CULTURAL FACTORS AND DOCUMENTED CONCUSISON REPORTS IN COLLEGIATE FOOTBALL PLAYERS: EXPLORING THE EFFECTS OF MACRO- AND EXO- SYSTEM FACTORS

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A Thesis

Submitted in Partial Fulfilment

of the Requirements for the Degree of

Master of Arts

in Psychological Sciences

Northern Arizona University

May 2018

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ABSTRACT

CULTURAL FACTORS AND DOCUMENTED CONCUSISON REPORTS IN COLLEGIATE FOOTBALL PLAYERS: EXPLORING THE EFFECTS OF MACRO- AND EXO- SYSTEM FACTORS

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Despite the well-publicized negative health consequences of repeated traumatic brain injury, non-reporting concussion rates have remained constant over recent years, especially in high-risk sports such as college football. This study, grounded in Bronfenbrenner's Ecological Systems Theory (1998), evaluates the hypothesis that the number of publicly acknowledged concussions by NCAA college football teams will be inversely related to the cultural factors hypothesized to constrain players' non-reporting behavior, and by extension, the number of publicly acknowledged concussions reported by NCAA football teams. All data used for this study was derived from publicly-reported data found online pertaining to teams playing during the 2017-2018 football season, using data scraping and mining methods using the open-source statistical package R, and R sub-packages, and secondary analyses of text data using LIWC. Indicators of the outcome variable, number of publicly acknowledged concussions, and all indicators were derived from various sources of online data including financial reports, team success records, and social media. A principal components analysis identified one component which, although unrelated to diagnosed concussions, was significantly related to suspected concussions (head and neck injuries). Implications include both methodological and applied outcomes regarding construction of cultural-level variables and football culture's impact on the safety and well-being of players.

Acknowledgements

I would like to express gratitude to my committee for their passion, creativity, and commitment to this project and to a much more taxing endeavor: trying to teach me about football. In particular, Dr. Heidi Wayment's willingness to offer the ideal balance of challenge and support through this process has exemplified her strengths as an academic, a mentor, and a role model. Dr. Brian Eiler's time and Drs. Ann Huffman and Virginia Blankenship's expertise have been especially helpful.

More generally, my cohort members have been incredibly supportive throughout this experience and I am very thankful for their friendship, kindness, and willingness to listen to me ramble about the struggles of running code until the early hours of the morning. To my parents and sisters, thank you for your constant reassurance - even if you had no idea what I was talking about most of the time.

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Introduction

On September 9th, 2017, the Auburn Tigers led the Clemson Tigers 6-0 just five minutes into the second half of the Saturday evening football game. Just after the Clemson quarterback threw an incomplete pass, he was tackled. Slow motion instant replay showed that the quarterback landed on his left shoulder, quickly followed by his head, and the defensive player landed on top of the quarterback's helmet. The quarterback struggled to pull himself onto his knees, took out his mouth guard, then slumped over and collapsed onto the turf. Athletic trainers rushed to assess the quarterback and, although he left the game for a few plays, he returned and scored two touchdowns leading Clemson to a 14-6 victory. Nothing about the play that briefly sidelined him was out of the ordinary in the realm of college football. Although the tackle did not make it to many of the highlight reels posted on YouTube in the following days (though his winning performance did), viewers, fans, and sportscasters on social media (e.g., Twitter) were concerned about the quarterback's health.

The Auburn-Clemson game, as well as the other 779 games played by over 70,000 student-athletes during the 2017 season, was managed by the National Collegiate Athlete Association (NCAA). A special focus of the NCAA during recent years, as evidenced by the $7 million in grant funding offered to various institutions and yearly reporting produced by the NCAA, has been players' brain health. Given the attention traumatic brain injuries have received in the past decade from both mass media outlets and by national sports organizations, it remains unclear as to why a promising football player (e.g., the Clemson quarterback) would put his life and future at risk to remain on the field?

Increased Attention to Health Consequences of Concussion

The Center for Disease Control and Prevention (2016) defines a concussion as, “a type of traumatic brain injury (TBI) caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to move rapidly back and forth.” Concussions can result from a direct hit to the head, or a hit to another part of the body that indirectly creates force on the brain (e.g., neck). Tackling is fundamental to football, and tackling can create both direct and indirect forces on a player’s brain (Aubry, et al., 2002; Bondi, et al., 2015; Gessel, Fields, Collins, Dick, & Comstock, 2007).

Concussion symptoms are variable, and depend on a wide range of factors (see Abrahams, McFie, Patricios, Posthumus, & September, 2014, for a systematic review of risk factors). The most common symptoms are headaches, sensitivity to light and/or noise, dizziness, fatigue, emotional distress, memory dysfunction, vision disturbances, and fatigue (Evans, 1994), most of which resolve within a few days or weeks of the concussive event (Alves, Colohan, O'Leary, Rimel, & Jane, 1986; Leninger, Gramling, & Farrel, 1990). However, some individuals who sustain concussions experience long-term or even permanent symptoms (Binder, 1986). Other threats to health of repeated head injury include Second Impact Syndrome (SIS) and Chronic Traumatic Encephalopathy (CTE). SIS occurs when an individual with a concussion sustains a second TBI before the first has resolved and this secondary trauma increases the risk for brain herniation, diffuse cerebral swelling, or sudden death (Weinstein, Turner, Kuzma, & Feuer, 2013). Although SIS is rare, it is more likely if players either do not recognize or choose to ignore symptoms and continue to play; the possibility of SIS reinforces the importance of identifying sub-concussive TBI and proper protocol overseeing athletes’ recovery (Dessy, Rasouli, & Choudhri, 2015). CTE is a neurodegenerative disorder thought to be caused by repeated TBI (Critchley, 1949; Martland, 1928), leading to the development of tau protein tangles in the frontal and temporal cortices and significant depigmentation and degeneration of the substantia nigra (Geddes, Vowles, Nicoll, & Revesz, 1999). CTE has been associated with impulsivity, emotional instability, recklessness, violence, and early (often self-inflicted) death (McKee, et al., 2013) and has received substantial coverage in the media (Khun, Yengo-Kahn, Kerr, & Zuckerman, 2017).

Sport is one of the leading causes of TBI in teens and young adults (Sosin, Sniezek, & Thurman, 1993). A growing body of literature links football with long-term negative health consequences (Gessel, Fields, Collins, Dick, & Comstock, 2007; Guskiewicz, et al., 2005; Mez, et al., 2017). Indeed, national and local organizations such as the NCAA and NFL have committed to addressing players' brain health. Most of these initiatives are designed to reduce long-term health risks by reducing the potential for head injury in practice and games and by educating players about the importance of reporting of potential concussion symptoms (Benson, et al., 2013). Despite interventions that include technological advances (Daneshvar, et al., 2011) and concussion-related education (Kroshus, Daneshvar, Baugh, Nowinski, & Cantu, 2014), it is estimated that 50% of all concussions are not reported (Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015). This underreporting, partnered with the increased awareness of risks associated with undiagnosed concussions, has led to a body of research dedicated to increasing concussion reporting behavior in athletes.

Concussion Reporting and the Ecological Systems Framework

To date, most of the research examining potential predictors of players' unwillingness to report concussion symptoms, and subsequent interventions, have been based on models that focus on individual factors such as athletes' knowledge about symptoms, their perceptions of risk, and their ability, willingness, and motivation to report symptoms (See Table 1 for details).

