The impact of NFL kickoff rule changes on player injuries: Forgoing excitement to reduce injuries?

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The impact of NFL kickoff rule changes on player injuries: Forgoing excitement to reduce injuries?

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Recognizing the increased danger during kickoff returns, the National Football League and National Collegiate Athletic Association changed rules aimed to reduce player injuries. Using a two-stage model, we examined the impact of rule changes on kickoff returns to the rate of player injuries. We estimated the impact of the changes on the number of kickoff returns using a difference-in-difference approach; from these estimates we created an instrumental variable measuring the local average treatment effect of the NFL rule change on player injuries. Our findings suggest that moving the kickoff location decreased both the likelihood of kickoff returns and player injuries.

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American football has reached a dramatic crossroad. On one hand it has overtaken baseball as the most popular sport within the United States, dominating TV viewership numbers in September 2017 with six of the top ten weekly shows being NFL games.(Steinberg 2017) Yet this popularity is juxtaposed with the increasing media attention paid to the inherent dangers of the sport which has seen a reduction in youth participation and has generated a great deal of uncertainty for the game's future.(Nuckols 2017) The media coverage surrounding player injuries has increasingly centered on player concussions, fueled by clinical study findings indicating that long-term risks from repetitive head injuries are associated with the development of chronic traumatic encephalopathy (CTE) later in life.

This increased press attention on the dangers of repetitive head injuries has coincided with the slowing of participation among youth football players. In response, rule-makers at all levels of

American football have made rule changes intended to increase player safety. The primary focus of this paper is on rule changes implemented in collegiate and professional football. In recognizing the rising need to protect players combined with increasing public pressure; the National Collegiate Athletic Association (NCAA) and the National Football League (NFL) implemented several new rules and rule changes. While these rule changes included changing the legal area in which players can hit one another and penalizing players for leading with the crown of their helmet on tackles; one of the most fundamental rule changes each league implemented was aimed at reducing the occurrence of what is perhaps the most dangerous play in football – the kickoff.

The primary goal of our paper is to examine the impact of rule changes that govern kickoffs in the NFL on player injuries. We use a two-stage approach that is designed to circumvent a lack of data to link injuries to a specific play. In the first stage, we estimate the causal impact that each rule change has on kickoff outcomes to create measures of player exposure to injuries related to rule changes using data from the NFL and the NCAA. Our second stage utilizes the first-stage estimates as an instrumental variable to estimate the local average treatment effect of the change in exposure to injury related to rule changes on player injuries.

I. Background

A. Health Impacts of Kickoffs:

One of the key characteristics of a kickoff is the free-running nature of the play. Unlike other plays where the majority of the players are immediately engaged with one another; kickoff returns begin with a large distance between the kicking and receiving teams. The free-running aspect of kickoffs creates both excitement and exposure to injury. Kickoff returns are fast paced, often with the possibility of game-changing plays. There is also an increased risk of injury because the distance between the two teams allows unimpeded players to reach top speed before initiating contact with the opposing team.(Ocwieja et al. 2012)

The elevated risk of kickoff returns is supported by academic studies which have found that kickoff returns are associated with 13.6% to 30% of all injuries suffered during games. (Prevention 2010, Houck et al. 2016) At the forefront of football injuries, concussions have drawn the most attention. Recent studies have emphasized the short- and long-term impact that concussions can have for NCAA and NFL players. Zuckerman and colleagues estimated that from the 2009-2010 to 2013-2014 NCAA seasons, there were 3,417 annual reported concussions for collegiate football players. (Zuckerman et al. 2015) In comparison, this same study found that the next highest collegiate sport, women's soccer, had 1,113 annual reported concussions. Evidence of the increased risk of injuries and concussions associated with kickoff returns has also been reported in the NFL. Estimates for NFL head injuries occurring on kickoff returns range from 2.2 to 4.4 concussions per 1,000 kickoffs. (Ruestow et al. 2015)

The increased exposure to injury during kickoff returns is primarily a function of the mechanics of the play and the bio-mechanics of the players. Unlike other types of plays, kickoffs occur with at least 15-yards of separation between kicking and receiving teams. This means that players from opposing teams are exposed to collisions at relatively high speeds because the players have room to accelerate before contact is made. The speed at the point of contact greatly increases the risk of an injury, particularly of a concussion. The bio-mechanical aspect of players' injuries was first studied by Ocweija and colleagues who found that the relative acceleration and head impact between players in the NCAA were significantly associated with player concussions as well as other types of injuries. (Ocwieja et al. 2012) Further, they reported that long closing distances ("when the striking player and player struck had traveled a combined distance of ten or more yards prior to the collision." (Ocwieja et al. 2012)) on special teams plays (i.e. kickoffs and punts) resulted in the most severe impacts during NCAA football games. Long closing distances such as those that often occur during kickoffs were further associated not just with severe impacts but severe head impacts compared to offensive and defensive plays from the line of scrimmage. (Ocwieja et al. 2012)

If a league wanted to reduce player exposure to injury, then reducing the number of kickoff returns is the logical place to start. Based on the various studies, simply removing the danger posed by reducing the contact through limiting the number of kickoff returns would tend to serve as a deterrent of player injuries. (Adelson 2012, Johnson 2012, Ruestow et al. 2015, La Canfora and Press 2011). Rather than eliminate kickoffs, both the NFL and the NCAA decided to change the rules governing kickoffs to reduce, but not eliminate, kickoff related exposure to injury. Both leagues moved the starting kickoff location forward to reduce the probability that the ball would be returned. In addition, the NCAA and NFL also limited the distance that the kickoff team could line up behind the kickoff location to only 5-yards, which limits running starts by the kickoff team in order to reduce the speed at which impact occurs during a return. Based on studies such as those performed by Ocweija et al., limiting the distance of impact between two players would likely reduce player injuries. (Ocwieja et al. 2012) However, others have noted that these rules likely underestimate the distance at which athletes can reach their top speed. Consider that research on athlete speed has found that athletes who participate in field and court sports are able to reach their top speeds at a distance between 30-45 meters (33-50 yards). (Association 2013) However, this same research also found that most athletes will reach 90% of their top speed in half that distance (15-22.5 m = 16-25 yds). (Association 2013) When viewed from this 90% lens, the 15-yards between kicking and receiving players suggests that combined impact for both players would be categorized in the riskier 'long distance' collision and would likely occur at very high speeds.

From a health perspective, we know that kickoffs are responsible for a greater number of player injuries and concussions than any other football play. These injuries are primarily due to the free-running nature of the play; players collide at great speeds, generally running unimpeded before colliding with one another. It is this bio-mechanical feature that leads to player injuries, and implies that limiting the 5-yard running-start is unlikely to be an effective way to reduce injuries. However, it is clear that reducing or eliminating kickoff returns would prevent injuries by limiting exposure.

B. Kickoffs and Strategy:

A kickoff is a play that occurs at the beginning of each half (1st and 3rd quarters of an American football game) and after either team scores. There are generally two results that occur after a kickoff[1], either a kickoff return or a touchback. A kickoff return is when the receiving team attempts to advance the ball after it is kicked and ends when the player returning the ball is either tackled, runs out-of-bounds, advances the ball for a touchdown, or loses control of the ball. A touchback occurs when the kicked ball travels beyond the goal-line, resulting either in the ball traveling out of the back of the end-zone or a player catching the ball in the end zone but not advancing beyond the goal-line.

Kickoffs determine where the receiving team will begin on offense. Receiving teams seek to advance the ball as far forward as possible, whereas the kicking team attempts to impede this advance. A touchback is analogous to a truce, where the location of the ball is determined by rules of the game and a return is avoided. Touchbacks prevent the high-speed contact between opposing

1 There are technically more than two results, but these are very rare, and do not fall into the scope of our study as currently constructed.

teams after a returner catches the ball. In the context of the game, coaches make strategic decisions that presumably maximize the expected number of wins over the course of a season. Coaches decide whether to instruct a kicker to kick the ball into the end zone to encourage a touchback or kick it in the area of the field that is likely to induce a return. These decisions take into account where the ball was kicked from and where the ball is placed after a touchback. Kicking location matters because placement close to the end zone makes it more likely that kickers can consistently kick the ball into the end zone. In addition, the kicking team would line up closer to the end zone increasing their ability to impede the opposing teams progress sooner. Coaches' decisions will also consider the placement of the ball after a touchback. If placement of a touchback is at the 20-yard line, coaches may prefer that their kickers attempt to kick for touchbacks because they are guaranteed that the opposing team would not progress farther. This avoids the potential for an explosive kickoff-return and leaves the opposing team with a greater distance needed to travel to score. However, if the touchback starting location was changed to the 25-yard line, coaches would reconsider strategic touchback decisions because the opposing team would be 5 yards closer to the ultimate goal of scoring points.

C. NFL and NCAA Kickoff Rule Change History

Prior to the start of the 2007 college football season, the NCAA rules committee voted to move the starting kickoff location to induce more kickoff returns. More specifically, the NCAA moved the line from where the ball will be kicked 5-yards further from the end zone (i.e. the area where a touchback could occur). Kickers had to kick the ball over 70-yards to induce a touchback versus 65 yards prior to the change. In addition, the teams would have to travel an additional five yards before making contact, which could favor a return. This rule change made it more difficult to kick deep into the end zone and consequently more likely that the receiving team would run back a kickoff in order to improve field position. (Adams 2007) The NCAA's stated reason for the 2007 rule change was a desire to increase the excitement of the game. (Brunt 2007) The 2007 rule change was implemented despite opposition from coaches who expressed fears that the rule change would increase player exposure to injury by increasing the number of kickoff returns, potentially increasing the risk of player injuries. (Brunt 2007)

Between 2007 and 2010, both the NCAA and NFL had identical rules governing the starting position of a kickoff (70 yards from the end zone). During this same period, a series of studies were published about the link between playing football in the NFL and the development of several types of brain disorders in later life. Associations from these studies were particularly concerning because the findings suggested that these brain injuries were likely associated with repetitive head collisions. (Guskiewicz et al. 2005, Lehman et al. 2012, Pellman et al. 2004, Ruestow et al. 2015) As these studies gained wider public attention, the NCAA and NFL began discussing and implementing various rule changes in their attempts to address exposure to injuries. Among these changes were the kickoff rules. The NFL acted first before the 2011 season and moved the kickoff location 5 yards closer to the opposing team's end zone (i.e. 65 versus 70 yards away) (La Canfora and Press 2011, NFL 2011). By moving the kickoff starting location, the NFL intended to increase touchbacks. In addition, the NFL limited the distance kickoff coverage players could accelerate before contact intending to reduce the speed at which collisions would occur. Both of these changes were expressly meant to reduce the frequency of injury on kickoffs. (Ruestow et al. 2015)

The NCAA followed suit the next season and implemented new kickoff rules for the 2012 season. (Redding 2012) The NCAA adopted the same rules as the NFL, but it also moved the ball placement following a touchback from the 20 to the 25-yard line. (Redding 2012, Johnson 2012) This change in ball placement reduced the incentive of the kicking team to force a touchback by kicking the ball into the end zone and increased the countervailing incentive of the receiving team to accept a touchback because of the more favorable ball placement. As with the NFL, the express intent behind this rule change was to curb the frequency of kickoff returns. The NCAA gave similar public statements, giving clear reasoning as to their decision moving the kickoff starting location to the 35-yard line. Yet, there was little explanation why the NCAA adopted the 25-yard line touchback placement portion of the rule other than vague references explaining that they did not want to harm offenses' ability to score. (Adelson 2012)

The differential timing of the rule changes for each league and the subsequent movement of the kickoff restraining line (NFL in 2011, NCAA in 2007 and 2012) and touchback location (NCAA in 2012) enables us to estimate the impact of the rule changes on the number of kickoff returns and thereby exposure to injury. As shown in Figure 1, the differential timing of the rule changes allows us to estimate the impact of both the kickoff and touchback location rules on kickoff returns during our 2005-2013 sample period. The NFL rules were stable between 2005-2010 with kickoffs occurring 70 yards from the end zone and the touchback ball placement 20-yards from the receiving team's end zone. In 2011, the NFL moved forward the kickoff location 5 yards (65 yards from the end zone) while touchback ball placement went unchanged. Figure 1 also displays the timing of the two NCAA rule changes. The NCAA initially had kickoffs occur 65 yards from the end zone with touchback ball placement at the 20-yard line during the 2005-2006 seasons. This was followed by the 2007-2011 seasons where kickoff location was moved back 5 yards, or 70 yards from the end zone, while touchback ball placement went unchanged. Then the NCAA again changed their kickoff location rules for the 2012-2013 seasons by moving the kickoff location forward 5 yards, or 65 yards from the end zone, and moved the touchback ball placement to the 25-yard line.

