A majority of TBI's during the 1st quarter lunar phase occurred within Northern and Southern regions, suggesting that lunar influence might have been predominantly a function of latitude during this phase. During the 1st quarter moon there was a reduced interest in cryptocurrency, as well as a significant reduction in transaction fees, which is a function of network usage as a method of global payments. Greater TBI severity occurred on the Northeast coast during waxing gibbous Moon and a majority of TBI's occurred from November to December during the most meteorologically unstable months of the year: the transition from fall to winter.

Full moon ratios were consistent across the U.S.; however, measures of TBI player height, weight and injury severity were predicted by increased solar and geomagnetic activity during injury which suggests a link between human behaviors and celestial alignment. Mass of players who acquired an injury was predicted by increased inclination and horizontal intensity associated with the Earth's geomagnetic intensity. These models were enhanced in Southern latitudes, and at lower altitudes suggesting spatial and temporal effects on human behavior. TBI player height was accommodated during the full moon by increased change in the orthogonal and East-West component of the field. Models predicting injured player's height were consistent in all four cardinal directions as well as at low altitude. Injury severity was associated with increased solar activity during this period, which was enhanced in the Southeast and at higher altitude.

TBI rates during waning lunar conditions were highest during the December Moon, and a majority of the injuries were severe. Waning lunar conditions also resulted in increased interest in cryptocurrency, suggesting this Moon may influence emotionality in humans. TBI's during the last quarter lunar phase were found to be more severe for smaller players, while bigger players were more affected during the waning crescent phase. These discrepancies in injury rates and severity throughout the duration of the lunar cycle, along with systemic variation in global interest in cryptocurrency indicate that exploring human behavior by lunar transit can be revealing. It may identify cyclical patterns of behavior that synchronize with environmental background phenomena, which may affect psychological states.

Solar and geomagnetic variation by lunar phase

The impact of solar activity has been demonstrated to impact economic activity. In specific, research has examined its effects on economic activity from 1996-2014. It was found that the solar disturbance storm index (Dst) had causal predictive ability in forecasting US telecommunications output at specific lags, which confirmed the impact of solar activity on US telecommunications (Daglis et al., 2019). Solar activity also cycles closely with the Moon, such that in 1612 Galileo discovered that the Sun has a differential rotation on its axis which varies according to latitude in 25 day cycles at the equator, 28 days at latitude of 40 degrees, and in 36 day cycles at latitudes of 80 degrees. This underscores the importance of taking an interdisciplinary approach to understanding natural phenomena. Enhanced solar activity prior to the new moon actually reduced injury severity during TBI acquisition, while the 3rd quarter lunar phase experienced systemic decreases in solar activity. A majority of TBI's occurred during the gibbous moon, specifically during solar quiet conditions. When enhanced solar activity was observed during the gibbous moon however, increased interest in cryptocurrency was observed. A reduction in solar activity during the waxing gibbous moon was associated with declining interest in Ethereum. The Earth's magnetic field also significantly varied by lunar phase displaying highest intensities during the full moon, and reduced intensities from the waning to waxing crescent phases.

Summary

The complex interaction between celestial bodies such as the Earth, Moon, and Sun during specific economic and sporting events and the diverse behaviors associated with it emphasizes the importance of an interdisciplinary approach to understanding human behavior.

These data suggest that on any given NFL Sunday, a concussion will occur, but certain player profiles are more susceptible to TBI acquisition than others. A cornerback who is bigger than average, playing in Green Bay on the frozen surface of Lambeau Field on a cold, damp December night is more likely to be seriously injured if concussed. A player with a high level of input in game flow such as a center, or one in an offensively skilled position such as a quarterback playing on a dry Sunny afternoon in Carolina, might escape injury entirely.

This study was limited to diagnosed concussions in the NFL. Many injuries may have gone unspotted or undiagnosed. The National Football League promotes a gladiator mentality that is glorified in sports media. Football is not a ‘contact’ sport, but rather a collision sport; and the amount of athletic exposure over the duration of an individual’s participation in it may be a significant predictor of chronic neurodegenerative disease.