While this empirical approach has often been used for the development of health promotion interventions (Carpenter, 2010), they are incomplete because they do not include the types of institutional or cultural factors that affect players' concussion-related attitudes, beliefs, and behavior (Kerr, et al., 2014).

Health researchers have long argued that a systems perspective is needed to understand predictors of health behavior. In the context of concussion reporting behavior Register-Mihalik and colleagues (2017) have recently made the same arguments with respect to concussion-reporting behavior. The Ecological Systems Framework (Bronfenbrenner & Morris, 1998) describes the reciprocal impact that nested systems have on individual behavior. In this framework, a football player's willingness to report concussion symptoms is influenced by and emerges as a result of interactions between multiple levels. The most distal level of influence is termed the *macrosystem*, the collection of pervasive values, customs, and beliefs that make up, in this case, "football culture." More specifically, football culture places emphasis on power, achievement, and conquest (Foley, 1990). Macrosystem values and norms influence, and are influenced by, exosystem institutions such as the NCAA, and the universities and colleges that field football teams whose policies offer more concrete indicators of these values; power, achievement, and conquest, then, are exemplified by practices that encourage competition. The next level is termed the microsystem, and it contains important social entities and settings football players occupy. For example, football practices and games, classroom settings, family and social settings. The relationship among those entities make up the *mesosystem*. Finally, at the individual-level are the factors (e.g., attitudes, beliefs, perceived risk, etc.) which are both products and propagators of these larger nested systems. See Figure 1. The bulk of research examining predictors of concussion-reporting behavior has examined only individual-level factors. Although higher level systems factors have been described as likely to play an important role on concussion reporting rates, to date the influence of macrosystem and exosystem influences have not been empirically examined.

Potential Cultural Factors Associated with Non-Reporting

Cultural factors are powerful shapers of behavior (Cialdini, 2001; Lapinski & Rimal, 2005). Yet, despite calls to do so (Kerr, et al., 2014), researchers have not yet empirically examined cultural beliefs about football, one of the important elements of the social-ecological framework believed to influence concussion-reporting behavior (Register-Mihalik, Baugh, Kroshus, Kerr, & Valovich McLeod, 2017). For example, extant research has focused on the fact that football players are reluctant to report head injuries because they do not want to leave the game, they do not want to miss playing time, and they want to contribute to their team's success and not let their teammates down (cf., Kroshus et al., 2015). Yet, these "individualistic" reasons reflect and enforce the cultural belief that football players are "tough" and that tough players play through injury (Kerr et al., 2014). These basic values and expectations reflect the importance of, and investments in success held by many stakeholders (players, teams, institutions, fans). Behavior falling outside of these expectations are even punished. For example, when athletes leave the field during a game, they are the subject of boos and jeers from the crowd (Rosen & Wetcher-Hendricks, 2013).

Indicators of football culture can be found outside of the stadium as well – in trophy halls, media outlets, and university boardrooms. Teams' win-loss records are publically scrutinized ad nauseam and more successful teams receive greater financial investment and have a stronger ability to sustain public attention when they are successful. This embeds these highly visible teams into the social fabric in ways that constrain interactions between players, coaches, fans, and institutions. For example, players are idolized not only when they play for the home team (e.g., a college team in a college town), but are also followed as they continue into the NFL as representative of a university's football success. An active fan base and centrality of the college football program in local and national culture is not only a reflection of a team's success, but it also exerts a sustained pressure to avoid losing. Of course, along with these pressures to please fans, the pressure to win is paramount, and evidence for this pressure is associated with several kinds of financial investments in support of a college football program: coaches' salaries, ticket cost, stadium size, and more. This financial investment also leaks into recruiting. For example, successful teams offer the finest facilities to athletes, heightening the sense of prestige that players may feel when playing for high profile football programs. Financial investments in football programs are positively associated with football players' level of commitment; players with increased financial stakes play significantly more, regardless of skill (Keefer, 2015). These resources are provided to athletes in exchange for their performance. Sitting out due to a concussion may be perceived by players as losing such benefits. Similarly, many players chose to join an NCAA team based on the team's record of success, above and beyond academic considerations (Dumond, Lynch, & Platania, 2008). Importantly, players can only reap the benefits (e.g. career success – being drafted in to the NFL) of this decision if they do not miss playing time (Hartman, 2011). A player who loses playing time to recuperate from a concussion may feel their NFL opportunities have been jeopardized. Despite the fact that only 2% of collegiate players play in the NFL after college (NFL, 2017), the large majority of football players believe they have a chance at playing professionally (National Collegiate Athletics Assocation, 2017). Yet, this goal may motivate players to maximize playing opportunities throughout their college football career to increase their visibility to NFL scouts at the expense of their own health.

Clearly, fan loyalty and financial investment in college football programs are reciprocally linked with a team's success (Martin, 2013). Fans display religious-like attitudes toward sports (Percy & Taylor, 1997) which contribute to the NCAA's nearly billion-dollar annual revenue (Deloitte & Touche, LLP, 2017). Players, teams, and the NCAA all have strong incentives to keep fans engaged and attending (Paul, Wachsman, & Weinbach, 2011). Increasingly complex media coverage allows influence, and reflects, fans feelings of ownership and identification with players (i.e., "vicarious management"; Oates, 2009, p. 320). Teams and the NCAA are increasingly spending resources regulating the digital identities of their organizations and players, often hiring social media managers and attempting to censor "inappropriate" content from players' personal accounts (Hernandez, 2013).

As these examples illustrate, financial investments, engaged fans, and players' performance are all important correlates of a college program's success, and that success, in turn, influences subsequent investments of time, energy, and commitment by the university, players, and fans. Players' performance expectations are influenced by Americans' love of football as a display of athletic prowess, toughness, and aggression (Kreager, 2007), and players who play aggressively meet these expectations and contribute to their team's success. Taken together, there are factors that operate at the exo- and macro-system levels that encourage, support, and reflect the cultural significance of football in American life. The number of suspected concussions reported by an NCAA football team has typically been treated in the literature as the result of athlete's personal decision-making processes, and to date, there has been no empirical examination of whether these cultural influences are related to how many concussions teams disclose. This study addresses this gap by examining whether cultural pressures on college programs to succeed and maintain their importance at university, local, and national levels, are associated with injuries – with the expectation that greater levels of pressure will be associated with reduced concussion reporting. It is expected that indicators from the macro- and exo-system in which NCAA football players and teams exist can be used to model a cultural-level variable. This variable should then be related to concussion injuries. Until recently, constructing such a variable was challenging given the lack of consistently available public data. However, computational social scientists taking advantage of the massive amount of data available online have begun to explore exactly this process.

New Methods for Cultural Analysis

Rich and compelling evidence regarding the influence of cultural factors on a variety of individual level health behaviors has almost exclusively relied on qualitative methods (see Mays & Pope, 2000). In the context of concussion-reporting behavior, this is also true (Lininger, Wayment, Huffman, Craig, & Irving, 2017). The rise in available information from the internet and social media have exploded in the past decade (Witten, Frank, Hall, & Pal, 2017), making possible new sources of both qualitative and quantitative data. These data provide a potential window into cultural factors that not only reflect football's principal place in American culture, but the pressures to succeed in the sport (Huffman, Wayment, & Irving, 2017). In fact, football incentivizes the creation of social media information; fans are able to contribute to databases used to predict outcomes of games and, subsequently, discuss and even place bets on teams' success (i.e., fantasy football leagues) which contribute to a multi-billion-dollar industry (Mahan, Drayer, & Sparvero, 2012). By utilizing public data, social scientists can begin to explore variables that contribute to the broad cultural structures that constrain behavioral patterns (Gold, 2012; Golder & Macy, 2011).