[Insert Figure 1 Here]

II. Data and Sample

A. Data

Data for our study is comprised of three unique data sets that are combined for each stage of the analysis. In the first stage analysis, we combined detailed play-by-play data for all NCAA and NFL games to model the probability of a kickoff return conditional on a kickoff occurring. Next we link the effect of the rule on kickoff returns to estimate the resulting impact on injuries using reported player injury information for the NFL to measure the association between kickoff returns and player injuries specifically associated with kickoff returns in the previous literature.(Hootman, Dick, and Agel 2007, Ruestow et al. 2015) Unfortunately equivalent injury data is not available from the NCAA.

NCAA play-by-play data was acquired from cfbstats.com (2013) and was accessed using the cached pages through the Wayback Machine.(Prevention 2015) The data includes information on every college football play during the 2005-2013 seasons. NFL play-by-play data was acquired through Armchair Analysis (Erny 2017) and includes the same game information, as the NCAA play-by-play data, for every NFL play during the 2005-2016 seasons. Injury data for the NFL was acquired from Football Outsiders Inc. (Schatz 2017) and includes information on weekly team-provided player injury information for the 2005-2013 seasons.[2]

2 Note that the Football Outsiders data is not currently a publicly available data set. It was provided for this study through the direct consent of Football Outsiders Inc. and must be requested from them.

B. Sample

We limited the combined play-by-play data to include only kickoffs in our primary analysis. This combined dataset is organized chronologically by within-game kickoff (first kickoff followed by each other kickoff that occurs during the game regardless of team) and includes a variety of potential control variables that reflect game-level factors, including: time left within the game; location of the game; current within-game score; the results of each kickoff; and the win percentage of the team and their opponent entering the game.

We limited this primary sample to NCAA and NFL regular season games yielding a balanced panel for all teams in our sample. We also limited the NCAA data to teams that played in a 'Power Conference'[3] and their opponents because the skill of the kickers and game strategy is more like the NFL than lower tier conferences.

The NFL injury sample is narrowed to include players who are likely to play on special teams and who have new injuries only. After careful consideration we only excluded quarterbacks from the injury sample because other position players may be on the field during a kickoff. While an argument can be made that we should not include 'star' players, the only definitive case of players unlikely to play on special teams and kickoffs are quarterbacks. Only the first instance that a specific injury is reported is included in the sample, we excluded injuries that are listed in consecutive weeks because they reflect the same injury. This allows us to focus on new injuries and exclude those with chronic or season long injuries that led them to appear every consecutive week.

III. Empirical Strategy

A. Approach Overview

Our econometric approach consists of two stages. In the first stage, we estimate the effect of the rule changes on the probability of a touchback occurring. The estimated probability of a touchback is used to measure the exposure to injury and how it changed in relation to rule changes. This was

3 Power conferences are defined by the NCAA and are made up of those schools belonging to conferences that are automatically granted spots in the major bowl games. The conference membership tied to a specific season is necessary since teams change conferences and Power Conferences may change over time. It should also be noted that in this Power Conference group is Notre Dame which does not belong to a conference but is allocated a spot in one of the major bowl games if they finish above a certain threshold in the NCAA end of regular season rankings.

used to compute the predicted probability of a kickoff return (inverse probability of a touchback occurring explained in detail below). To achieve this, we complete the following steps:

(1) Estimate a model of the probability of a touchback occurring
(2) Calculate the predicted probability of a touchback
(3) Calculate the counterfactual which is the probability a touchback would have occurred absent the respective NFL and NCAA rule changes.
(4) Calculate the change in exposure, which is the difference between the predicted probabilities under the actual rules and the counterfactual.
(5) Calculate each kickoffs probability of being returned and count the number of kickoffs predicted to be returned to the game-season level. [4]

The estimated exposure variables (step (4)) calculate the change in the number of touchbacks attributable to the NFL and NCAA rules. Step (5) is needed to generate the predicted number of returns[5] in each game which is used as an instrumental variable in the second stage injury model.

B. Probability of a Touchback

We estimated probability of a touchback using difference-in-differences estimation. Specifically, the probability that kickoff (*i*) for a team (*j*) during game (*g*) in season (*s*) resulted in a touchback (*Y*) as follows:

$$(1)\ P\left(Y_{ijgs}=1\middle|\bar{Z}\right)=\beta_0+\beta_1\,Kickoff\,35\,Yd_{ijgs}+\beta_2\left(NFL_{ij}\times Kickoff\,35\,Yd_{ijgs}\right)+\beta_3\,NCAA_{ijgs}+\beta_4\left(NCAA_{ijgs}\times Kickoff\,35\,Yd_{ijgs}\times Touchback\,25\,Yd_{ijgs}\right)+\beta_5\,\bar{X}_{ijgs}+\beta_6\,Game\,Month_{ijg}+\beta_7\,Quarter\,Trend_{ijg}+\varepsilon_{ijgs}$$

where $Kickoff\ 35\ Yd_{ijgs}$ =1 when the kickoff was at the 35 yard line and is 0 otherwise; $NFL_{ijgs}\times Kickoff\ 35\ Yd_{ijgs}$ represents the difference in touchback probability between the NFL from the 35-yard line compared to the NCAA; $NCAA_{ijgs}$ equals 1 if NCAA game and equals

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4 It is possible that injuries could occur during kickoffs that result in touchbacks, but without being able to capture the inj uries specific timing we initially assume that injuries occur only during returns given that impact is considerably more likely than when kickoffs result in touchbacks. Thus the probability of a kickoff return is equivalent to 1-P(Touchback) as we treat the result of a kickoff as a dichotomous variable where the only options are a kickoff resulting in a touchback or return.

5 Discussed later, the focus is switched from touchbacks to kickoff returns as returns are the result of kickoffs that are more likely to result in player injuries. The rule changes explicitly emphasized increasing touchbacks while implicitly emphasizing decreasing returns.

0 if it is an NFL game; $NCAA_{ijgs} \times Kickoff\ 35\ Yd_{ijgs} \times Touchback\ 25\ Yd_{ijgs}$ equals 1 if the kickoff occurred in an NCAA game when the kickoff was at the 35 yards line and touchback ball placement was at the 25 yard line; $\bar{X}_{ijgs}$ is a vector that includes control variables; $Game\ Month_{ijg}$ is a vector of month fixed effects; $Season\ FE_s$ is a vector of season fixed effects; $Quarter\ Trend_{ijg}$ varies from 1-4 reflecting each of the four quarters in a game; and ε_{ijgs} is the error term.

The primary focus from this model is on the kickoff-location-specific variables. The effect of moving the kickoff to the 35-yard line regardless of the specific league is given by the coefficient (β_1) for the variable $Kickoff\ 35\ Yd_{ijgs}$ and the coefficient (β_2) for interacted variable $NFL_{ij} \times Kickoff\ 35\ Yd_{ijgs}$ measures the incremental impact of kickoff location in the NFL. The coefficient β_4 measures the incremental impact in the NCAA of ball placement at the 25-yard line after a touchback. We estimated Equation 1 without fixed effects, with season fixed effects, and with season and team fixed effects. Each specification control for team and game specific variables that are accounted for in the vector $\bar{X}_{ijgs}$. These include: time left within the game, location of the game (home or away), current within game score, whether the game is a conference game[6], and the win percentage of each team prior to the start of the specific game.

Eq. (1) is used to estimate both the marginal effects of each variable and the predicted probability of each kickoff resulting in a touchback. Using the predicted probabilities, we estimated the exposure variables for each rule change by summing the predicted probabilities to the *season* level.[7] Each exposure variable can be interpreted as the number of touchbacks that would not have occurred had the given rule change not occurred. Because kickoffs result in either a return or a touchback, it can be thought of as the number of returns averted by the rule change. This distinction will be key in the second-stage of the analysis.

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6 Measured in two ways for the NFL. The first is that a conference game is simply a game where a team faces an opponent within their own division (there are 8-divisions consisting of 4 teams each) the second is measured as a team facing a team within their own conference (there are two conferences made up of 16 teams each). The second measured is used as the goal is to measure commonality and the NFL uses a formula where each team will play each other team in their own conference at least once every three years and teams in the other conference at least once every four years.

7 If we had access to the NCAA injury data, it would make more sense to sum the exposure to the game-season level, so we could tie the different changes in exposure to specific games. Without this data we have no comparison group which necessitates not only and IV approach but makes using the Exposure variables meaningless in the second stage of the analysis. Please see the appendix for further discussion.

C. Estimating the effect of rule changes on injury

We estimated the effect of the NFL rule changes on the number of injuries to translate the change in returns into a change in actual injuries. One approach would be to simply obtain the marginal effect of an additional return on the number of injuries using the entire sample period and assume that a kickoff return is exogenous. However, the number of kickoff returns may be endogenous if increased understanding of the risk of injury leads to changes in coaching strategies that factors the risk of player injury into decisions about calling for a touchback versus a return. Thus, we use an instrumental variable approach to measure the local average treatment effect of kickoff returns averted due to the rule changes on the number of injuries.

Eq. (2) presents the reduced form model of player injuries ($\overline{Injuries}_{gs}$) as a function of game-specific variables ($\bar{X}_{gs}$) and the local average treatment effect of kickoff returns ($Actual\ Returns_{gs}$):

$$(2)\ \overline{Injuries}_{gs} = \gamma_0 + \gamma_1 \bar{G}_{gs} + \gamma_2 Actual\ Returns_{gs} + \gamma_3 Report_{gs} + \varepsilon_{gs}$$

The reduced form model in Eq. (2) would suffice if the number of returns per game ($Actual\ Returns_{gs}$) was exogenous. As discussed above, this is highly unlikely. In addition, because our injury data is at the week/team level we cannot tie an injury to a specific play and it is important to isolate variation in returns specifically due to the rule change and estimate the local average treatment effect. We use the predicted number of returns in each game from Equation 1 as an instrument variable (IV) for the actual number of returns. Clearly this IV will predict actual returns. In addition, it credibly satisfies the exclusion restriction because predicted returns will only influence injuries through actual returns. The strength of this approach is that the variation of predicted return will only reflect the rule changes and not other factors. The local average treatment effect interpretation of the complier is returns that were averted by the rule changes and the IV estimate is interpreted as the change in injuries that were due to rule change related returns averted.