The relative cost associated with BTC and other cryptocurrencies have been considered the primary determinates of price. The drivers in the cryptocurrency market however are the level of competition in the network of producers, which may very well be stimulated by meteorological variation. A biometeorological influence on humans during participation in the cryptocurrency market was apparent. If the twenty-four hour a day exchange of economic signal across a global network of users is influenced by cyclical and varying background meteorological conditions it is important to further quantify the relationship between mass psychological states and fields naturally produced by our planet or the phases of its natural satellite.

Chapter 5 - General Conclusion

Biometeorological effects on human behavior are extensive and evident within multiple facets of various human activities such as Traumatic Brain Injury (TBI) acquisition in professional football, and during aggregate participation in traditional and digital finance. Numerous environmental factors can directly influence the physiology of humans, possibly affecting the nervous system and manifesting as susceptibility or anomalous psychological states measureable in global aggregate group behaviors. This data can be used to identify the potential preconditions of the neurometabolic cascade following a concussion, and the environmental conditions which enhance or inhibit it.

Traditional considerations

Current predictive models regarding TBI's have not focused on preventative strategies of TBI acquirement, but rather on adaption after injury. For example, hospital acquired pneumonia has been found to be a predictor of poor global outcomes in severe TBI cases up to five years after discharge from the hospital. Furthermore, studies exploring magnetic resonance spectroscopy (MRS) of children and adolescence 4-6 days post TBI was found to improve prognostic ability and provided valuable information regarding treatment and early intervention planning (Babikian et al., 2006). Other research attempted to predict postinjury fitness regarding returning to safe driving after TBI acquirement. The results indicated that about 50% of the patients continued driving after the TBI, and those who did were found to have shorter coma durations then those who did not. Safe driving was found to be predicted by the number of years post injury, violations and accidents pre-injury, as well as pre-TBI-risky-personality-index and pre-TBI-risky-driving-style-index scores (Pietrapiana et al., 2005). A subsequent study sought to explore the relationship between employment status' 1-3 years following TBI acquirement with age, education, preinjury productivity (PIP), Glasgow Coma Scale scores, in addition to a functional rating score at admission and discharge from rehabilitation. The results indicated that education, admission and discharge functional rating scores and preinjury productivity all significantly correlated with follow-up employment status (Gollaher et al., 1997). Other research has focused on investigating performance of International Mission on Prognosis and Analysis of Clinical Trials (IMPACT) as a prognostic tool for predicting the outcome measure of 14-day mortality rates in TBI patients. The results indicated that the 14-day mortality rate was 23% and displayed excellent calibration, such that it was concluded that the model validly predicted 14-day mortality within the analysis (Roozenbeek et al., 2012). Similar research has attempted to create outcome prediction models in a prospective cohort study of 147 patients aged 16-65 years of age who sustained a mild TBI using magnetic resonance imaging (MRI) 4 weeks after TBI acquirement. Other dependent variables collected were demographics, global functioning levels, post-concussion symptoms and mental health. The results indicated that there was a strong correlation between observed and predicted outcomes for the clinical model with a Pearson r value of .55. MRI predictive equations performed at chance expectations, and the combined model was less predictive then the clinical model in-and-of-itself. The authors concluded that there was no added predictive value of MRI based measures of cortical activity or subcortical volume that were more sufficient then demographics and clinical features (Hellstrom et al., 2017). Federally funded research has begun to attempt to prevent or at least reduce TBI severity through increasing the viscosity of cerebrospinal fluid (CSF) which is a fluid that surrounds the brain and protects it from impact. The method includes the preparation of medically effective treatments in addition to the administration of an apparatus in the form of a helmet that reduces the temperature of the head however this intervention has only just begun the patent application process (Johnson, 2019).

Preventative measures are of extreme importance insofar as neuroinflammation is a well-known contributor to secondary injuries after a TBI has occurred and is initiated by neuronal permeability. Furthermore, active up-regulation of synthesis and release of various molecules drive immune cell reactivity. It is well known that tumor necrosis factor alpha (TNF), interleukin 6, and interleukin-1beta are major contributors to neuroinflammation, while interleukin-10 acts as an anti-inflammatory molecule (Wofford et al., 2019).

Phenomena intrinsically associated with the NFL and global digital currency market did appear to have a significant impact on injury acquisition and interest in cryptocurrency. For example, competitive considerations influenced systemic variation in injury rates and severity. For example, injury severity was greater during losses and away games, and was reduced during wins and home game. Furthermore, over the course of the investigation league wide passing plays increased, which may have made positions such as cornerbacks more susceptible, since they cover the wide receivers that catch the ball during passing plays.