Thus, the current study is based on the idea that indicators of macro- and exo- systems can be captured through archival and online sources of information (Bail, 2014). In so doing, this research builds on recent research using public sources of data to examine sports-related questions. For example, sports history data has been used to capture important cultural elements and historical contexts (Borish & Phillips, 2012). Additionally, the prevalence of online "fantasy football" programs in which fans carefully monitor and even bet on teams' success has been cited as evidence of the competitive nature of the sport (Guschwan, 2014). Social media data have been used to document fans' belief that they have a more direct outlet through which they can communicate with teams and players (Parks, Quarterman, & Thibault, 2010). This recent surge in publicly-available data on social media platforms involving football programs, players, and fans provides a unique opportunity to quantify cultural influences in relation to college programs' disclosure of concussions.

The Current Study

This project aims to answer two primary questions regarding pressure to succeed and concussion-related risk. The relationship between the pressure to succeed and four types of sports injuries will be examined: reported concussions, as well as head, neck, and knee injuries. All three types of these injuries may be more likely among teams who play more aggressively, potentially due to the cultural "pressures to succeed." However, these injuries may be uniquely related to cultural pressure to succeed. For example, head and neck injuries are of interest because they often result in concussive or sub-concussive incidents (Rosenbaum & Arnett, 2010; Funk, et al., 2011). Further, given that football players may be dissuaded to report concussions because of the stigma surrounding the diagnosis (Wolverton, 2015), head and neck injuries may be a less stigmatized way to report head injuries. Knee injuries are included as a comparison injury because they have different etiologies than head injury, and have recently been shown to be negatively related to concussions, attributable to recent regulations regarding tackling protocol (Westermann, Kerr, Wehr, & Amendola, 2016). Thus, this study seeks to address two research questions: 1) Can publicly-available data (from a variety of sources, reflecting a variety of indicators) from all NCAA football programs be used to capture macro- and exo-level system influences such as the "pressures to succeed" (see Figure 2) and 2) Is such a variable related to concussion-related injury such as reported concussions and suspected concussions? It would be expected that pressure to succeed would be inversely related to publically acknowledged concussions and positively related to suspected concussions. As pressure increases, players are incentivized to avoid a concussion diagnosis and instead have a head or neck injury after sustaining a serious hit. No prediction was made regarding knee injuries (see Figure 2).

Method

Data Collection

Data were automatically collected from publicly-available online sources using the package *rvest* (Wickham, 2016) for R (R Core Team, 2013) to extract html code. Data were also collected from Twitter from the Twitter application programming interface (API) using the R package *twitteR* (Gentry, 2015). Examples of R code used for these purposes can be found in Appendices A (twitteR) and B (rvest). Data were organized and converted into CSV files using R and compiled using commands from Microsoft Excel (e.g., VLOOKUP, COUNTIFS). A table including information regarding variables collected (e.g., missingness, measures of central tendency, minimum and maximum values) can be found in Appendix C.

Subjects

Data were collected from each of the 130 NCAA Division I football teams. The sample was limited to teams in the most competitive division (Division I) to ensure a high likelihood of the availability of the desired indicators. Consent was not required from team as the indicators used were all publically available.

Measures

Injuries. The National Football League (NFL) has, since 1946, required teams make public the injuries each of their players sustain. While the practice emerged as a way to reduce the likelihood of games being "fixed" by players faking injuries, it is now most often used by gamblers to anticipate teams' performance (Paulas, 2016). Under threat of fines, teams are expected to report, "credible, accurate, timely, and specific" information retarding information on "player availability" to all interested parties (NFL, 2017, p. 1). These reports are publically available and include information regarding the names of the players, their injuries, their participation level in recent practices, and their anticipated participation in upcoming games.

The NCAA does not have a similar mandate requiring the public reporting of injuries for college players. However, given the utility that these metrics have for prediction of team success in upcoming games (cite), it is not surprising that gambling sites have taken it upon themselves to closely monitor players who will not be participating in these games. Since these unofficial metrics were easily found across the web, this is how injuries were measured for each team.

Originally, metrics were pulled from multiple sites every week and aggregated using the *rvest* package for R and the Automator application for Mac. However, data monitoring revealed that these sites were reporting the exact same data. Data were then pulled from a single site (statfox.com) to reduce redundancy.

Publicly Acknowledged Concussions. Injury data included name of player, name of team, date of injury, and type of injury, along with other information. To adequately measure *Publically Acknowledged Concussions*, a COUNTIFS command was run using Excel to identify the number of concussions were found throughout the season for each team (e.g., Number of *Publically Acknowledged Concussions* for the Air Force team=COUNTIFS([INSTITUTION], "=Air Force", [INJURY], "=Concussion").

Suspected Concussions. After focal impact applied to the skull, the two most common pathways by which concussions occur are consistent with Marmrou impact acceleration model (Marmarou, et al., 1994) and the head rotation model (Gennarelli, et al., 1982), both of which are likely to be relevant for head and neck injuries sustained by football players. In these models, blows to the rest of the body that result in force being exerted on the brain are understood to also result in TBI. Because of this, suspected concussions included head and neck injuries as these often result in concussions or sub-concussive brain trauma (Funk, et al., 2011; Rosenbaum & Arnett, 2010).

Following a similar process to the measurement of *Publically Acknowledged Concussions*, this metric also included COUNTIF commands in Excel. Each command was run for injuries listed as "head" and again for "neck". These totals for each team were then summed to create a *Suspected Concussion* measure. No distinctions were made between the types of head and neck injuries; neck sprain, skull fracture, and vertebral compression, for example, were all treated as a suspected concussion.

Knee Injuries. Past research using privately-maintained databases owned by the NCAA have identified knee injuries as the most common severe injury across football, wrestling, and men's ice hockey (Kay, Register-Mihalik, Gray, Dompier, & Kerr, 2016). Similar to suspected concussion injuries, no distinctions were made between different types of injuries – meniscal tears, dislocations, fractures, and generalized “knee” injuries were collapsed. The total number of knee injuries per team was assessed from the same injury databases as concussion, head, and neck injuries. By including a type of injury expected to be unrelated to potential damage to the brain, we hope to make the case for divergent validity – this hypothesized pressure should only be related to publically acknowledged and suspected concussions.

Exo- and Macro-System Indicators. In order to create a factor that reflects pressure to succeed, a total of 14 indicators were compiled for this study. Several indicators related to program success were captured and operationalized using publicly-available data sources listed in Appendix D.

Indicators included each college team’s total win:loss record and the number of alumni from each school currently playing in the NFL. Many NCAA athletes report one of their primary goals to be getting drafted into a professional league and this metric addresses each teams’ likelihood of offering this as a possibility. Since each NCAA football game attracts over 2 million viewers (Kaplan, 2016), other indicators were included to reflect fan engagement including stadium size, total university enrollment (because winning football records are strong predictors of number of applicants for the following academic year; Murphy & Trandel, 1994) and number of followers across social media sites (Facebook, Instagram, Twitter). The Linguistic Inquiry and Word Count (LIWC; (Penebaker, Booth, Boyd, & Francis, 2015) was used to quantify the language used on each team’s official Twitter account. For example, indicators included LIWC-generated estimates of psychological drives reflected in the Tweets: Affiliation, Achievement, Power, Reward, and Risk. Financial investment was operationalized by using head coach’s salary and season ticket cost.