We implement the IV using two-stage residual model (2SRI), where we instrument number of returns with the predicted number of returns estimated from Eq. (1). To complete this we estimate Eq. (3) – Eq. (5) below. Eq. (3) estimates the predicted number of returns from Eq. (1) which is the sum of each predicted kickoff return to the *game-season* level.

$$(3)\ \widehat{Returns}_{gs} = \sum\left(1 - P\left(Y_{ijgs} = 1 \middle| \bar{Z}\right)\right)$$

Eq. (4) and Eq. (5) are the first and second stage of the instrumental variable specification, respectively. We use the 2SRI because the number of injuries in a game is estimated using a non-linear Poisson count data model. The 2SRI method (as suggested by Terza et. al) is unbiased when the second-stage is nonlinear and is estimated by including the predicted error term ($\hat{u}_{gs}$) from the first stage in the second stage along with the actual number of returns. (Terza, Basu, and Rathouz 2008)

$$(4)\ Actual\ Returns_{gs} = \delta_0 + \delta_1\ \widehat{Returns}_{gs} + \delta_2\bar{G}_{gs} + \delta_3 Report_{gs} + u_{gs}$$

$$(5)\ \overline{Injuries}_{gs} = \gamma_0 + \gamma_1\bar{G}_{gs} + \gamma_2 Actual\ Returns_{gs} + \gamma_3 Report_{gs} + \gamma_4\hat{u}_{gs} + \varepsilon_{gs}$$

Eq. (5) represents the final model in our analysis of player injuries. Instrumenting number of returns allows us to capture within game factors that affect whether a kickoff results in a touchback or return exogenous of player injuries. This is confirmed by comparing the results of the reduced form model Eq. (2) and the IV model Eq. (5). Both models include two other key variables that are not included or accounted for in Eq. (1). $\bar{G}_{gs}$ is a vector of game level variables, it is made up of game specific factors such as if a game is conference game, month the game occurs in, and the week of the game. Also included is the winning percentage of the home and road team entering the game[8] and we include a group of field specific variables that accounts for game weather factors including the temperature, humidity, and wind-speed; the field vector also includes other factors associated with player injuries in addition the weather variables including dummy variables for whether the game takes place in a dome and if the field the game is played on is turf or natural grass. These variables accounted for by $\bar{G}_{gs}$ either appear in alternative form in Eq. (1) (i.e. team winning percentage) due to the nature of how the second-stage data is constructed or were never

[8] Second-stage data is at the game-season level therefore we do not have team specific information, so instead of estimating team specific winning percentages we use the winning percentages of the home and away teams.

included in the first-stage since they were only available for the NFL data (i.e. weather and field data was only made available for the NFL and not available for the NCAA).

The other key variable that is included in Eq. (2) and Eq. (5) that does not explicitly appear in Eq. (1) is $Report_{gs}$. This variable is a dummy variable equal to one if the game occurs during or after the 2010 season to reflect a change in reporting required by the NFL for how teams report concussions. Though prior to the 2009 season there was considerable research showing the negative association between football, concussions, and development of later life brain diseases; it was not until September of 2009 that the pressure began to build on the NFL to consider the impact of concussions on player health.(Ezell 2013) While the pressure mounted during the 2009 season including Congressional testimony about football and concussions, it was not until December 2nd, 2009 that the NFL instituted the first of many revised 'return to play' guidelines. If we fail to account for this change in the guidelines, the results for Eq. (5) will be biased. To correct for this, we include the 2010 and after dummy variable while also dropping all games in December 2009. We drop the December 2009 observations as the new guidelines were given little time for teams to adapt to the shift in the remainder of the 2009 season, but in 2010 and after they were sufficiently prepared for the new guidelines. It is also important to note that when the coefficient for this variable is positive we could interpret it as the new guidelines increased the number of player injuries. However, more likely the proper interpretation is that after the new guidelines went into place, teams were simply more judicious in reporting player injuries such that the guidelines did not cause more injuries but that teams simply reported more injuries after the new guidelines in general.

D. Specification Tests and Sensitivity Analysis

Specification Tests.—

Owing to the use of difference-in-differences analysis in the first stage, pre-trend analysis is completed for each of the model types used in Eq. (1). These pre-trend tests use the generalized model in Eq. (*i*) below:

(i) $$P(Y_{ij} = 1 | \overline{Z}) = \beta_0 + \beta_1\, Quarter\ Trend_{ijg} + \beta_2\, NCAA_{ijgs} + \beta_3\, (NCAA_{ijgs} \times Quarter\ Trend_{ijg}) + \beta_4\, \bar{X}_{ijgs} + \beta_5\, Game\ Month_{ijgs} + \varepsilon_{ijgs}$$

In this pre-trend analysis, we want to understand if the NCAA and NFL had similar touchback probabilities during the seasons (2007-2010) where they shared similar kickoff rules. We also use a visual examining to inspect if this parallel trend assumption holds during the time in which the rules for each league were similar. Using both a visual inspection and then validating the findings by testing if the coefficient for the variable $NCAA_{ijgs} \times Quarter\, Trend_{ijg}$ is statistically different than zero, we can determine if the two leagues are roughly similar over the tested period.

We perform a second specification test for our NCAA sample. Since we utilize only a sample of all the NCAA games, testing for any bias in this primary sample is necessary. To test for this bias in the NCAA primary sample we create two sub-samples to compare our primary sample with. These samples consist of only 'Power Conference' teams without their opponents and of only NCAA teams. By including only 'Power Conference' teams we compare if there are team specific factors that are confounded when teams within a 'Power Conference' play teams outside these conferences. The NCAA only sample allows us to measure if there is any detectable difference between 'Power Conference' teams and those not in a 'Power Conference' during the study period.

Sensitivity Analysis. —

Two key sensitivity analyses are performed for Eq. (1) to confirm the validity of the initial results. We first complete a placebo test, where the outcome is changed from kickoff touchbacks to fair catches occurring during punts. Since the rule changes in the NCAA and NFL were exclusively targeted at kickoffs, there should be no association between the timing effects of the rule changes and fair catches occurring during punt plays. The second sensitivity analysis is a falsification test to determine if spurious correlation is affecting the results from the primary model. We complete this by estimating Eq. (1) but replace the initial key variables with other coincidental rule changes between the NCAA and NFL in previous seasons. Specifically, we change the key outcome to reflect a set of rule changes that were instituted in the NCAA and NFL in 2010 where both leagues implemented rules to curb player targeting and head first collisions. These two player collision rules were enacted at the same time between the two leagues but were not targeted at kickoffs specifically, therefore these rule changes in each league should have minimal or no direct impact on touchback probability. These two sensitivity analyses for the first stage of modeling should serve to determine if there is some form of confounding in the primary modeling results.

In the second-stage of the analysis we perform two key sensitivity analyses to determine the strength of our instrument and whether number of returns is truly endogenous. The strength of the instrument is judged using the standard F-Test where we obtain the F-Statistic in the first stage of the model for the instrumented variable. If this test returns a F-Statistic greater than 10 for predicted number of returns than we say our instrument is strong.

IV. Results

A. Descriptive Statistics

Tables 1A, 1B, and 1C provide basic descriptive information for the two-stages of the analysis. In the first stage of the analysis there are 63,998 total kickoffs for the entire sample. More kickoffs occur during conference games in the NCAA (55.4%) compared to the NFL (36.9%), this is attributable to the size of a conference/division (NCAA conferences often are made up of at least 8-teams while NFL divisions are made up of 4-teams, though NFL division teams play each other twice each season compared to only once per season in the NCAA). As reported in Table 1A, over half of all kickoffs occur during home games, it's important to remember that each game does not have an equal number of kickoffs. For the continuous measures, teams in the NCAA have higher winning percentages than NFL teams (57.8% vs. 48.8%) as well as opponents having higher winning percentages on average comparatively (51.1% vs. 46.3%). The point differential at the time of any kickoff also is higher in the NCAA with a kickoff occurring with an average point differential of 6.675 points to the NFL with a 4.550 average point differential. Given the high frequency of blowouts (games with one team having significantly bigger leads than their opponent), these differences are on par with what we would expect.

[Insert Table 1A Here]

Table 1B presents game averages for the total number of kickoffs in the sample as well as averages for each league individually. A total of 6,214 games occurred during the sample period, with 2,304 games occurring in the NFL and 3,910 games occurring in the NCAA. The average number of kickoffs overall was 10.32 per game, with slightly more occurring per-game in the NCAA (10.72) than in the NFL (9.64). The greater number of total kickoffs is not surprising given the higher total scoring in the NCAA compared to the NFL (see average point differential in Table

1A). The total number of touchbacks per game being relatively equal is slightly misleading, we expect these two averages to be relatively equivalent when kickoff rules in each league were the same.

[Insert Table 1B Here]

To test if kickoff results were the same, we also include the summary statistics for kickoffs during the three unique time periods of the study in Table 1C. These three time periods correspond to: when the NCAA was kicking from the 35-yard line and the NFL was kicking from the 30-yard line; when both league's kickoffs were from the 30-yard line; and after each league change their rules post the 2011/2012 seasons. In each of the three time periods the NCAA still averages about one kickoff more per game than the NFL. The most important factor in Table 1C is the average number of touchbacks/returns when comparing the NCAA and NFL during each of the three periods. We can see that when the two leagues shared the same rules, the average number of touchbacks were essentially the same, the number of returns is essentially the same as well if we were to adjust the total number of kickoffs on average to be the same.

[Insert Table 1C Here]

From Table 1C we also see that during the post rule change period (post 2011 for the NFL, post 2012 for the NCAA) the average number of touchbacks and returns now are not equal. More touchbacks occur in the NFL than the NCAA. This is an important characteristic for two key reasons. First, this difference supports what is graphically seen when plotting the average number of touchbacks by season for each league as is shown in Figure 2. Figure 2 is key as it serves as a visual test of the parallel-trends assumption necessary to use a difference in differences approach. Therefore, the second important characteristic of the results in Table 1C is that it too supports on a rudimentary level the parallel-trends assumption.

[Insert Figure 2 Here]

Descriptive statistics for the second-stage of the analysis are provided in Table 1D. After removing the information for the December 2009 games (*per the sample selection described in the data section*) there are 2,304 observations in the second stage of the analysis. Each game averaged

2.28 injuries in the sample, with the majority being some other type of injury than the three general injury types we are concerned with. During the sample there was an average of 0.131 – 0.150 concussions per game, while the most common location for injuries was to a lower extremity. Lower extremity injuries being the most common is not an unexpected result, most lower body injuries tend to be non-severe or season threating injuries such as sprained ankles, pulled hamstrings, and other muscle/ligament strains to the lower body that do not result in ligament tears. For the game level information, we note that 26.1% of all games were played in a dome and 42.2% of all games were played on some type of artificial/turf field. These factors not only will likely affect kickoff results (no weather allows for more control on kickoffs) but are also linked to potential player injuries (some studies suggest artificial field surfaces increases the risk of ligament and head injuries (Meyers and Barnhill 2004)).