Attributes associated with players' profile also exhibited different responses to injury. For example, players who exhibited different body mass characteristics experienced different injury severity levels, with bigger players actually obtaining more severe injuries in comparison to smaller players. Increased athletic exposure was another prominent factor in TBI acquisition, as the number of years playing professional football was the most prominent career related statistic that accommodated head trauma history. With regard to global interest in cryptocurrency, factors such as the number of daily payments on the network were strong predictors of cryptocurrency price. Traditional market indicators also predicted price action, but were found to vary together with natural background signals such as solar geomagnetic and lunar contributions. This suggests that some market patterns could be attributable to the influence of the environment on the humans whose aggregate behavior creates the markets. Meteorological factors could also affect intrinsic human attributes associated with behavioral finance, which is the integration of classical economics with psychology and decision making. It attempts to understand the causes of exceptions to the rules in the financial literature, and can be considered the study of how investors systemically make mental mistakes. The components of this theory are threefold; snake bites, mental accounting and keeping distant from remorse or regret. Behavioral factors of this theory include; anchors, stereotyping, overconfidence, availability heuristics and gamblers fallacies.

Other components of behavioral finance include: Loss aversion, endowment bias, affinity bias, anchoring and adjustment bias, outcome bias, mental accounting bias, snake bite bias, illusion of control, availability bias, self-attribution bias, recency bias, cognitive dissonance, self-control bias, confirmation bias, hindsight bias, representativeness heuristic, overconfidence, paradox of choice, regret aversion bias, unit bias, information bias, bandwagon effect, disposition effect, familiarity bias, restrain bias, survivorship bias. These are just some of the attributes that affect our thinking and it's the more likely the interconnectedness and interactions between these factors that influence behavior.

Loss aversion

Studies indicate that choice is dependent upon the status quo or changes in comparison to a previous reference level, wherein reversals in preference can occur such as loss aversion (Tversky & Kahneman, 2005). Furthermore, individuals usually experience greater emotion to losses then to gains of the equivalent amount, research indicates that a broad set of cortical regions showed increased neuronal firing as potential gains increased, specifically within midbrain's dopaminergic response as well as the efferent pathways (Tom et al., 2008). Time series analysis of individual stock returns indicated that stocks like digital currencies can have high means, and excess volatility. Cross section analysis on the other hand indicates that there is a substantial premium in the value, wherein stocks with lower price ratios in relation to fundamentals typically have higher returns on average (Barberis & Huang, 2001). Investigations into the boundaries of loss aversion found that if exchanged goods are given up as intended, people do not experience loss aversion (Novemsky & Kahneman, 2005).

Anchoring and adjustment bias

With regard to anchoring and adjustment bias traders often anchor at previously supports or resistances even if there is information that suggests that prices could fluctuate beyond these predetermined prices. Decision support systems are designed to lessen the effects of limitations in decision making and have been demonstrated to be successful (George et al., 2000). Anchoring bias has also had an effect on Bitcoins network of users wherein trading decisions were anchored to changes in Bitcoins market cap, suggesting that this heuristic can lead to both negative and positive consequences dependent on investor perception (Lam, 2018).

Outcome bias

Outcome bias refers to people's tendency to focus on the outcome instead of the process. Information can have two effects on evaluation; one on the judged probability of outcomes and on the judged quality of the decision (Baron & Hershey, 1988). Studies indicate that motivated reasoning is a major determinant of when outcomes would bias judgement, such that objective elaboration minimizes outcome bias in accuracy goals, while defensive goals enhance outcome bias through promoting selective processing and outcome-biased judgments which result from impression goals (Agrawal & Mahewaran, 2005).

Mental accounting bias

Mental accounting bias is when people group assets and money into distinct mental accounts, which can lead to excessive risk taking. It can also be thought of as a set of cognitive operations that are used by individuals in order to organize, evaluate, and track economic activity (Thaler, 1999). Studies indicate that people create mental constructs for time and balance their time between work and non-work activities (Rajagopal & Rha, 2009). Personal and situation specific mental models are important for the fact that two people who are presented with the same problematic stimulus might in fact be solving different mental problems. This is to say that a decision problem results in a mental representation of the problem which in turn leads to a judgement and ultimately a decision or choice (Soman, 2004).