Results

Factor Reduction – Principal Components Analysis

Principal components analysis (PCA) is an exploratory statistical technique designed to reduce the complex dimensionality of a collection of variables into more manageable metrics that retain the characteristics of the indicators they represent. By grouping highly-correlated variables together, PCA identifies structures that are thought to be caused by a single component. PCA is not only useful for understanding the structure of large data sets, but also allows researchers to explore relationships between variables without increasing the likelihood of type-one error by including more variables than necessary in later tests.

All 14 indicators were entered into a PCA to create combinations of fewer variables that accounted for covariance between the observed indicators (Tabachnik & Fidell, 2013). Given the disparate scales of the 14 indicators, all were standardized (mean = 0, standard deviation = 1) prior to analysis. Standardized variables were entered into a PCA using SPSS Version 24. Results indicated four distinct components which accounted for a total of 68.00% of the variance. Visual inspection of the scree plot (Figure 3) suggested a single-component structure. After employing a varimax rotation to increase the distinction between factors (Tabachnik & Fidell, 2013), a single clearly-interpretable factor remained and was named using the causal method suggested by Rummel (1967) in which components are given a name based on theoretically relevant emergent causal factors. The emergent factor was named *Program Prestige*. Component interpretation was limited to those variables with factor loadings above .45, as suggested by Comrey and Lee (1992). See Table 2 for the rotated component matrix from the PCA.

The *Program Prestige* component included (in order of strongest factor loadings) number of followers on Twitter, stadium capacity, Facebook followers, season ticket price, head coach's salary, Instagram followers, win:loss record, and number of alumni currently in the NFL. This factor displayed high reliability (*a*=.92), which would not improve if any of the items were to be deleted. No variables were removed from the construction of the component and regression-based scores (Tabachnik & Fidell, 2013) for each team were then generated. Higher scores on this factor reflect a greater *Program Prestige*.

Correlational Results

The PCA-derived component was computed and correlated with the indicator of publically acknowledged concussions and suspected concussions sustained by each team during the 2017 season. The correlation between *Program Prestige* and publicly acknowledged concussions was non-significant (r = .11, p = .26). The correlation between the *Program Prestige* and suspected concussions was significant (r = .26, p < .01). Thus, the expectation that any cultural component generated by the first analysis would be inversely related to concussions or suspected concussions was not supported. A post-hoc power analysis indicated adequate (.92) power to detect an effect for this significant correlation.

To test the relationship between *Program Prestige* and head/neck injuries as a unique function of football culture, a similar process was completed using the number of knee injuries each team sustained during the 2017 season. Knee injuries were frequent (n = 1642 during 2017). This correlation was nonsignificant (r = .06, p = .57).

Discussion

Despite anthropologists, sociologists, and ecological psychologists advocating for the inclusion of culture into investigations of behavior, much of the work surrounding concussion reporting has failed to adequately measure or account for the influence of macro and exo systems. Recognizing the opportunities made available by the expansive datasets found online and the skills used to harvest them, this study aimed to address this gap in the literature by constructing a cultural variable and exploring its' relationship to football teams' publically acknowledged injuries.

The first goal of this study was to examine whether publically-available data could be used to model a variable that reflects the suspected reasons concussions are under reported in college football. The emergence of a single component structure from the principal components analysis supports this goal. The central hypothesis was that cultural indicators of the *Program Prestige* would be related fewer disclosed concussion. This hypothesis was not supported. However, exploratory analyses revealed that *Program Prestige* was associated with head and neck injuries. The results suggest that among Division I NCAA football teams; those who face greater cultural *Program Prestige* may be at higher risk for injuries associated with long-term brain health consequences.

Using Big Data to Reflect Cultural Influence

One of the unique contributions of this study was the ability to successfully quantify a measure that reflects "pressure to succeed" from publically available data. Assembled from indicators collected from sources other than the players and teams, this cultural variable is clearly distinct from individual and microsystem measures. Furthermore, the research rested on the theoretical proposition that this pressure reflects macro and exo-level factors that heretofore have not been measured in the concussion-risk literature. These factors have been implicated by researchers as systemic reasons football players are at risk for concussion and are reluctant to disclose that type of injury. For example, dozens of studies have suggested links between facets of American Football Culture like masculinity (Foote, Butterworth, & Sanderson, 2017), legislation (Chrisman, Schiff, Chung, Herring, & Rivara, 2014), and education for both administrators (Murphy, et al., 2012) and students (Kroshus, Daneshvar, Baugh, Nowinski, & Cantu, 2014) and players' behavior regarding brain health. However, none of these studies have measured exo- or macro-level factors, instead their analyses have primarily relied on athlete self-reports of their own perceptions and feelings. The results from the current study complements and adds to this existing literature by demonstrating that publically available data reflecting important university-level and cultural-level indicators can be used to quantify macro- and exo-system level factors as they relate to football culture.

Analyses revealed that eight of the 14 indicators created a reliable *Program Prestige* factor: followers on social media sites, cost of tickets, head coach's salary, historical win record, and number of alumni currently playing in the NFL. The greater number of followers on social media is a possible example of the expectations that fans have for their teams. As more people follow along with the team, players have more audience members who demand quality performance (Schlenker & Leary, 1982). Ticket prices reflect the value of a team; people pay higher prices for games that involve more prestigious programs. Coaches' salaries are clearly tied to *Program Prestige* and expectations for success. In addition to base salaries, coaches are incentivized with bonuses to win high profile games (e.g., conference championships and bowl games), and these incentives conceivably affect the way players' injuries are perceived and diagnosed. For example, coaches who need their most talented player to participate may prioritize the player's continued performance over the accurate diagnosis of a concussion. This indicator also represents the amount of financial investment each institution has in the success of their team, supplying another potential source of pressure for players to succeed. The final two indicators of the *Program Prestige* factor were historical winning record and number of players in the NFL. These indicators reflect program legacy and importance and influence the recruiting cycle by incentivizing continued success after college for high profile players. Organizational success, in terms of both number of games won since inception and ability to place players in a professional league, is something to which the best high school football recruits would be drawn and could be negatively affected by a high number of concussions reported during the season. Lacking temporal precedence, this cross-sectional analysis cannot address how these variables became indicators of the *Program Prestige*, though we believe that they develop concurrently. As teams begin to establish large followings, increase their financial resources, and improve their record of success, they experience more *Program Prestige*.

***Program Prestige* and Football Injury**

The main hypothesis of this study, a negative correlation between *Program Prestige* and disclosed concussions, was not supported. As expected, the correlations between *Program Prestige* and head and neck injuries were significant and positive. These results may have important implications for the relationship between cultural level pressures to succeed and concussion risk. Since these head and neck injuries are likely to be associated with concussions or at least sub-concussive injuries (see: alternative TBI models), it is clear that players on these high-achieving teams are at an increased risk for these specific types of injuries associated with TBI.