[Insert Table 1D Here]

B. Effects of Rule Changes on Touchback Probability

The first-stage of our analysis, not to be confused with the first-stage of the IV analysis in the second-stage of the analysis, focuses on the marginal effects of touchback probability due to the different league rule changes. Marginal effects of touchback probability are presented in Table 2. We find that when a kickoff occurs from the 35-yard line compared to the 30-yard line the probability of a touchback increases between 25.44 - 27.55%. This implies that if a league wants to significantly reduce the number of kickoff returns, the movement of the kickoff location is indeed beneficial. Though moving the kickoff location is beneficial, our results show that when the NCAA instituted it's 2012 rule change ($NCAA_{ijgs} \times Kickoff\ 35\ Yd_{ijgs} \times Touchback\ 25\ Yd_{ijgs}$) moving both the kickoff and touchback locations, it reduced the potential number of touchbacks that could have occurred had they only moved the kickoff location. Increasing the touchback location from the 20 to 25-yard line in the NCAA decreased the probability of a kickoff would result in a touchback by 7.49 – 10.93%. Essentially the NCAA's inclusion of the 5-yard change for touchback locations reduced the effectiveness of the kickoff rule changes compared to if they had only moved the kickoff location, they took what could be a great change and made it only a good change by changing both the kickoff and touchback locations.

The marginal effects for the NFL's 2011 rule change ($NFL_{ijgs} \times Kickoff\ 35\ Yd_{ijgs}$) are insignificant when season or season-team fixed effects are not included. For the season and fixed effects models the relative reduction in the number of touchbacks we attribute to the total number of kickoffs per game compared to the NCAA (NCAA has more total kickoffs *see Table 1B*). Further, when taken in context to the coefficient for a kickoff occurring in the NCAA ($NCAA_{ijgs}$), the difference between the NCAA only and the NFL's 2011 rule change ($NCAA_{ijgs} - (NFL_{ijgs} \times Kickoff\ 35\ Yd_{ijgs}) = -0.0069$) the difference is essentially zero implying that there is no difference between the NCAA and NFL if the kickoffs occur at the same point. This follows what was graphically illustrated in *Figure 2*. These results also support the idea that it is the location of a kickoff/touchback that influences kickoff results and not a skill gap between NFL and NCAA players.

Marginal effects for game-specific and within-game variables also have interesting influences on touchback probability, particularly variables associated with specific coaching strategies and player decisions. Conference games are associated with an increase of 1.64 – 1.71% in the probability of a kickoff resulting in a touchback compared to non-conference games. Home games also increase the probability of a touchback by roughly 2.49%. A one-unit increase in a team's winning percentage increases touchback likelihood by 2.51 – 2.52 percentage points. These game level variables help to describe the influence that factors beyond the coach/player's control but likely influence the strategies employed when considering kickoffs. Those variables that coaches and players can control for that are significant includes the time remaining in the game and the point differential for any kickoff during the game. Time remaining though significant is essentially equal to zero, thus for each second remaining in the game there is a significant but marginally small effect on kickoff probabilities. For each additional point in the absolute difference between the two teams scores, the probability of a touchback occurring increases by 0.05 percentage points. Both results being significant and positive is intuitively logical, coaches reduce player risk both as less time remains in the game and as games become less competitive.

As we use a difference-in-difference approach we also check the parallel trends assumption between the NCAA and NFL when the two leagues shared similar kickoff rules. We present the chi-squared and p-values in Table 1 which confirm that when the two leagues shared a common rule set for kickoffs, they were indeed roughly equal (full results for this are available in Appendix

Table 1). Therefore, we are confident that the difference-in-difference estimation is appropriate for the first stage of the analysis.

The results in Table 2 guide our simulation of the impact on the total number of kickoff returns per season associated with each rule change. These simulated results presented in Appendix Table 3 are the relative exposure measures estimated by Eq. (2) & (3). Appendix Table 3 shows that on average, moving the kickoff location to the 35-yard line reduces the number of returns by 632.2 – 721.4 returns per season. It also illustrates the negative impact that the 2012 NCAA rule had with respect to the potential gains. Had the NCAA only moved the kickoff location, we predict they would have had 858.6 – 973.3 less kickoff returns. By moving both the kickoff and touchback locations, the 2012 NCAA rule change reduced kickoff returns by 154.4 – 339.3 in our simulated results. While the remainder of our analysis for the second-stage specifically focusses on the NFL's rule change and player injuries, it's important to note the significant number of simulated returns that are not avoided when moving the kickoff location (*see discussion section for more detail*).

C. Effects of the NFL Rule Change on Player Injuries

In the second-stage of the analysis we analyze the association between kickoff returns, the NFL's 2011 rule change, and player injuries. Though we know the number of returns for each game and can count the number of player injuries, there is a certain level of nuance we lose when simply counting only the number of returns. Not only do we not know when players are injured from our data, but we also cannot specifically measure the rule changes in the NFL directly on player injuries. This is the reason we instrument the number of returns with the predicted number of returns from the first-stage of the analysis. As shown in Table 3, not only are predicted returns a strong instrument for number of returns (*F-Statistic = 2,218.97;* minimum suggested F-Statistic must be greater than 10 at least for an instrument to be considered not-weak), the instrumented number of returns captures finite granular details for each kickoff result as well as capturing the effects of the 2011 NFL rule change on kickoff return probability.

[Insert Table 2 Here]

Table 3 presents three different models that estimate the association between total number of injuries and kickoff returns: (1) Non-instrumented number of returns, (2) Number of returns instrumented by predicted number of returns from the first-stage of the analysis, and (3) Number of returns instrumented by predicted number of returns and including home and away team fixed effects. These results are interpreted as the average change in injuries given a one-unit change in the number of returns. Thus, we expect total injuries to increase by 0.0289 – 0.0503 for each additional kickoff return that occurs. A more intuitive way to think about these results is to interpret the change in injuries for every 100 kickoff returns. In this case, for every 100 kickoff returns that occur, total injuries increase by 2.89 – 5.03 injuries.

[Insert Table 3 Here]

While models (1) & (3) show significance for the number of returns, there is concern in the specification for two distinct and different reasons. Model (1), as discussed, fails assumes endogeneity and may reflect changes in strategy related to increased awareness of injuries, so we suggest it under reports the injury impact of kickoff returns due to the rule change on injuries. Model (3) on the other hand has a large amount of the variation accounted for with the team fixed effects, but this may not accurately reflect the true impact of returns only and instead overstate team specific factors.[9] Our preferred specification is model (2) which uses instrumented number of returns but does not include team level fixed effects. This specification implies that every 100 kickoff returns are associated with 5.03 total injuries. When we test the strength of the instrument for models (2) & (3), our findings yield a F-test statistic of 2218.97 for the strength of the IV variable which is greater than the rule-of-thumb of 10.

Regardless of the specification, there is a significant relationship between returns and the number of returns. However, also seen in Table 3 is that there is a significant relationship between the post-concussion reporting policy change and total injuries. The positive coefficients for the post "return to play" guidelines being put in place imply that the guidelines led to more injuries reported because the bar for reporting injuries was lowered. These injuries were likely already occurring, they were just underreported prior to the rule changes. In this context then, the inclusion of the implanted guidelines variable serves to control for the uptick in reporting within the data

9 We cannot specifically capture these team specific factors, but these could range from the riskiness of a coach in their decision making or could include health specific factors such as poor training methods or a poor medical staff.

but has little meaning to us as it only accounts for the likely increased reporting of injuries and not new or additional injuries in general.

Using kickoff returns instrumented by the predicted number of kickoff returns from the first-stage analysis, we then estimate the association between kickoff returns and the nine-different injury measures. Table 4 presents the marginal effects for the instrumented number of returns associated with each specific injury type. It also includes the implied number of injuries that we predict are averted after the NFL's rule change and the number of injuries that could have potentially been averted had no kickoff returns ever occurred. (For the full results for each of injury model types see Appendix Table 4). We find that instrumented returns are significantly associated with total injuries, concussions broadly defined, concussions narrowly defined, and injuries to the head or neck area. These implied results are computed through predicted injuries using the instrumented model, wherein we calculate the difference in predicted number of injuries, predicted injuries as a function of the difference between the number of returns and the estimated exposure of the rule change, and the difference in predicted injuries had not returns ever occurred and if no policy were ever put into place. Each of these measures is estimated through 500 bootstraps and Table 4 presents the average from this sample. For the four significant implied injury estimates, we find that the NFL's 2011 rule change is associated with a reduction of 34.45 injuries per season in total. The implied estimates also show that the rule change is associated with a reduction in concussions or head/neck injuries ranging from 9.21 – 15.50 per season. The final column of Table 4 presents the implied change in injuries when we simulate no kickoff returns ever occurring during the entire sample.

[Insert Table 4 Here]

When we compare the results of the kickoff rule change to these predicted results we can see that the 2011 rule was mostly effective in reducing concussions compared to if no returns ever occurred, with 60.1 to 63.4% of possible concussions being prevented by the 2011 rule change ($100 \times ((2011\ Rule\ Change)/(No\ Returns\ Ever))$. While the NFL's rule change would be effective in preventing concussions, it would appear to be less so in the context of prevention of any injuries. Our predicted results suggest that the rule change is associated with a reduction of 34.45 injuries per season, yet if no kickoff returns ever occurred the implied results suggest that the NFL would reduce total injuries by 87.63 per season. This implies that the rule change only prevented 39.3% of all injuries in comparison. Even though the NFL's rule change did not reduce all injuries by the same predicted factor had no kickoff returns ever occurred, the results to imply that the NFL was successful in preventing those that are most likely to occur on kickoffs, concussions and/or head/neck injuries, as was their specified purpose.

D. Sensitivity Analysis

Punt Return Sensitivity Analysis. —

The rule changes by the NCAA and NFL while written formulaically as specific locations for kickoffs and touchbacks, are no different than season specific timing effects. Each rule change can be measured as a season (year) shock which we leverage to complete a placebo test of our first-stage results. Replacing kickoffs with punts and touchbacks with fair catches we estimate Eq (1) a second time. Appendix Table 7 shows the results for our hypothesis test: The overall effect of the timed rule changes in each league is equal to zero ($H_0\colon ME_{League\ Rule\ Change} = 0$). Overall impact of each league's rule change is calculated as the sum of the marginal effects for a kickoff occurring from the 35-yard line ($Kickoff\ 35\ Yd_{ijgs}$) and the league specific rule changes ($NFL_{ij} \times Kickoff\ 35\ Yd_{ijgs}$) or ($NCAA_{ijgs} \times Kickoff\ 35\ Yd_{ijgs} \times Touchback\ 25\ Yd_{ijgs}$). Appendix Table 7 shows the chi-squared and p-values when we test if these sums for both punts and kickoffs are statistically different from zero. The results from this placebo test support our theory that the rule changes we examine impact only kickoffs and not all plays in general. For each of the estimated model types, the chi-squared and p-values are statistically significant while the placebo test values are insignificant when using our preferred models (2) and (3).