Snake bite bias

Snake bite bias refers to when investors suffer huge losses and therefore tend to avoid all risk, and refers to dangers that can threaten investors. Snake bites can be used as a forecasting tool which is considered a dominant behavior of decision making in uncertain contexts (Ghelichi et al., 2016). The snake-bite effect can also be considered a reduction of an investor's position as a result of previous loss, such that a trader who has suffered a loss will likely only open positions with smaller investments or stop trading all together (Keller & Pastusiak, 2016).

Illusion of control

Illusion of control is a dynamic wherein individuals think they control outcomes even when that is not the case. It can be defined as the inappropriate expectancy of personal success when objective probability is not in accordance with those expectations (Langer, 1975). Risk takers that frequent economic markets are likely prone to this effect, responsible risk culture in-and-of-itself includes 3 primary domains: responsibility, flexibility and resilience. Responsibility refers to when decisions are made under uncertain conditions, but includes the risk to admit mistakes post-hoc. Flexibility refers to adaptation to future developments during situations that are far from the equilibrium. Resilience is the capacity to absorb disturbance and maintain function which includes the monitoring of precursors (Milkau, 2017).

Spatial considerations

Variation in the Earth's geomagnetic field may be a factor in spatial clustering and temporal sequences of TBI ratio, insofar as ratios and injury severity was enhanced in the Northwest, and reduced in the Southeast. Among the candidates that might be responsible for this effect are weather related factors such as temperature, humidity and winds. The Northwest coast, along the storm track, is associated with enhanced cognitive capacities, which has been attributed to the region's meteorological instability. Major cities within the U.S. and worldwide which demonstrated the most interest in cryptocurrency during its massive bull run of 2017, were found to display unique geomagnetic tendencies, that changed as a function of latitude and longitude.

Earth's geomagnetic field

Increased intensity of the Earth's geomagnetic field was not only associated with increased TBI severity but was also found to correspond with global aggregate behaviors, which suggests that it could influence decision making and emotional states by interacting with the nervous system. Geomagnetic activity may also be a factor in the spatial clustering of brain injuries since overall geomagnetic intensity changed as a function of latitude and longitudinal considerations. Interest in cryptocurrency was found to correspond positively with moderate global geomagnetic intensities, while unpopular days occurred during extremes of variation in geomagnetic intensity. Increased intensity of the horizontal component corresponded with enhanced global interest in Ethereum; however horizontal intensity is the component of the geomagnetic field most responsive to solar flare activity. Importantly, the influence of solar activity on economic popularity and injury acquisition was found to be altered during the lunar cycle.

Lunar phase

Lunar phase contributed to increased TBI severity, specifically when the Moon was positioned closer to the Earth, and when the Moon was leading the Sun from an earthbound observer. TBI acquisition at the beginning of the lunar cycle, specifically during the new moon, was most frequent in Eastern and Western regions within the U.S. which suggests that this Moon influences human behavior more as a function of longitude then it does latitude. Injuries during the new moon were also most prevalent during the September lunar phase. The highest proportion of waxing crescent lunar phase TBI's occurred in the Northeast. A majority of TBI's during the 1st quarter lunar phase occurred within Northern and Southern regions, suggesting that lunar influence might have been predominantly a function of latitude during this phase. During the 1st quarter moon there was a reduced interest in cryptocurrency, as well as a significant reduction in transaction fees, which is a function of network usage as a method of global payments. Greater TBI severity occurred on the Northeast coast during waxing gibbous moon and a majority of TBI's occurred from November to December during the most meteorologically unstable months of the year: the transition from fall to winter.

Full moon ratios were consistent across the U.S.; however, measures of TBI player height, weight and injury severity were predicted by increased solar and geomagnetic activity during injury which suggests a link between human behaviors and celestial alignment. Mass of players who acquired an injury was predicted by increased inclination and horizontal intensity associated with the Earth's geomagnetic intensity. These models were enhanced in southern latitudes, and at lower altitudes suggesting spatial and temporal effects on human behavior. TBI player height was accommodated during the full moon by increased change in the orthogonal and East-West component of the field. Models predicting injured player's height were consistent in all four cardinal directions as well as at low altitude. Injury severity was associated with increased solar activity during this period, which was enhanced in the Southeast and at higher altitude.