It is important to consider additional explanations for these results, within the context of existing research. The relationship between *Program Prestige* and increases in head and neck injuries may be shaped by existing policies within the NCAA. As of August 2017, the NCAA officially endorsed a formalized Return to Play policy for athletes who have sustained a diagnosed concussion. This protocol, designed by the University of Miami Department of Athletics, includes baseline testing and educational materials, along with a six-step process athletes are expected to complete post-concussion diagnosis. These steps are as follows: No Activity, Light Aerobic Exercise, Sport-Specific Exercise, Non-Contact Training Drills, Full Contact Practice, and, finally, Return to Play. Progression through each of the steps must be supervised by the team physician and are complemented with players' return-to-baseline scores on various cognitive and behavioral measures.

However, well-documented and NCAA-endorsed programs regarding other injuries do not exist for all teams (Daruwalla, Greis, Hancock, Group, & Xerogeanes, 2014). The progress of players suffering these injuries is supervised by medical professionals, though the NCAA does not have any suggestions for markers of the appropriate time to return to play. Because of this, a star player who sustains a tackle that resulted in a concussion could benefit from this injury being called a head injury rather than a concussion. As this *Program Prestige* increases for teams, they are incentivized to perform and, thus, may be tempted to assign a diagnosis to a player that is associated with a shorter, or at least less standardized, recovery protocol. As demonstrated by players' willingness to perform poorly on pre-season baseline concussion tests so they can avoid being diagnosed with a concussion later (referred to as "sandbagging"), players intentionally subvert their teams' medical professionals. Given the NCAA's focus on concussion education, players may use their more complete understanding of concussion symptoms to avoid reporting symptoms that they know would be cause for concern from athletic trainers and physicians.

Another potential reason the *Program Prestige* is related to suspected concussions is players' future goals. Similar to the concerns regarding the return to play protocols, teams with high *Program Prestige* may be concerned about by the way a concussion diagnosis affects players' post-NCAA careers. Due to the stigma surrounding concussions in football (Wolverton, 2015), especially for those players who are NFL hopefuls (Abdullah, Grady, & Levine, 2015), it follows that they are more likely to want to report sustaining a head or neck injury (potentially serious enough to miss a game) than assume the title of "concussed" and risk draft chances. Since concussions are associated with mental health stigma (DeLenardo & Terrion, 2014) which has much more negative consequences than physical health stigma (Schmelkin, Wachtel, Schneiderman, & Hecht, 1988), players are less socially impaired with the perceptions of a head or neck injury than with those of a concussion.

No causation can be inferred from the nature of these data. However, the identification of significant correlations between players' health and factors under the control of teams, universities, and fans encourages a critical assessment of the relationship that the NCAA constructs with their policies, incentive structures, and publicity strategies. Similarly, fans who commit to supporting these teams are complicit in that they encourage these value systems that downplay the importance of players' health to continue on. By contributing to the *Program Prestige*, teams, universities, fans, and the NCAA share the responsibility of players' brain health.

Limitations

There were three main limitations to this investigation. First, data regarding injuries were collected from online databases that were not confirmed using official medical records. While this is certainly a methodological limitation in terms of external validity, I argue that the primary goal of these sites, to inform those who are willing to bet money on the performance of these teams, supports the claim that they are accurate. Second, many of the indicators that could have been useful in creating a factor that captured the types of pressure that lead to head injury and a reluctance to report those injuries, this study was limited to publically available data. While many of the indicators were able to be found online, some of the indicators that would have been useful (e.g., merchandise sales, program budget, alumni network size) were not publically available. Third, there are limitations in generalizability. The results cannot be extended to teams from other divisions, other sports, or other years. However, since many of the indicators develop over long periods of time (a team's historical win:loss record or stadium size, for instance), we would expect to find an enduring pattern across years.

Future research should include the contributions of football culture into models designed to predict concussion identification by individual athletes. By employing techniques like multilevel modeling, researchers can make better use of the Social-Ecological Framework, including indicators of *Program Prestige* – or pressure to avoid a concussion diagnosis – in the appropriate levels of the model. Like past research, which is limited by its focus on the individual, these findings account for a meaningful, though incomplete, piece of the factors constrain concussion reporting and, thus, players' health behavior.

Conclusion

This study makes two primary contributions to the literature on concussion risk. First, this study is the first to use publically available data to create an indicator of a cultural factor theorized to influence concussion risk in American football: *Program Prestige*. This factor represents pressures evident at both the macro- and exo-level. Interdisciplinary researchers could benefit from this method, in combination with traditional estimates of individual-, micro-level, and meso-level factors to provide a more comprehensive examination of the factors that influence concussion-reporting behavior. Second, the cultural variable was positively associated with indicators of concussion risk: head and neck injuries. The implications of this research relate directly to the growing body of literature regarding concussions in collegiate sports. Specifically, this study highlights constraining nature of culture for football players that increase their risk for head and neck injuries.

In recent years, there have been calls by the NCAA and NFL to “change the culture” of concussions (Belson, 2016). These efforts have included policy change (especially regarding high-risk tackling strategies), technological advances, and explorations of the factors that contribute to non-reporting. There have been few empirical investigations that have been able to examine the impact of “culture” on concussion reporting although many (Kerr, et al., 2014; Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015) argue for the importance of the social-ecological model which highlights the overarching influence of culture on institutional and personal settings that influence individual behavior. One of the most likely reasons concussion and health researchers have not examined cultural influence is because this information is difficult to obtain. Instead, studies rely on athletes’ perceived “pressure” not to report, or athletes’ sense that their efforts to report would be supported. These types of data are important. However, as articulated by a systems model, it is also critical to understand the remaining spheres of influence, that range from the thoughts and feelings of important people in the athletes’ world to the broad institutional concerns and policies and cultural pressures that influence the game and its popularity with the American public. Thus, this study begins to shed light on possible components of what the NCAA refers to as "culture" that might influence concussion reporting behavior. Implications of this work are not limited to methodological advances for constructing cultural-level variables. The awareness that there are cultural influences related to player brain health are important for all, including players, coaches, and athletic trainers, by virtue of their endorsement of football as a national pastime and form of entertainment, contribute to the very factors that may put players at increased risk for concussion.

Additionally, many of the indicators that are found within this cultural pressure are far easier to change than an abstract concept like "football culture" – though these analyses are correlational, the NCAA may use these findings to justify policies that regulate facets of this pressure and, thus, may have an effect on the accurate reporting of concussions. Capping coaches' salaries, for instance, may begin to constrain the financial pressure that affects injury reports. However, given the multi-billion-dollar industry that is the NCAA's football programs, it is unlikely that such a financially successful organization would make choices that could negatively affect their profits.

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Table 1

Brief summary of existing research investigating individual-level variables that contribute to concussion non-reporting.