NCAA Sample Selection Analysis. —

The second sensitivity analysis we employ focuses on the NCAA sample selection. An area that could bias our results is the use of only NCAA games which had one or more 'Power Conference' teams involved. Games where at least one of the participants comes from a 'Power Conference' is justified as the players from these schools tend to have the closest skill-gap to NFL players. To accurately measure the difference in touchback probability attributable to each league's rule changes, then the players involved in kickoffs in the NCAA and NFL must be comparable to one another. We first test the comparability of kickers by examining what conferences/schools the set of NFL kickers in our sample attended prior to playing in the NFL. Though 61.84% of NFL kickers came from a 'Power Conference' in the NCAA, this approach is anecdotal as the sample of NFL kickers from 2005 – 2013 consisted of only 128 different kickers.

The more appropriate method is to estimate Eq. (1) utilizing a sample from the NCAA that excludes the 'Power Conference' teams and compare the results between the primary and secondary samples. Appendix Table 8 presents the compared results using the basic logit and logit with season fixed effects specifications for both the primary and secondary samples. Our key variables in the initial analysis that were significant remain significant when using the secondary sample. However, the results using the second sample were always smaller than the primary sample. When kickoffs occur from the 35-yard line regardless of league there is a reduction from a 25.44 – 26.44 percentage point increase in the probability of a touchback occurring to a 19.05 – 19.97 percentage point increase when using the secondary sample. This reduction holds true also for the 2012 kickoff rule change, touchback probability is reduced from 7.49 – 8.81 percentage point decrease using the primary sample to a 2.96 – 3.05 percentage point decrease. While these differences between the samples could be indicative of coaching decisions, it is more likely attributable to a skill difference between the primary and secondary samples.

Our final test of the sample selection is to compare the within NCAA variation between games with a 'Power Conference' team and games which did not include a 'Power Conference' team. We do this by dropping the NFL games from the sample, and estimating a modified version of Eq. (1) estimated by Eq. (*ii*):

$$\text{(ii)} \quad P(Y_{ijgs} = 1 | \overline{Z}) = \beta_0 + \beta_1\, Kickoff\ 35\, Yd_{ijgs} + \beta_2\, (Power_{ij} \times Kickoff\ 35\, Yd_{ijgs}) + \beta_3\, Power_{ijgs} + \beta_4\, (Power_{ijgs} \times Kickoff\ 35\, Yd_{ijgs} \times Touchback\ 25\, Yd_{ijgs}) + \beta_5\, \bar{X}_{ijgs} + \beta_6\, Game\ Month_{ijg} + \beta_7\, Quarter\ Trend_{ijg} + \varepsilon_{ijgs}$$

The emphasis for Eq. (*ii*) is on the marginal effects of the 'Power Conference' ($Power_{ijgs}$) and 'Power Conference' interacted variables. This sensitivity analysis shows that for the key interacted variables, all estimates are significant. Of the four key variables of concern, we are particularly interested in the three which are interacted with the different rule changes. Notably the results suggest that for both 'Power Conference' games and teams (column (1) and column (2) respectively) there is a statistically significant skill difference between teams in or not in a 'Power

Conference'. As the results are significant and show that 'Power Conference' teams statistically outperform their counterparts, we believe our initial 'Power Conference' – NFL sample to appropriately match for the difference in differences approach.

V. Discussion

The decision to change kickoff rules for the NCAA and NFL was widely cited by both to protect players and curb injuries. Our findings suggest that in the attempt to reduce the number of kickoff returns, each league was successful, only there were varying degrees of success depending on the changes each instituted. We have shown that moving the kickoff location closer to the opponent's end-zone is an effective way to reduce the number of returns. It is also clear that these potential gains from moving the kickoff location are offset when the touchback location is also changed in favor of the receiving team. We also showed that rule changes resulting in fewer returns are effective at reducing injuries.

While we can conclude analytically that the 2011 NFL rule change was beneficial and successful in reducing player injuries, we cannot be as explicit in terms of the impact of the NCAA's 2012 rule change with respect to injuries to players. Given the relative similarities between the NCAA and NFL for the first-stage of the analysis and relying on findings in the previous literature, we can theorize as to what the impact on player injuries from the 2012 rule change may be. Based on the ratio from the first stage of the model, the NCAA's rule was 58.32% as effective compared to the NFL rule change.[10] Extrapolating from this estimate, we can then theoretically estimate that the NCAA's rule was roughly 60% as effective as the NFL's. This implies that the NCAA rule prevented 5.37 – 9.04 concussions or head/neck injuries per season compared to the 9.21 – 15.50 concussions or head/neck injuries per season prevented by the 2011 NFL rule change. In theory this estimate is likely very conservative when we compare the number of kickoff returns that were averted and the total number of kickoffs in the NCAA and NFL. As shown in Appendix Table 3, we predict that had the NCAA only moved the kickoff location there would have been an average of roughly 200 less kickoff returns compared to the NFL. If we factor in that the NCAA only prevented one-third of the returns they could have, it's possible that the NCAA's rule prevented

10 Calculated by taking the sum of the marginal effects for the NCAA's rule change and dividing it by the sum of the marginal effects for the NFL's rule change = 58.32%

only 0.71 – 3.30 concussions or head/neck injuries per season (or one-third of 5.37 – 9.04). In theory then, moving the touchback location in addition to the kickoff location resulted in the NCAA preventing roughly only 19% of the total number of injuries, especially head/neck and concussions, compared to had only the kickoff rule change occurred.

We emphasize the change in the touchback location as it significantly changes the results of not only kickoffs but has tremendous implications with respect to player injuries. Prior to the 2016 season, five seasons after changing the kickoff location, the NFL decided to follow suit and moved the touchback location to the 25-yard line. The lack of research comparing the NCAA to the NFL and the differences the two rule changes had on kickoff results was unknown. So, the NFL decided that they too would move the touchback location, once again allowing the NCAA and NFL to have matching kickoff rules. While we do not have data on the NCAA after the 2013 season, we can surmise the effect that the change in touchback location had on kickoff results. If the pattern holds between the NCAA and NFL than the move of the touchback location likely reduced the number of touchbacks significantly. As we have shown the effectiveness of kickoff rule changes on player injuries relies entirely on reducing the number of returns. Should even one additional return occur, it increases player exposure and the likelihood of player injuries. While not willing to openly admit to the issues for kickoffs and the impact of the current rule set, the NCAA at least implicitly has shown they know something may be happening as they too changed their kickoff rules again prior to the 2018 season to decrease the number of returns.

This paper provides a unique approach to determine the impact of football rule changes to both the targeted play and the effects of the rules on player safety. Recent trends in both college and pro football have been to implement new rules largely in the name of reducing the risk to players. Despite this, there are few studies that examine the impact these changes have. Given the lack of data on player injuries and the often misspecification of the rule changes at the play level, it is unsurprising that little research in this area has been completed. As is often the case, the impact of rule changes like these two kickoff rules is looked at from a cursory stand point and in isolation of one another, so that the true impact is seldom recognized. While there is no way to be entirely certain as to the impact any of these rule changes have on player injuries, the methods we employ are sound and a first for this type of policy analysis.

Using approaches such as ours opens the opportunity for future studies with respect to the policy changes that football rule makers institute in the name of player safety. The key to such changes and the analysis that applies to them is understanding that there are unintended consequences to all rule changes. Being cognizant of these is the first step to implementing true change that increases player safety in football.

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VI. Figures and Tables

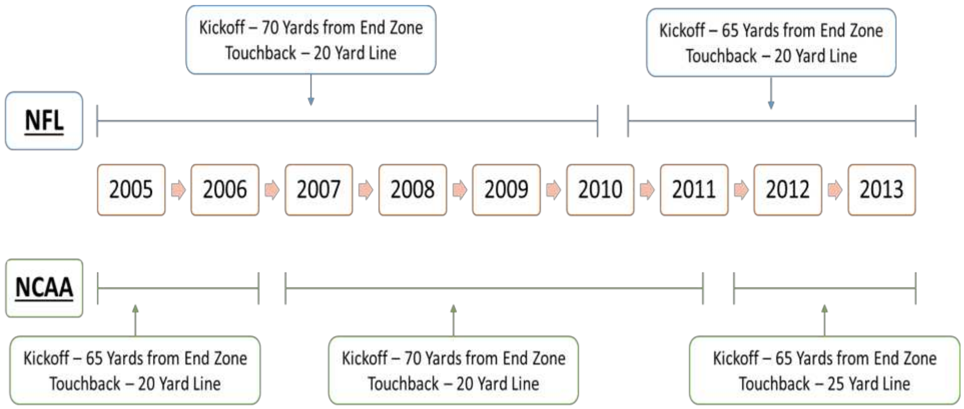

FIGURE 1 - TIMELINE OF KICKOFF RULE CHANGES FOR THE NCAA AND NFL

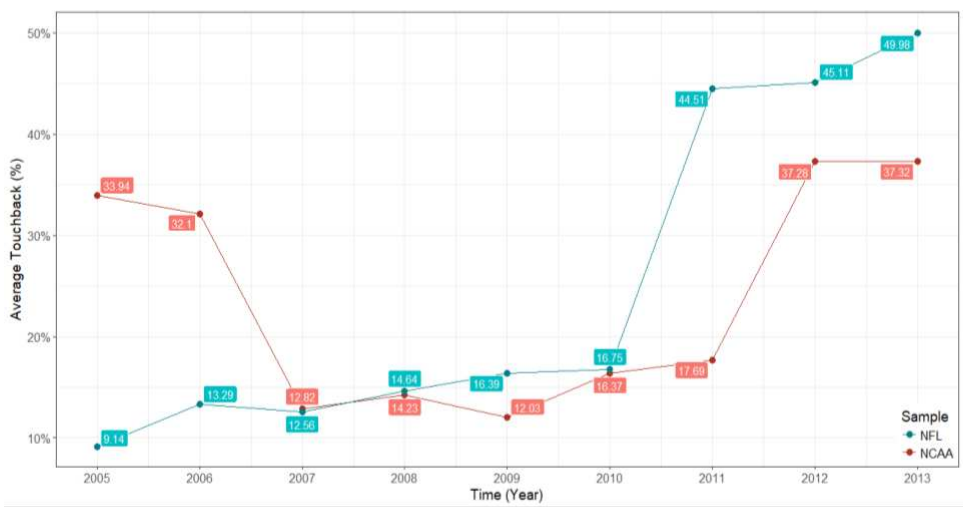

FIGURE 2 – MEAN NUMBER OF TOUCHBACKS BY SEASON FOR THE NCAA VERSUS THE NFL. ALL FIGURES ARE PERCENTAGES.

The average number of touchbacks in the NCAA and NFL respectively between the 2005 – 2013 seasons.