TBI rates during waning lunar conditions were highest during the December Moon, and a majority of the injuries were severe. Waning lunar conditions also resulted in increased interest in cryptocurrency, suggesting this phase may influence emotionality in humans. TBI's during the last quarter lunar phase were found to be more severe for smaller players, while bigger players were more affected during the waning crescent phase. These discrepancies in injury rates and severity throughout the duration of the lunar cycle, along with systemic variation in global interest in cryptocurrency indicate that exploring human behavior by lunar transit can be revealing. It may identify cyclical patterns of behavior that synchronize with environmental background phenomena, which may affect psychological states.

Solar and geomagnetic variation by lunar phase

Solar activity was also found to transition with the lunar cycle, which underscores the importance of taking an interdisciplinary approach to understanding natural phenomena. Enhanced solar activity prior to the new moon actually reduced injury severity during TBI acquisition, while the 3rd quarter lunar phase experienced systemic decreases in solar activity. A majority of TBI's occurred during the gibbous moon, specifically during quiet solar conditions. When enhanced solar activity was observed during the gibbous moon however, increased interest in cryptocurrency was observed. A reduction in solar activity during the waxing gibbous moon was associated with declining interest in Ethereum. The Earth's magnetic field also significantly varied by lunar phase displaying highest intensities during the full moon, and reduced intensities from the waning to waxing crescent phases.

Summary

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The relative cost associated with BTC and other cryptocurrencies have been considered the primary determinates of price. The drivers in the cryptocurrency market however are the level of competition in the network of producers, which may very well be stimulated by meteorological variation. A biometeorological influence on humans during participation in the cryptocurrency market was apparent. If the twenty-four hour a day exchange of economic signal across a global network of users is influenced by cyclical and varying background meteorological conditions it is important to further quantify the relationship between mass psychological states and fields naturally produced by our planet or the phases of its natural satellite.

Future research should not only take into consideration traditional predictors of health related phenomenon such as Traumatic Brain Injuries in sport - or price fluctuation in traditional and digital economic markets - but should also take an transdisciplinary approach to understanding potential background causal influences that may have an influence on these events. This would require not only integrating knowledge bases from several perspectives, but also consulting invested stakeholders and policy-makers.

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Appendix A – Principles of Concussion (Persinger)

Principle 1

Persinger (1995) outlined the principles of TBI's, the first principle is that an individual's phenomenological profiles and subjective experiences are determined by the relative mosaic brain activity. Studies have indicated that that a person's behaviors and experiences are determined by the most metabolically active region of the brain (Chugani and Phelps, 1986). This implies that under normal conditions, metabolic activity reflects the influence from perceptual and sensory stimulation, or the selective disinhibition of the frontal, cortical and subcortical regions of the brain, which is supported by measures of metabolic activity within these regions (Andreasen, 1988). Strong temporal associations have also been documented between specific panic experiences and mild asymmetries in hemispheric activation (Reiman et al., 1984; p. 684, table-2), specifically increased right para-hippocampal gyrus activation relative to the left. Sequential organization of verbal behavior and limb movement, as well as thinking responses has been localized to hyper-metabolism within the left orbitofrontal cortices, whereas socially inappropriate behavior has been discovered to manifest through hypo-metabolism of this region (Oder et al., 1992).

Principle 2

The second principle states that aberrant neuronal activation - as opposed to necrosis - causes anomalous behaviours, insofar as behavior and experience associated with brain injuries are the result of enhanced neuronal activity, not through the absence of neurons (Persinger, 1995; p. 709). Correlative behaviors of TBI's have been found with the disinhibition of viable neurons within the damaged region of the brain, or in areas proximal to it (Coyle and Puttfarcken, 1993). Behaviors associated with brain injuries could also reflect activation of regions which are not identifiable by MRI images or CT scans (Reila and Penry, 1990; As cited in Persinger 1995; p. 709).