Author (year)	Model used	Outcome(s)	Individual level variables used	Finding(s)
Baugh, Kroshus, Daneshvar, & Stern (2014)	Theory of Planned Behavior	Frequency of concussion non-reporting	Perceived levels of support from (1) coaches and (2) teammates	Perceived coach support is a significant predictor of concussion reporting
Chrisman, Quitiquit, & Rivara (2013)	Health Belief Model	Identification of barriers for concussion reporting	Knowledge of symptoms and possible consequences of non-reporting	Focus groups revealed athletes' desire to not report concussions
Kaut, DePompei, Kerr, & Congeni (2003)	Theory of Reasoned Action	Concussion symptom history and behavioral responses	Knowledge of concussion symptoms	Deficiency in knowledge and connom practice of non-reporting
Bramley, Patrick, Lehman, & Silvis (2011)	Theory of Planned Behavior	Concussion-symptom reporting	Previous history of concussions, player's knowledge of concussion symptoms, importance of competitive context (game vs. scrimmage)	Athletes who have experienced concussions in the past (and, thus, have personal experience) are more likely to report
Register-Mihalik, Guskiweicz, McLeod, Linnan, Mueller, & Marshall (2013)	Theory of Planned Behavior	Intentions to report concussion symptoms	Attitude, perceived norms, and perceived behavioral control	Attitude, norms, and behavioral control were all related to intention which was related to reporting
McCrea, Manneke, Olsen, Leo, & Guskiewizcz (2004)	Health Belief Model	Concussion symptom reporting, reasons for not reporting a concussion	Previous history of concussions, knowledge of symptoms	Lack of knowledge of the consequences of reporting concussions was the most common reason for non-reporting

Table 2

Rotated PCA solution with loadings less than .35 suppressed.

Indicator	Component 1	Component 2	Component 3	Component 4
Twitter Followers	.86			
Stadium Capacity	.84			
Facebook Followers	.83			
Season Ticket Price	.83			
Head Coach’s Salary	.82			
Instagram Followers	.79			
Win/Loss Record	.75			
NFL Alumni	.68			
University Enrollment	.40			
Drive: Achievement		.82		
Drive: Reward		.77		
Drive: Affiliation		-.57	.56	
Drive: Power			.92	
Drive: Risk				.87

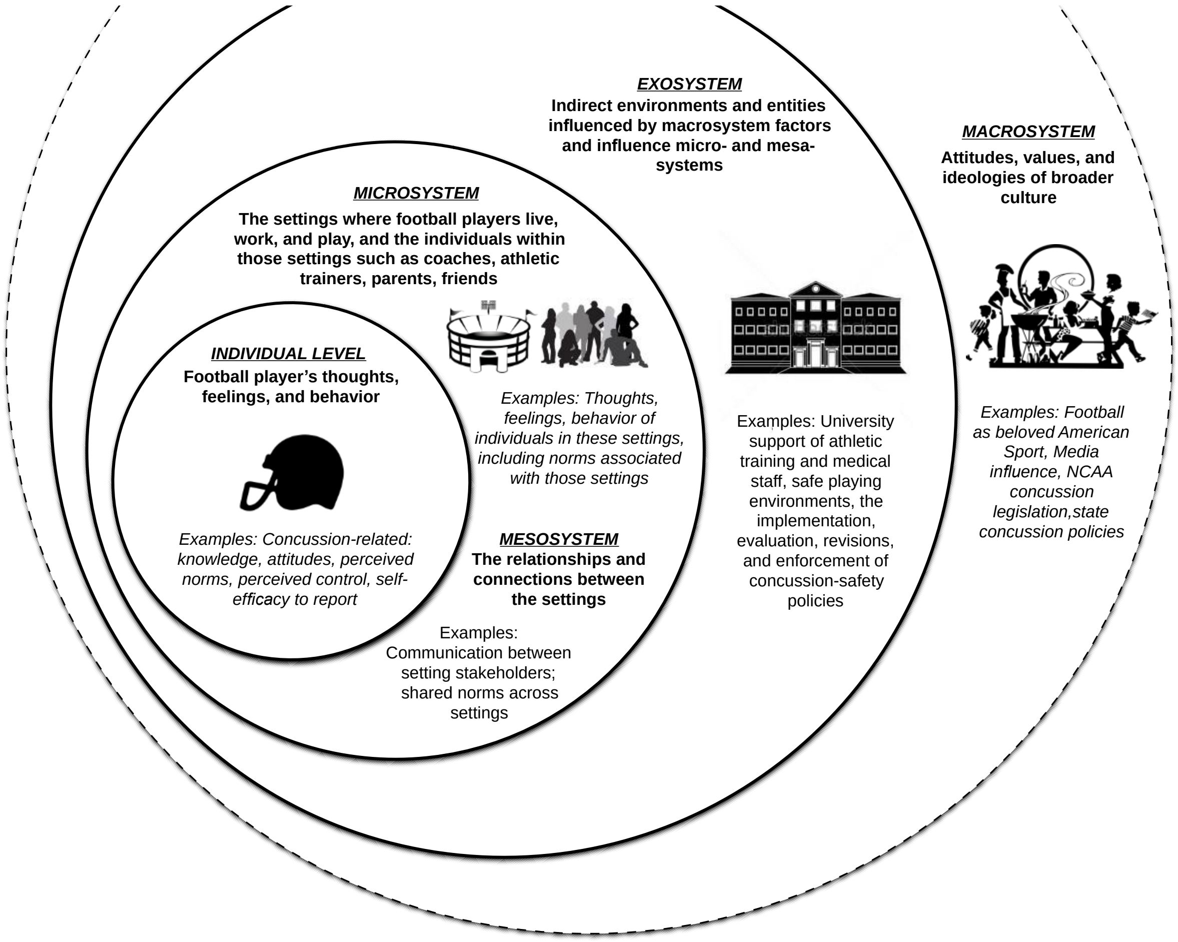

Figure 1. The ecological framework highlights the importance that each nested level has on a player's experience. See text for details.