TABLE 1A—DESCRIPTIVE STATISTICS FOR FIRST-STAGE ANALYSIS

Mean (SD)	Total (n = 63,998)	NFL (n = 22,213)	NCAA (n = 41,785)
Within Game Dichotomous Variables			
Conference Game (NFL = Division)	0.490 (0.500)	0.369 (0.483)	0.554 (0.497)
Home Game	0.536 (0.499)	0.521 (0.500)	0.544 (0.498)
Within Game Continuous Variables			
Team Win Percentage	0.547 (0.332)	0.488 (0.286)	0.578 (0.350)
Opponent Win Percentage	0.494 (0.331)	0.463 (0.283)	0.511 (0.353)
Point Differential	5.938 (13.70)	4.550 (10.15)	6.675 (15.20)

TABLE 1B—GAME AVERAGES OF KICKOFFS & KICKOFF RESULTS

Mean (SD)	Total (n = 6,214)	NFL (n = 2,304)	NCAA (n = 3,910)
All Seasons			
Number of Kickoffs	10.320 (2.515)	9.641 (2.136)	10.719 (2.633)
Number of Touchbacks	2.511 (2.367)	2.419 (2.472)	2.565 (2.301)
Number of Returns	7.808 (2.946)	7.222 (2.765)	8.154 (2.994)

TABLE 1C—GAME AVERAGES OF KICKOFFS & KICKOFF RESULTS (KICKOFF LOCATION BREAKDOWN)

Mean (SD)	Total	NFL	NCAA
2005 - 2006 Seasons			
Number of Kickoffs	9.791 (2.412)	9.264 (2.106)	10.110 (2.528)
Number of Touchbacks	2.472 (2.206)	1.039 (1.337)	3.340 (2.177)
Number of Returns	7.319 (2.66)	8.225 (2.212)	6.770 (2.758)
2007 - 2010/2011 Seasons			
Number of Kickoffs	10.380 (2.508)	9.600 (2.167)	10.751 (2.574)
Number of Touchbacks	1.534 (1.649)	1.448 (1.6)	1.575 (1.671)
Number of Returns	8.846 (2.694)	8.151 (2.449)	9.176 (2.742)
2011/2012 - 2013 Seasons			
Number of Kickoffs	10.633 (2.545)	9.948 (2.072)	11.208 (2.755)
Number of Touchbacks	4.387 (2.513)	4.633 (2.513)	4.181 (2.497)
Number of Returns	6.246 (2.828)	5.315 (2.496)	7.027 (2.855)

TABLE 1D—DESCRIPTIVE STATISTICS FOR THE SECOND-STAGE ANALYSIS

Mean (SD)	NFL (n = 2,304)
General Injuries	
Total Injuries	2.283 (1.829)
Concussion (Broad Definition)	0.150 (0.429)
Concussion (Narrow Definition)	0.131 (0.380)
Ligament Tear	0.104 (0.364)
Injuries by Body Location	
Head/Neck	0.212 (0.506)
Upper Extremity	0.254 (0.563)
Trunk/Back	0.132 (0.382)
Lower Extremity	1.636 (1.625)
Other	0.0491 (0.223)
Game-Level Information	
Game Temperature	62.95 (14.81)
Game Humidity	41.10 (30.29)
Game Wind-Speed	6.557 (6.107)
Dome-Game	0.261 (0.440)
Turf Field	0.422 (0.494)

TABLE 2—MARGINAL EFFECTS OF RULE CHANGES ON TOUCHBACK PROBABILITY

	(1)	(2)	(3)
Key Variables			
Kickoff from 35-yard line	0.2544	0.2664	0.2755
	(0.0080)	(0.0115)	(0.0095)
2011 NFL Rule Change	-0.0189	-0.0385	-0.0480
	(0.0132)	(0.0157)	(0.0204)
NCAA	-0.0429	-0.0454	-
	(0.0062)	(0.0068)	
2012 NCAA Rule Change	-0.0749	-0.0881	-0.1092
	(0.0096)	(0.0123)	(0.0177)
Game Specific Variables			
Conference Game (NFL = Division)	0.0164	0.0171	0.0024
	(0.0038)	(0.0038)	(0.0047)
Point Differential	0.0005	0.0005	-0.0001
	(0.0001)	(0.0001)	(0.0002)
Time Remaining in Game	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Home Game	0.0247	0.0249	0.0168
	(0.0033)	(0.0033)	(0.0039)
Game Month			
August	0.0414	0.0356	0.0256
	(0.0140)	(0.0150)	(0.0147)
September	0.0136	0.0092	0.0103
	(0.0047)	(0.0063)	(0.0066)
October	ref.	ref.	ref.
November	-0.0428	-0.0386	-0.0412
	(0.0044)	(0.0059)	(0.0072)
December	-0.0774	-0.0711	-0.0809
	(0.0058)	(0.0083)	(0.0118)
January	-0.0492	-0.0422	-0.0389
	(0.0156)	(0.0177)	(0.0235)
Team Win Percentage	0.0251	0.0252	0.0032
	(0.0054)	(0.0054)	(0.0068)
Opponent Win Percentage	-0.0098	-0.0099	-0.0090
	(0.0054)	(0.0054)	(0.0064)
Quarter Trend	0.0040	0.0000	-0.0048
	(0.0004)	(0.0037)	(0.0045)
Pseudo R2	0.0817	0.0820	0.0860
Observations	63,998	63,998	63,746
Pre-Trend P-Value	0.2523	0.2419	0.3042

Robust standard errors in parentheses

Notes:

(1) - Simple logit specifications

(2) - Season fixed effects logit specifications

(3) - Team and season fixed effects logit specifications

Note – Season marginal effects are included for models (2) and (3) but the marginal effects are not reported in Table I to truncate the reported results. See the corresponding Appendix table for the full table including the marginal effects for each season respectively.

TABLE 3—MARGINAL EFFECTS OF PREDICTED KICKOFF RETURNS ON ALL INJURIES

	(1)	(2)	(3)
Key Variables			
Number of Returns	0.0289 (0.0164)	0.0503 (0.0217)	0.0379 (0.0219)
Post-Concussion Reporting Policy	0.3482 (0.0861)	0.3954 (0.0919)	0.3829 (0.0918)
Game Variables			
Divisional Game	0.0290 (0.0833)	0.0327 (0.0834)	0.0337 (0.0821)
Home Team Win Percentage	0.1163 (0.1495)	0.1191 (0.1496)	-0.0331 (0.1572)
Away Team Percentage	-0.2137 (0.1391)	-0.2291 (0.1408)	-0.2575 (0.1391)
Game Temperature	-0.0016 (0.0037)	-0.0008 (0.0037)	0.0010 (0.0046)
Game Humidity	-0.0024 (0.0021)	-0.0024 (0.0021)	-0.0026 (0.0021)
Game Wind-Speed	0.0031 (0.0081)	0.0043 (0.0082)	0.0028 (0.0084)
Dome-Game	0.0439 (0.1561)	0.0461 (0.1560)	-0.3406 (0.3221)
Game Occurs on Turf Field	0.1474 (0.0898)	0.1428 (0.0897)	0.1773 (0.3627)
Week Game Occurred During	-0.0138 (0.0347)	-0.0131 (0.0347)	-0.0175 (0.0357)
Game Month			
September	ref.	ref.	ref.
October	-0.0731 (0.1806)	-0.0822 (0.1819)	-0.0273 (0.1759)
November	-0.1569 (0.3113)	-0.1741 (0.3122)	-0.0776 (0.3157)
December	0.0103 (0.4401)	-0.0064 (0.4404)	0.1175 (0.4529)
Observations	2,096	2,096	2,096
F-Statistic (IV Strength)	-	2,218.97	

Robust standard errors in parentheses

Notes:

(1) – Reduced Form without Instrumental Variables

(2) - Kickoff Returns Instrumented by Predicted Number of Kickoff Returns

(3) - Kickoff Returns Instrumented by Predicted Number of Kickoff Returns with Home and Away Team Fixed Effects

TABLE 4—IMPLIED NUMBER INJURIES PREVENTED BY 35-KICKOFF RULE CHANGE IN THE NFL

	Effect of Returns	Post Rule Change	No Returns Ever
Injury Type			
Total Injuries	0.0503	-34.45	-97.86
	(0.0217)	(15.89)	(43.05)
Concussion (Broad Def.)	0.0088	-9.21	-23.66
	(0.0049)	(5.51)	(12.61)
Concussion (Narrow Def.)	0.0104	-10.99	-27.19
	(0.0046)	(5.33)	(11.22)
Ligament Tear	0.0042	-3.67	-8.93
	(0.0047)	(4.41)	(11.04)
Injury Location			
Head/Neck	0.0170	-15.5	-38.98
	(0.0059)	(6.25)	(13.3)
Upper Extremity	-0.0005	0.03	0.88
	(0.0068)	(4.22)	(12.98)
Trunk/Back	-0.0004	0.2	1.27
	(0.0045)	(2.42)	(7.66)
Lower Extremity	0.0290	-19.95	-56.43
	(0.0187)	(12.55)	(34.47)
Other	0.0039	-3.37	-8.03
	(0.0024)	(2.23)	(4.87)

Robust standard errors in parentheses

Effect of Returns - Reports the coefficients and standard errors using the specification in Table 3, Column (2)

Post Rule Change - Measures the implied number of injuries that were averted due to NFL's 2011 Kickoff Rule Change

No Returns Ever - Measures the theoretical number of injuries that would have been averted if every kickoff over the study period had never been returned

The impact of NFL kickoff rule changes on player injuries: Forgoing excitement to reduce injuries? (Appendix)

BY ZACHARY S. RICHARDSON AND RICHARD C. LINDROOTH

I. Appendix

A. Injury Breakdown Explanation

Using NFL injury data, we estimate nine different injury measures at the *game* level. Each injury measure is summed to the game level for all players, other than Quarterbacks, who report a new injury in that game. Injuries to quarterbacks are excluded because they are extremely unlikely to be exposed to injury during a kickoff. These injury measures were broken into four distinct groups counting the number of injuries for each variable:

(1) Total number of injuries (Total Injuries)

(2) Total number of concussions defined in two ways. (1) Any injury categorized as a concussion, head, or head/neck injury (Concussion: Broad Definition); (2) Any injury only categorized as only a concussion (Concussion: Narrow Definition).

(3) Total number of injuries that are categorized as a ligament tear in the Knee or Ankle, injuries that are often associated with high speed collisions (Ligament Tear)

(4) Number of injuries that fall into one of five injury groups, drawn from the NCAA and NFL literature (Dick et al. 2007, Hootman, Dick, and Agel 2007): (1) Head/Neck, (2) Upper Extremity, (3) Trunk/Back, (4) Lower Extremity, and (5) Other/System.

B. Further Model Specification Explanation

Touchback probability was estimated using logit, team fixed effects logit, and team-season fixed-effects logit specifications. These specifications take advantage of both within season, within team, and between team variation to account for variation that occurs due to team specific strategy. The nine different injury measures are estimated using a Poisson regression model reflecting the dependent variables which measure the count of each type of injury. Initially we estimated a reduced form model of the association between returns per game (exact number not predicted). We then estimated the relationship between the number of injuries and number of returns using an instrumental-variable approach, with the predicted number of returns calculated by using the parameters from the analysis of touchbacks and the rule changes. We also control for the changes in reporting of concussions in the NFL by including a control variable capturing the variation in injury reporting both before and after the NFL adapted their return to play guidelines. This control is discussed in further detail later, specifically how this control is implemented and what the implications/interpretation of this control means.