Principle 3

The third Principle insists that any stimulus which affects the synaptic substrate within a functional region will be associated with complimentary changes in overt and covert behaviors. Behaviors, personality and other phenomenological experiences, which include the sense of self, emerge from the temporal increments and spatial resolutions of aggregate synapses and receptor activation within localized regions of the brain (Persinger, 1995; p. 709). Altered brain activity can interfere with physiology such as blood flow, capillary perfusion, or glial cell invasion, such that loss of consciousness is not necessary for brain damage to occur (Parker, 1990; p. 100-101). Microscopic alterations can generate behavioral changes which are equal to the complete loss of tissue, insofar as similar behavioral deficits were observed in rats which experienced extreme malformations in response to prenatal or postnatal ionizing radiation or low frequency magnetic fields in comparison to those which developed no discernable alterations in morphology (Persinger, 1995; p. 710). 50-70% of patients who did not display gross neurological indicators at the time of brain injury acquisition - by means clinical observation or structural anomalies - were ultimately found to have lesions which were verified by CT-scans, or developed neurological conditions (Cummings, 1985; as cited in Persinger, 1995; p. 710).

Principle 4

The fourth principle suggests that positive symptoms are due to the diminution of inhibitory processes. Maintained inhibition of neurons is a requirement of the normal operative process of the brain, such that 25-40% of trans-cerebral synapses involve GABA which is an inhibitory transmitter that is dependent upon glucose metabolism via the GABA shunt (Olsen and DeLorey, 1999). The most vulnerable regions of the brain, albeit by means of contact with humoral enzymes, reduced oxygenation, or proximity to the mechanical force are prevalent with GABA neurons and receptors, which can detect subtle microenvironment alterations (Bekenstein and Lothman, 1993). Changes in these susceptible regions can disrupt circadian rhythms, which are GABA driven, which can influence sleep-wake cycle (Moore and Speh, 1993). Mechanical impacts lead to selected sensitivity of inhibitory processes as a result of physical forces, which can in turn directly or indirectly lead to dysfunction in hippocampal formation. This region serves as the gateway to memory, the formation of which depends on the hippocampus's ability to generate inhibitory postsynaptic potentials (Michelson and Wong, 1991). Micro-seizures within the boundaries of the hippocampal-amygdaloid region have been found to encourage hallucination like experience (Ardila and Gomez, 1988). Hallucinatory experience has been found to be suggestive of electrical activity evoked by surgical stimulation (Bancaud et al., 1994). Administration of antipsychotic neuroleptics to patients displaying schizophrenic hallucinations (Ardila and Gomez, 1988) could be counterproductive at the risk of cholinergic overshoot, or rebounded limbic seizures.

Principle 5

The fifth principle implies that there is an inverse relationship between the severity, chronicity, and clinical conspicuousness of cerebral impairment and the numbers and magnitude of multifocal dysfunctions. This suggests that consequences from aggregate brain injuries might exceed the normal variation of brain activity, but exist below the just noticeable difference. Repeated head trauma can also have combined intermittent and aperiodic periodicities that can potentially evoke transient extreme impairments. The extent of spatial or temporal impairment cannot be fully understood from isolated overarching measures such as verbal fluency from brief clinical examinations. Clinical impairment is defined as discrepancy in behavior from baseline or population averages of two or more standard deviations. Traumatic brain injuries which result in consistent but minute deficits in a variety of behaviors may be undetected by neurological, neuropsychological or psychological impressions.

Principle 6

Principle number six reiterates that behaviors are due to convergent brain activations from parallel and multiple sources, such that identical behavioral manifestations do not necessarily represent identical etiologies. This is to say that the over generalization of the finite qualitative criteria of concussion tests - such as the DSM-IV - might mislabel or group overt behaviors which originate from distinct mechanisms. Regions of the brain are typically designated for specific behavioral assignment; combinations of non-local deficits however, have been found by to generate equivalent abnormalities in behavior, for which they are not typically associated (Persinger, 1995; p. 714).