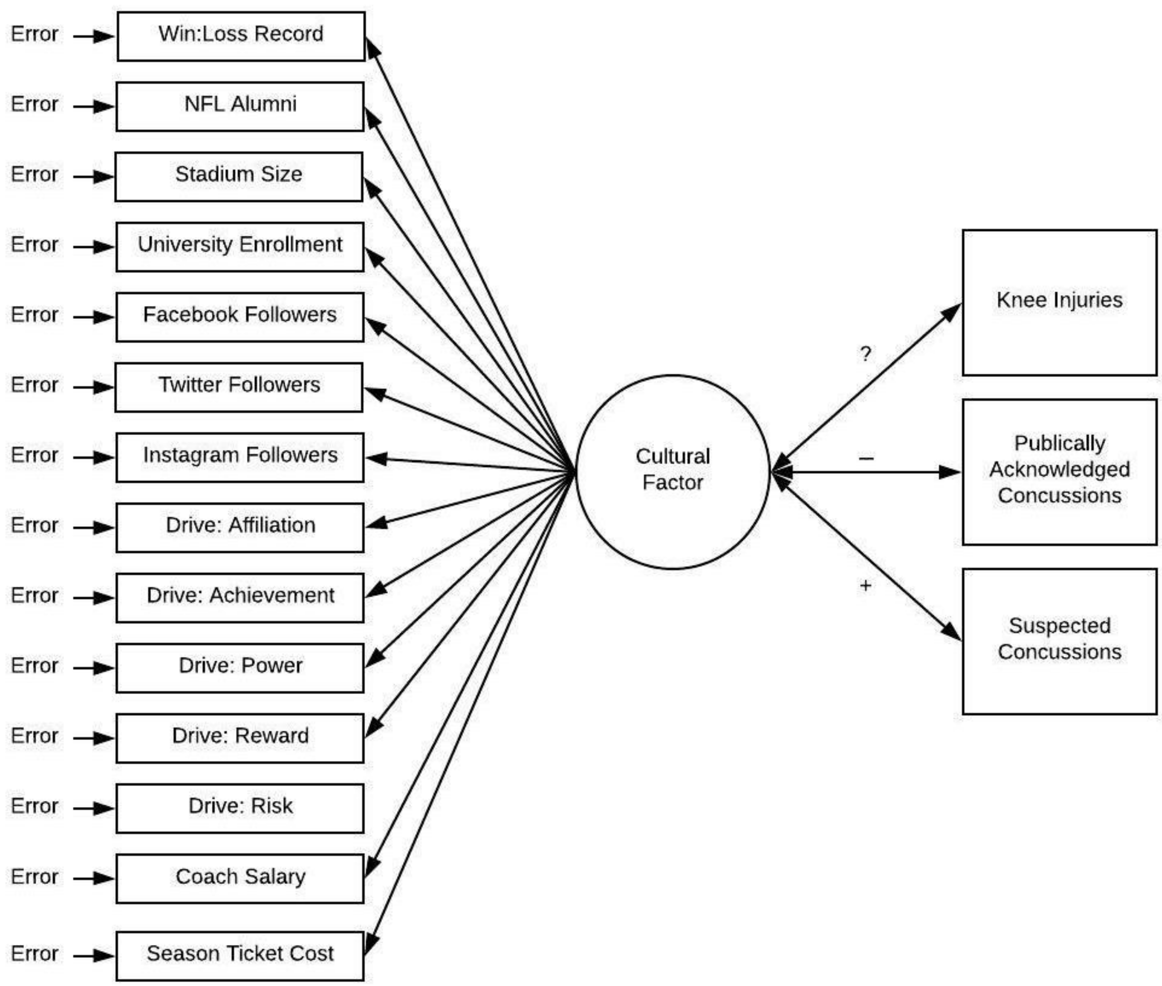

Figure 2. Example of how observable variables created from publically-available data contribute to a cultural factor which is negatively related to Publically Acknowledged Concussions and positively related to suspected concussions. No prediction was made regarding knee injuries.

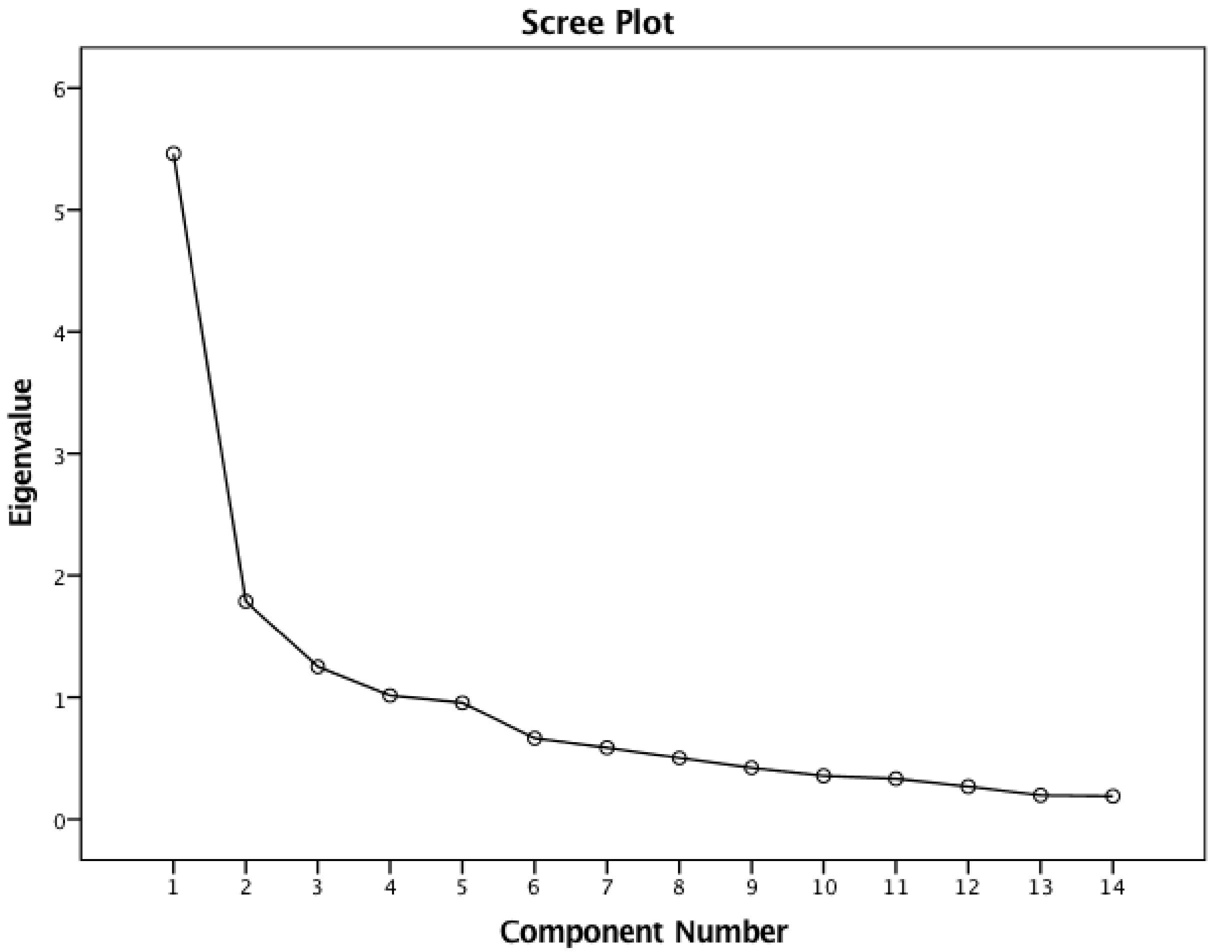

Figure 3. A scree plot indicating the results of the Principal Components Analysis.

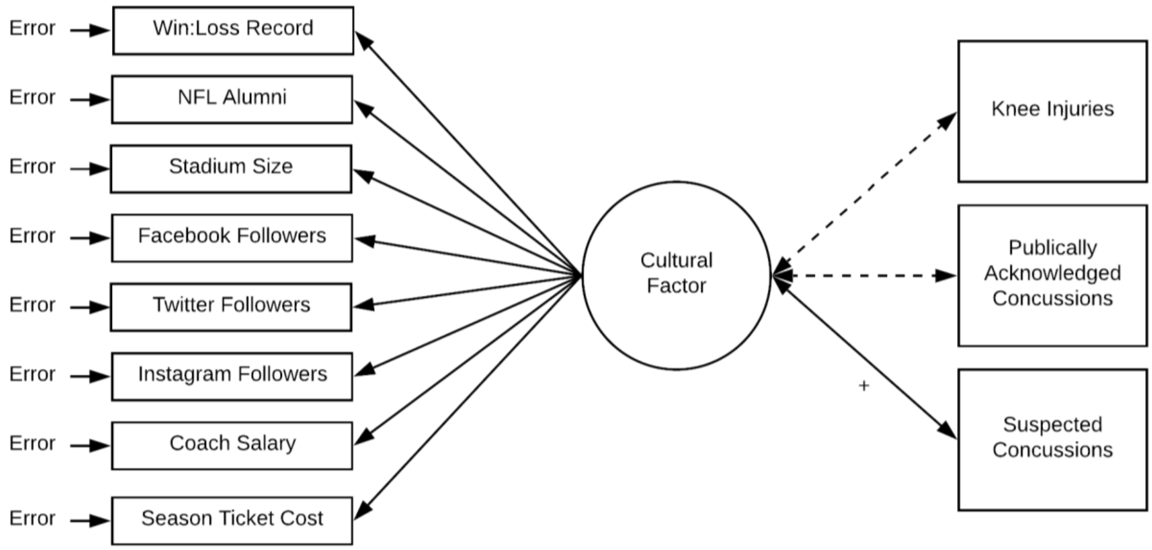

Figure 4. The hypothesized model was partially supported by the construction of a cultural variable and its relationship to injury reports.