C. Parallel Trends Results

Appendix Table 1 shows the results for the pre-trend analysis of the first-stage models estimating the effect of the kickoff rule changes on touchback probability. We test the standard null-hypothesis of whether the two comparison groups statistically differ from each other in the pre-rule change period. That is, we test if there is a statistically significant difference between the NCAA and NFL when they shared the same set of rules in the 2007 – 2010 seasons. The chi-squared and p-values in Appendix Table 1 show that for each of the three estimated models we fail to reject the null-hypothesis, therefore we are confident that our difference-in-differences approach is appropriate for the first-stage of the analysis.

APPENDIX TABLE 1—KICKOFF RULE CHANGES PRE-TRENDS ANALYSIS

Model	Chi-Squared Statistic	P-Value
Logit	1.31	0.2523
Logit Season Fixed Effects	1.37	0.2419
Logit Team-Season Fixed Effects	1.06	0.3042

D. Full Results of Analysis of Touchback Probability

Appendix Table 2 is the extended version of Table 2 in the main text. The specification is the same as Table 2 but includes the marginal effects for each season for the second and third models (season fixed effects and season-team fixed effects respectively). Our primary model we utilize throughout the remainder of the analysis is the second model (column (2)) presented in this table.

APPENDIX TABLE 2—MARGINAL EFFECTS OF RULE CHANGES ON TOUCHBACK PROBABILITY

	(1)	(2)	(3)
Key Variables			
Kickoff from 35-yard line	0.2544***	0.2664***	0.2755***
	(0.0080)	(0.0115)	(0.0095)
2011 NFL Rule Change	-0.0189	-0.0385**	-0.0480**
	(0.0132)	(0.0157)	(0.0204)
NCAA	-0.0429***	-0.0454***	-
	(0.0062)	(0.0068)	
2012 NCAA Rule Change	-0.0749***	-0.0881***	-0.1092***
	(0.0096)	(0.0123)	(0.0177)
Conference Game			
Conf Game (NFL = Division)	0.0164***	0.0171***	0.0024
	(0.0038)	(0.0038)	(0.0047)
Point Differential	0.0005***	0.0005***	-0.0001
	(0.0001)	(0.0001)	(0.0002)
Time Remaining in Game	0.0000***	0.0000***	0.0000***
	(0.0000)	(0.0000)	(0.0000)
Home Game	0.0247***	0.0249***	0.0168***
	(0.0033)	(0.0033)	(0.0039)
Game Month			
August	0.0414***	0.0356**	0.0256*
	(0.0140)	(0.0150)	(0.0147)
September	0.0136***	0.0092	0.0103
	(0.0047)	(0.0063)	(0.0066)
October	*ref.*	*ref.*	*ref.*
November	-0.0428***	-0.0386***	-0.0412***
	(0.0044)	(0.0059)	(0.0072)
December	-0.0774***	-0.0711***	-0.0809***
	(0.0058)	(0.0083)	(0.0118)
January	-0.0492***	-0.0422**	-0.0389*
	(0.0156)	(0.0177)	(0.0235)
Team Win Percentage	0.0251***	0.0252***	0.0032
	(0.0054)	(0.0054)	(0.0068)
Opponent Win Percentage	-0.0098*	-0.0099*	-0.0090
	(0.0054)	(0.0054)	(0.0064)
Quarter Trend	0.0040***	0.0000	-0.0048
	(0.0004)	(0.0037)	(0.0045)
Season			
2005	-	*ref.*	*ref.*
2006	-	0.0003	0.0268
		(0.0138)	(0.0246)
2007	-	0.0304	0.0939*
		(0.0234)	(0.0483)
2008	-	0.0505	0.1427**
		(0.0354)	(0.0697)
2009	-	0.0420	0.1530*
		(0.0493)	(0.0886)
2010	-	0.0813	0.2168**
		(0.0645)	(0.1072)
2011	-	0.1015	0.2553**
		(0.0814)	(0.1221)
2012	-	0.1203	0.2849**
		(0.1004)	(0.1347)
2013	-	0.1325	0.3090**
		(0.1187)	(0.1441)
Pseudo R2	0.0817	0.0820	0.0860
Observations	63,998	63,998	63,746

Robust standard errors in parentheses

Notes:

(1) - Simple logit specifications

(2) - Season fixed effects logit specifications

(3) - Team and season fixed effects logit specifications

E. Exposure of Rule Changes and Season Total Predictions

As there are two key changes in terms of the kickoff and touchback location, we create two exposure variables: exposure attributed to moving the kickoff to the 35-yard line and exposure attributable to moving the touchback starting position to the 25-yard line. To calculate each exposure, we take the baseline predicted probabilities estimated in Eq. (1) in the text and then estimate the counterfactual assuming the rule change had not occurred. The difference between these is the change in exposure:

$$\text{(1a)}\quad Exposure_{s}^{35\,Yd\,Kickoff\,Rule} = Touchback_{s}^{30\,Yd\,KO\,\&\,20\,Yd\,TB} - Touchback_{gs}^{Baseline}$$

$$\text{(2a)}\quad Exposure_{s}^{25\,Yd\,Toucbhack\,Rule} = Touchback_{s}^{20\,Yd\,TB} - Touchback_{s}^{Baseline}$$

Eq. (1a) measures the change in exposure related to a rule change that moves the kickoff from the 30 to the 35-yard line. It is expected to be negative in seasons where the kickoff is from the 35-yard line as touchbacks are easier to kick when the kickoff is closer (35-yard line) to the goal line than when they are further away (30-yard line). If this holds true, then it means that the rule change moving the kickoff to the 35-yard line reduced injury exposure. Eq. (2a) measures the change in exposure related to a rule change that moves the touchback ball placement from the 20 to the 25-yard line. We expect that the results of this exposure calculation will be positive during NCAA seasons when the placement was at the 25-yard line as touchbacks are less likely when the benefit of a touchback to the receiving team is larger. Thus, the 25-yard line touchback placement rule increased kickoff return exposure and increased exposure of player injury.

Appendix Table 3 presents the estimated season total predicted number of returns averted due to the NFL and NCAA rule changes. These results confirm that exposure was significantly reduced when the kickoff location changes to the 35-yard line (**Δ_1**). It also confirms that when touchback location is changed returns increase by more than they would had only the kickoff rule changed (**Δ_2**). When we compared the net impact of changing both rules (**$\Delta_1 - \Delta_2$**) we find that this significantly reduced the number of returns averted when compared to when only the kickoff location changed.

APPENDIX TABLE 3—SEASON TOTAL CHANGES IN KICKOFF RETURNS USING SIMULATED KICKOFF LOCATION

	NFL				NCAA				NCAA Net Impact	
	(1)		(2)		(1)		(2)		(1)	(2)
Season	Δ1	Δ2	Δ1	Δ2	Δ1	Δ2	Δ1	Δ2	Δ1 – Δ2	
2005	0.0	0.0	0.0	0.0	-921.0	0.0	-973.3	0.0	-921.0	-973.3
2006	0.0	0.0	0.0	0.0	-966.2	0.0	-967.4	0.0	-966.2	-967.4
2007 - 2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	-653.0	0.0	-632.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	-682.6	0.0	-660.7	0.0	-875.6	584.1	-858.6	704.3	-291.5	-154.4
2013	-721.4	0.0	-690.9	0.0	-961.4	622.1	-930.2	745.7	-339.3	-184.5

Simulation for the team-season fixed effects model (3) are not possible so only simulated results for models (1) & (2) are reported

Δ_1 - Sum of predicted kickoff returns that can be expected if kickoffs were only from 35-yard line.

Δ_2 - Sum of predicted kickoff returns expected if kickoffs were from the 30-yard line as opposed to the 35-yard line.

Δ_1 - Δ_2 - Difference in the number of predicted returns for the NCAA if they had only changed kickoff location

F. Effects of Returns on Player Injuries by Injury Type

Appendix Table 4A presents the full results of the instrumental variable model presented in Tables 3 & 4 by injury type. The results for instrumented number of returns are identical to the marginal effects reported in Table 4. Full results by injury group are mostly consistent with a few interesting exceptions. Ligament tears are estimated to occur more frequently when the game occurs in a dome compared to an outdoor game. When we combine this result with lower extremity injuries occurring more often on turf fields, it's reasonable to assume that catastrophic ligament tears are the extreme of the lower extremity injuries. We also report the marginal effects for the reduced form model without an instrumental variable in Table 4B

G. Instrumental Variable First Stage Results

Table 3 in the main text reported the relevant F-Statistic to evaluate the strength of our instrumental variable model. The results of the first-stage model are in Appendix Table 5. Given the strength of the instrument it is unsurprising that each predicted return is highly predictive of the actual number of returns. As we discuss, instrumenting for the number of returns using the predicted first stage results allows us to estimate the local average treatment effect based on kickoffs averted specifically due to the rule change and not other confounding factors.

Appendix Table 4A— Marginal Effects of Predicted Kickoff Returns on Player Injuries in the NFL by Injury Type (IV Specification)

		Concussion			General Location of Injury				
	Total Injuries	Broad Definition	Narrow Definition	Ligament Tear	Head/Neck	Upper Extremity	Trunk/Back	Lower Extremity	Other
Key Variables									
Number of Returns	0.0503	0.0088	0.0104	0.0042	0.0170	-0.0005	-0.0004	0.0290	0.0039
	(0.0217)	(0.0049)	(0.0046)	(0.0047)	(0.0059)	(0.0068)	(0.0045)	(0.0187)	(0.0024)
Post-Concussion Reporting Policy	0.3954	0.1667	0.1596	0.0731	0.1913	0.0265	-0.0355	0.1795	0.0325
	(0.0919)	(0.0238)	(0.0224)	(0.0210)	(0.0286)	(0.0283)	(0.0190)	(0.0814)	(0.0116)
Game Variables									
Divisional Game	0.0327	0.0332	0.0281	0.0060	0.0238	0.0102	-0.0198	-0.0047	0.0255
	(0.0834)	(0.0197)	(0.0177)	(0.0169)	(0.0228)	(0.0274)	(0.0168)	(0.0736)	(0.0114)
Home Team Win Percentage	0.1191	-0.0481	-0.0512	-0.0128	-0.0721	0.0441	0.0232	0.1146	-0.0053
	(0.1496)	(0.0384)	(0.0346)	(0.0264)	(0.0449)	(0.0505)	(0.0342)	(0.1282)	(0.0187)
Away Team Percentage	-0.2291	-0.0453	-0.0296	0.0043	-0.0628	-0.0450	-0.0005	-0.0998	-0.0270
	(0.1408)	(0.0351)	(0.0319)	(0.0276)	(0.0421)	(0.0433)	(0.0288)	(0.1255)	(0.0192)
Game Temperature	-0.0008	-0.0013	-0.0010	-0.0004	-0.0009	-0.0008	-0.0011	0.0030	-0.0004
	(0.0037)	(0.0008)	(0.0007)	(0.0008)	(0.0009)	(0.0011)	(0.0007)	(0.0035)	(0.0004)
Game Humidity	-0.0024	-0.0001	0.0001	0.0002	0.0000	-0.0005	-0.0001	-0.0016	-0.0002
	(0.0021)	(0.0004)	(0.0004)	(0.0003)	(0.0005)	(0.0006)	(0.0004)	(0.0019)	(0.0002)
Game Wind-Speed	0.0043	0.0032	0.0018	0.0013	0.0041	-0.0021	-0.0023	0.0038	0.0005
	(0.0082)	(0.0016)	(0.0016)	(0.0015)	(0.0021)	(0.0023)	(0.0018)	(0.0074)	(0.0008)
Dome-Game	0.0461	-0.0004	0.0140	0.0707	0.0066	-0.0158	0.0156	0.0482	-0.0073
	(0.1560)	(0.0305)	(0.0287)	(0.0353)	(0.0386)	(0.0468)	(0.0325)	(0.1405)	(0.0169)
Game Occurs on Turf Field	0.1428	0.0274	0.0209	0.0060	0.0416	-0.0160	-0.0265	0.1358	0.0089
	(0.0897)	(0.0205)	(0.0184)	(0.0174)	(0.0248)	(0.0270)	(0.0190)	(0.0802)	(0.0110)
Week Game Occurred During	-0.0131	0.0063	0.0028	0.0092	0.0192	-0.0244	-0.0119	0.0017	0.0030
	(0.0347)	(0.0078)	(0.0071)	(0.0072)	(0.0095)	(0.0120)	(0.0071)	(0.0299)	(0.0043)
Game Month									
September	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.
October	-0.0822	-0.0424	-0.0246	-0.0415	-0.1239	0.0537	0.0302	-0.1189	0.0108
	(0.1819)	(0.0585)	(0.0455)	(0.0735)	(0.1068)	(0.0381)	(0.0282)	(0.1619)	(0.0264)
November	-0.1741	-0.0309	0.0039	-0.1061	-0.1624	0.1628	0.0730	-0.2819	-0.0257
	(0.3122)	(0.0845)	(0.0691)	(0.1105)	(0.1454)	(0.1050)	(0.0645)	(0.2748)	(0.0497)
December	-0.0064	-0.0543	-0.0175	-0.1253	-0.2213	0.3208	0.1607	-0.2075	-0.0279
	(0.4404)	(0.1088)	(0.0916)	(0.1225)	(0.1710)	(0.2039)	(0.1318)	(0.3787)	(0.0583)
Observations	2,096	2,096	2,096	2,096	2,096	2,096	2,096	2,096	2,096