Principle 7

The seventh principle notes that the relationship between the magnitude of neuropsychological impairment and the chronicity of deficit is not linear. Psychometric tests assume that patient performance is defined by standard deviation, or the distance from a particular reference point. As individuals score farther from the mean, the behavior typically gets labelled on an axis ranging from mild, traumatic and severe. Deficits receive graduated scores through execution of particular tasks which requires integrity of the brain region, as well as its graduated state of hypo-metabolism (Pawlik and Heiss, 1989). Brain tissue which is permanently damaged will exhibit chronic or tonic hypo-metabolism relative to other regions. Doctors traditionally look for deficits through hypo-metabolic activity with associated neurocognitive correlates; however brief periods can result in hyper-metabolism wherein behavior and experience are driven by the functional correlates of the brain region (Jibiki and Yamaguchi, 1994; As cited in Persinger, 1995; p. 715). Increases in non-chronic characteristics of a TBI, such as multifocal and intermittent activations, are similar to partial epileptic seizures. Interictal or between seizure hypo-metabolism and ictal or during seizure hyper metabolism have resulted in visual hallucinations (Phelps and Mazziotta, 1985) and compelling ictal experiences (Bancaud et al., 1994) in brain injured patients. Patients who have sustained brain trauma have also reported to feel a sensed presence along the back or to the left which is associated with god like experience, and has been hypothesized to be a correlate of brief activation of the right temporo-parietal cortices (Persinger, 1995; p. 716).

Principle 8

Principle eight states Indices of dynamic correlates are more indicative of behavioral deficits than inferences of structural anomalies. This is to say that the images produced by MRI or CT scans reflect static lesions, such that attribution of behavioral change associated with focal discontinuities is correlative in nature as opposed to causal. Behaviors are dynamic process which can be reflected in the results of standardized neuropsychological tests, insofar as they can be effective at identifying regional dysfunction.

Principle 9

Principle nine acknowledges that diffuse brain injury simulates normal effects of aging, insofar as normal aging occurs with the loss of neurons and regression of higher order dendrites, in addition to the loss of receptor subtypes (Arnsten and Goldman-Rakic, 1985; Weiland and Wise, 1990; As cited in Persinger, 1995; p. 716). Brain injuries were found to correlate with reduced neuronal potential, decreased protein synthesis, as well as reductions in capillary capacity, oxygen availability and intermembrane diffusion. Reduction in synaptic potential brings about hypoxic conditions, which dampen neuroexcitatory correlates and microvascular events which could lead to future behavioral deficits, such as further injury (Terry and Hansen, 1988; Pokras, 1994; as cited in Persinger, 1995; p. 717). Acceleration in the ageing process of neurons results from head injuries (Barnes1994; As cited in Persinger, 1995; p. 717), which can lead to the early onset of senile dementia who sustained closed head injuries (Gedye et al., 1989).

Principle 10

This principle states that while the brain merely adapts due to brain injuries it does not recover after cell death. This is because neurons which are killed do not recover. This results in 'dieback' of dendritic spines, such that metaphors of a 'healing brain' or its 'return to normalcy' are false and misleading to the patient, as well as their family. Remaining healthy neurons are activated after a brain injury and are able to maintain the capacity to represent experience through re-adaption. Recovery is often misattributed insofar as verbal fluency is over-learnt, such that the verbal social interaction rich in intra-verbal sequence is highly ritualistic and driven by procedural learning and is often the last functional domain in senile dementia.

Principle 11

The eleventh principle is with regard to learning insofar as it can be delayed, but not eliminated if the functional modules remain, this implies that brain injured patients do not lose the ability to remember, it's just that they remember less. Patients who sustained moderate brain injuries still have the ability to learn new strategies but require more time wherein mild injuries usually require twice the time, insofar as the amount of additional time or additional trials needed to learn a task has been determined by impairment severity (Jarvis and Barth, 1984; as cited in Persinger, 1995; p. 721). Optimal measures in order to discern neuropsychological deficits should include comparisons of standardized scores for measures in; intelligence, memory, educational achievement, neurocognitive proficiency.

Principle 12

Principle twelve reminds that trans-neuronal degeneration contributes to the altered mosaic of neuronal patterns and changes in behavior, such that although the asymptote of neuronal dropout within the cerebrum occurs within forty days of a brain injury - transneuronal degeneration can occur for years after – and involves reduction in viable activity of neuronal aggregates through upregulation of receptors. Diffuse loss of input from cortical neurons has been observed after trans-neuronal degeneration within the mesencephalon (Bigler et al., 1992; Faden et al., 1989; Povlishock, and Coburn, 1989; as cited in Persinger, 1995; p. 720). Stimuli which disrupt schedules or produce vascular deficiencies in the characteristics of the cell membrane will alter genetically determined immunological characteristics and ultimately generate behavior (Roberts and Bruton, 1990).