Appendix A

Full code used to mine and organize Twitter data with annotations. API access information (analogous to the researcher's password) has been replaced with ***. For information about APIs, including requesting access information, go to http://apps.twitter.com.

Read in the list of Twitter accounts from the CSV containing all thesis variables.

```
library(readxl)
Thesis_Variables <-
read_excel("~/Dropbox/THESIS/Thesis_Variables.xlsx")
tsn <- Thesis_Variables$TwitterSN
```

Load relevant packages used to access the Twitter API and format Twitter data.

```
library(twitteR)
library(bitops)
library(RCurl)
library(RJSONIO)
library(stringr)
api_key <- "***"
api_secret <- "***"
token <- "***"
token_secret <- “***"
setup_twitter_oauth(api_key, api_secret, token, token_secret)
```

The following code it to be used only during the first data collection. In later collections, the researcher can either:

- comment out the entire chunk by adding a # to the beginning of each line or
- separate this code into two separate R files.

The second option may be easier if the process is being automated through a third-party application like Automator. That way, the initial code would be run a single time and the update code will be run as needed by the researcher.

In this next section, all tweets since August 1st, 2017 from each team are requested through the API. These tweets (along with meta-data from them like number of likes and timestamp) are then saved into a single CSV titled with the name of the Twitter account.

```
for(i in 1:130) {
      tweets <- userTimeline(tsn[i], since=2017-01-08)
      tweets.df <- twListToDF(tweets)
      name <- paste(tsn[i],".csv",sep="")
      write.csv(tweets.df, file=name)
      }
```

Before we get into collecting the rest of the tweets, I want to make sure that my data collection is not redundant. To do so, I am going to use date markers to stop twitter from pulling too much. This is also useful because if I were to pull the accounts' full timelines each week, I would expect to hit rate-limit before the collection could be completed. These next lines of code generate dates based on the day that the code is run, followed by the date of the week before. These are then formatted to be used with twitteR.

```
date <- Sys.Date()
week <- date - 7
date <- format(date, format="%Y-%d-%m")
week <- format(week, format="%Y-%d-%m")
```

This next code is used to update the CSVs created in the previous chunk with tweets that were posted throughout the rest of the season. By doing this, all text and linguistic analyses can be completed on a single dataset instead of later compiling each. It took quite a while to figure this one out, but it definitely made the process much easier than I was originally expecting

```
for(i in 1:130) {
      earlytweets.df <-
      read.csv(paste(tsn[i],".csv",sep=""),header=TRUE,sep=",")
      newtweets <- userTimeline(tsn[i], since=week)
      newtweets.df <- twListToDF(newtweets)
      earlytweets.df$X <- NULL
      updated.df <- rbind(earlytweets.df,newtweets.df)
      write.csv(updated.df, file=name)
}
```

The last step involved using the Mac application Automator to run this code weekly. Each week, these CSVs are updated and re-saved into my Dropbox which I scheduled to give me notifications when this process was completed – that way I was able to monitor the code by making sure I was receiving 130 notifications each week.

Appendix B

Example of code used to mine and organize html data with annotations. This code pulled win-loss record (wlr) for each team from a Wikipedia page.

Load in package used to pull data from html formatted websites.

```
library(rvest)
```

Save as an object the source site and use rvest to access the site.

```
wiki <- read_html('
https://en.wikipedia.org/wiki/NCAA_Division_I_FBS_football_win-
loss_records ')
```

Now that the website is loaded, this next step reads in the site in its http format. Next, it identifies all tables found on the page. The last bit of code here selects the third table on the page (which is the table that includes the data of interest) and disregards the others. Overall, this saves just the table that has the following variables: Team, Won, Lost, Tied, Pct., Years, Total Games, and Conference as the object "wlr."

```
wlr <- wiki %>%
      html_nodes('table') %>%
      html_table(fill=TRUE) %>%
      .[[3]]
```

Though the table included a metric regarding the teams' percentage of won games, these numbers were not accurately calculated based on the number of games listed in the table. Before exporting these data into a CSV to be included in the primary dataset, I created a new column (titled "Percentage") using the following code that calculated a new percentage of total games won per team.

```
wlr$Percentage <- wlr%Won/(wlr$Won+wlr$Lost+wlr$Tied)
```

Finally, the data were exported to a CSV to be included in the primary dataset.

```
write.csv(wlr, file="wlrpercentages.csv")
```

Appendix C

Variables collected for each team.

Name	Mean (SD)	Minimum	Maximum	Cases Missing
Twitter followers	121198.54 (175072.19)	3720	909000**	0
Facebook followers	171776.87 (295224.79)	1362	1633514	0
Instagram followers	56457.85 (107612.79)	365	752600**	0
Season ticket price (USD)	188.03 (132.46)	48	715	5 (4%)
Home capacity	56193.53 (21971.38)	5248	107601	15 (12%)
Head coach's salary (USD)	2312960.11 (1903731.49)	376044	11132000	10 (8%)
University enrollment	28500.81 (13113.50)	4237	65302	1 (<1%)
Drive: Affiliation	3.54 (1.74)	0.77	11.21	0
Drive: Achievement	1.74 (.92)	0.16	6.41	
Drive: Power	2.71 (1.39)	.43	12.77	0
Drive: Reward	1.45 (.68)	0.18	3.22	0
Drive: Risk	0.11 (0.11)	0.00	0.50	0
Total Win:Loss record	0.54 (0.09)	0.29	0.74	1 (<1%)
NFL alumni	14.13 (11.23)	0	47	4 (3%)
Concussions	2.38 (3.88)	0	15	0
Suspected concussions	1.16 (2.66)	0	17	0
Knee injuries	12.63 (12.25)	0	55	0

**Twitter and Instagram truncate number of followers exceeding five digits– this means that these numbers are rounded to the nearest hundred.

Appendix D

List of sources for cultural indicators and injuries.

Variable Name	Source	Website Link	Approximate Date Collected	Method
Injuries	StatFox	http://www.statfox.com/cfb/injuries.asp	Various	rvest package
Win:Loss Record	Wikipedia	https://en.wikipedia.org/wiki/NCAA_Division_I_FBS_football_win-loss_records	February 2018	rvest package
NFL Alumni	ESPN	http://www.espn.com/nfl/college/	October 2017	rvest package
Stadium Size	Wikipedia	https://en.wikipedia.org/wiki/List_of_American_football_stadiums_by_capacity	February 2018	rvest package
Total University Enrollment	US News & World Report	https://www.usnews.com/best-colleges/search?_mode=table	February 2018	manual*
Social Media Followers	Twitter, Facebook, & Instagram	http://www.twitter.com http://www.facebook.com http://www.instagram.com	November 2017	manual*
Teams' Language on Twitter	Twitter	http://www.twitter.com	Various	twitteR package

*Due to the nature of these sites, data collection could not be automated. Instead, these metrics were collected by the first author by looking up each individual institution and copying and pasting the relevant information into a spreadsheet. While this process is certainly not ideal, it is necessary when site structures make automation challenging or impossible