Principle 13

Principle thirteen is the final principle which states that mild brain impairments are associated with; more conspicuous changes in the sense of self and personality in comparison to severe vegetative impairments. Ontogenesis or the development of behavior is associated with an increasing cascade of neurocognitive processes which emerge overtly as personality and covertly as the individual's sense of self. Impairment of these processes - such as dementia – can alter consciousness and result in rapid intellectual decline in comparison to preinjury baseline profiles. Injuries which occur within the left temporal or right prefrontal lobes, would demonstrate the greatest loss of the pre-traumatic self, insofar as they correlate with. Mild impairments including multifocal disruption can evoke asymmetric and transient increases in subcortical limbic activity.

Chronic fatigue syndrome has been associated with diffuse disruption of limbic structures which modulate humoral and cellular immunological systems. Post-concussion syndrome can result in neurosis, which could be attributable to increased complex partial epileptic seizures. Immunosuppression can result from brain injuries which shift the ratio of hemispheric activity, such that net predominance of the right hemisphere over the left occurs (Goldstein, 1993; Miller, 1993; Biziere et al., 1985; as cited in Persinger, 1995; p. 722).

Appendix B

Altcoins: Any Cryptocurrency that is an alternative to Bitcoin

Alzheimer's disease: irreversible progressive neurodegenerative disease which is the most common form of dementia

Average True Range (ATR): A technical analysis indicator which gives an idea of the range of an asset over a specified period of time

Aroon up and down: A technical indicator that is used in economic markets in order to identify changes in the price trend of an asset

Biometeorology: An interdisciplinary field that investigates the relationship between living organisms with dynamic processes associated with the atmosphere

Bitcoin: a digital currency that acts as an electronic peer-to-peer network, a medium of exchange and store of value which is not dependent upon a third party.

Blockchain: A public ledger that is decentralized and open sourced record of transactions, registrations and inventory

Circatringintan cycles: 30 day periodicities

Cryptocurrency mining: A self-governing process wherein transactions on the blockchain are validated through the application of computational power, such that a reward is provided for the task

Cryptocurrency: A disruptive technology

Chronic Traumatic Encephalopathy (CTE): A degenerative brain disease which can be caused by repeated head trauma or forceful blows to the head

Decentralized applications: (DApps): Applications that can run on decentralized peer-to-peer networks that are governed by all members in the network

Distributed Autonomous Organization (DAO): open-sourced, transparent, incorruptible and distributed autonomous networks of like-minded individuals

Dow Jones: Stock market index, which indicates the value of 30 large and publically owned companies in the United States

Ethereum: Foundation of a new internet era, wherein users can use their own data and have access to open financial systems

Ethereum Virtual Machine (EVM): quasi-Turing complete machine responsible for handling internal states on the Ethereum network

Efficient Market Hypothesis (EMH): An investment theory that assumes that prices reflect all available information

Geomagnetic Storms (GMS): Disturbance of the Earth's naturally occurring geomagnetic field often caused by extra-terrestrial influences including enhanced solar activity

Heiken Ashi: Translates from Japanese to English as average bar and effectively filters out market noise, and is used by technical traders

Internet of Things (IoT): A vast number of things connected to the internet in order to share data with other things, including applications, devices and machines

Injury Severity: Amount of games missed due to Traumatic Brain Injury (TBI)

Market Cap: Aggregate market value of an assets total dollar amount, calculated by multiplying the number of coins in circulation by the price of the asset in-and-of-itself

Proof of Work (PoW): An economic protocol with the main goal of deterring cyber-attacks such as spam through requiring energy intensive operations from a miners computer who validate transactions on the blockchain

Second Impact Syndrome (SIS): occurs when an athlete suffers from post-concussive symptoms following a head injury and then returns to play and sustains second head injury, wherein diffuse cerebral swelling, brain herniation and death can occur

Seasonal Affective Disorder (SAD): a type of depression that is the result of diminished Sunlight from fall to winter months, and is most pronounced in northern latitudes

Sudden Infant Death Syndrome (SIDS): Unexplained death of children under the age of 1

Syzygy: the astronomical alignment of three or more celestial bodies including the Earth-Sun & Moon

Traumatic Brain Injuries (TBI's): occur from a violent blow or jolt to the head or body

Value Approximation (AV): A single value calculated for each player in the National Football League (NFL) for the purpose of comparing players across generations and player positions