Robust standard errors in parentheses

APPENDIX TABLE 4— MARGINAL EFFECTS OF PREDICTED KICKOFF RETURNS ON PLAYER INJURIES IN THE NFL BY INJURY TYPE (REDUCED FORM WITHOUT IV SPECIFICATION)

	Total Injuries	Concussion: Broad Definition	Concussion: Narrow Definition	Ligament Tear	General Location of Injury: Head/Neck	General Location of Injury: Upper Extremity	General Location of Injury: Trunk/Back	General Location of Injury: Lower Extremity	General Location of Injury: Other
Key Variables									
Number of Returns	0.0289	0.0009	0.0031	0.0027	0.0074	-0.0022	-0.0022	0.0216	0.0032
	(0.0164)	(0.0039)	(0.0033)	(0.0037)	(0.0046)	(0.0052)	(0.0033)	(0.0141)	(0.0018)
Post-Concussion Reporting Policy	0.3482	0.1489	0.1426	0.0697	0.1697	0.0228	-0.0393	0.1629	0.0311
	(0.0861)	(0.0203)	(0.0193)	(0.0198)	(0.0250)	(0.0258)	(0.0182)	(0.0770)	(0.0109)
Game Variables									
Divisional Game	0.0290	0.0308	0.0260	0.0056	0.0211	0.0099	-0.0200	-0.0059	0.0253
	(0.0833)	(0.0197)	(0.0176)	(0.0169)	(0.0227)	(0.0275)	(0.0168)	(0.0735)	(0.0113)
Home Team Win Percentage	0.1163	-0.0485	-0.0516	-0.0129	-0.0726	0.0439	0.0228	0.1136	-0.0054
	(0.1495)	(0.0384)	(0.0346)	(0.0263)	(0.0449)	(0.0505)	(0.0341)	(0.1281)	(0.0187)
Away Team Percentage	-0.2137	-0.0396	-0.0244	0.0053	-0.0561	-0.0438	0.0007	-0.0944	-0.0265
	(0.1391)	(0.0348)	(0.0316)	(0.0272)	(0.0419)	(0.0431)	(0.0287)	(0.1237)	(0.0191)
Game Temperature	-0.0016	-0.0017	-0.0014	-0.0005	-0.0013	-0.0009	-0.0012	0.0027	-0.0004
	(0.0037)	(0.0007)	(0.0007)	(0.0008)	(0.0009)	(0.0011)	(0.0007)	(0.0034)	(0.0004)
Game Humidity	-0.0024	-0.0001	0.0001	0.0002	0.0000	-0.0005	-0.0001	-0.0016	-0.0002
	(0.0021)	(0.0004)	(0.0004)	(0.0003)	(0.0005)	(0.0006)	(0.0004)	(0.0019)	(0.0002)
Game Wind-Speed	0.0031	0.0028	0.0014	0.0012	0.0035	-0.0022	-0.0024	0.0034	0.0004
	(0.0081)	(0.0016)	(0.0015)	(0.0015)	(0.0020)	(0.0022)	(0.0018)	(0.0074)	(0.0008)
Dome-Game	0.0439	-0.0019	0.0126	0.0705	0.0051	-0.0159	0.0155	0.0474	-0.0074
	(0.1561)	(0.0303)	(0.0285)	(0.0353)	(0.0383)	(0.0468)	(0.0325)	(0.1407)	(0.0168)
Game Occurs on Turf Field	0.1474	0.0297	0.0227	0.0062	0.0443	-0.0156	-0.0262	0.1374	0.0091
	(0.0898)	(0.0205)	(0.0184)	(0.0174)	(0.0248)	(0.0269)	(0.0190)	(0.0803)	(0.0111)
Week Game Occurred During	-0.0138	0.0058	0.0025	0.0092	0.0189	-0.0245	-0.0120	0.0015	0.0030
	(0.0347)	(0.0078)	(0.0071)	(0.0072)	(0.0095)	(0.0120)	(0.0071)	(0.0299)	(0.0043)
Game Month									
September	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.
October	-0.0731	-0.0368	-0.0204	-0.0400	-0.1152	0.0542	0.0306	-0.1156	0.0111
	(0.1806)	(0.0558)	(0.0436)	(0.0721)	(0.1030)	(0.0380)	(0.0280)	(0.1613)	(0.0261)
November	-0.1569	-0.0217	0.0112	-0.1040	-0.1498	0.1644	0.0743	-0.2760	-0.0249
	(0.3113)	(0.0816)	(0.0672)	(0.1089)	(0.1409)	(0.1050)	(0.0645)	(0.2745)	(0.0493)
December	0.0103	-0.0455	-0.0107	-0.1233	-0.2095	0.3228	0.1623	-0.2018	-0.0271
	(0.4401)	(0.1060)	(0.0896)	(0.1210)	(0.1664)	(0.2042)	(0.1323)	(0.3788)	(0.0580)
Observations	2,096	2,096	2,096	2,096	2,096	2,096	2,096	2,096	2,096

Robust standard errors in parentheses

APPENDIX TABLE 5—FIRST-STAGE INJURY RESULTS

	Number of Returns
Key Variables	
Predicted Number of Returns	0.9938 (0.0211)
Post-Concussion Reporting Policy	0.0272 (0.0906)
Game Variables	
Divisional Game	0.1308 (0.0790)
Home Team Win Percentage	-0.0868 (0.1375)
Away Team Percentage	0.2275 (0.1369)
Game Temperature	-0.0375 (0.0031)
Game Humidity	0.0065 (0.0019)
Game Wind-Speed	-0.0361 (0.0072)
Dome-Game	0.0138 (0.1521)
Game Occurs on Turf Field	0.1466 (0.0804)
Week Game Occurred During	-0.0088 (0.0304)
Game Month	
September	ref.
October	0.0370 (0.1600)
November	-0.0232 (0.2737)
December	-0.3551 (0.3893)
Observations	2,096

Robust standard errors in parentheses

H. Kickoffs vs. Other Types of Plays

The focus of our paper is on the change in the number of touchbacks/kickoff returns that occur due to each respective leagues rule changes. Appendix Table 6 presents an interesting side note about each league's decisions to change rules specifically aimed at kickoffs. When taken in context with the other play types that occur during a game, kickoffs make up on average only 6.4% of all play types. Unsurprisingly, passing and rushing plays make up over 80% of all types of plays; and while leagues have implemented rule changes aimed at increasing player safety, few of these specifically target play types like they have done with kickoffs. Given that kickoffs are one of the plays in football most often associated with high injury risks, each injury reduced is perhaps more impactful given the rarity of the event when compared to all other play types.

APPENDIX TABLE 6—NUMBER AND PERCENTAGE OF PLAY-TYPES

Play Type	N	% of Plays
Total		
Kickoff	64,341	6.4%
Pass	412,769	40.7%
Rush	416,343	41.1%
Punt	61,568	6.1%
Field Goal/Extra Point	58,085	5.7%
NFL		
Kickoff	22,359	6.3%
Pass	164,423	46.2%
Rush	126,704	35.6%
Punt	22,060	6.2%
Field Goal/Extra Point	19,995	5.6%
NCAA		
Kickoff	41,982	6.4%
Pass	248,346	37.8%
Rush	289,639	44.0%
Punt	39,508	6.0%
Field Goal/Extra Point	38,090	5.8%

Note – This table presents the total over the entire sample and not by season

I. Placebo Test - Punts

There is a possibility that the results we find for the change in probability of touchbacks are the result of unobserved contemporaneous factors, including a change in coaching strategies to reduce exposure to injury. We tested this using a placebo test looking at the effect of each league's rule change for both kickoffs and then again for punts. Since the rules themselves specifically targeted kickoffs then the equivalent of no punt returns (fair catches) should be insignificant when estimated in the same way. On the other hand, if coaches specifically changed their strategy to reduce exposure to injury then punts would also be affected. Appendix Table 7 shows that the rule changes for the NFL and NCAA were unrelated to the probability of a fair catch. Supporting the causal impact of the kickoff rules changes on the number of kickoff returns.

J. Sensitivity Analysis

The sample selection process, particularly related to which NCAA games are included as control, introduce the possibility of bias in our results. Appendix Table 8 shows that when we use an alternative specification for which NCAA games are included the 2012 NCAA rule change has slightly less impact on reducing touchback probability than the original sample. We attribute this difference as the alternative sample showing less comparability in terms of skill between the NCAA and NFL which would confirm that using our primary sample is the correct specification.

APPENDIX TABLE 7—PLACEBO TEST OF KICKOFF/PUNT RESULTS

	(1)	(2)	(3)
Punt - Fair Catch			
NFL Sum	3.07	0.13	0.21
	0.0798	0.7222	0.6497
NCAA Sum	6.15	0.33	0.11
	0.0132	0.5654	0.7454
Kickoff - Touchback			
NFL Sum	987.51	568.18	156.12
	0.0000	0.0000	0.0000
NCAA Sum	1105.74	353.33	103.12
	0.0000	0.0000	0.0000

Differences are calculated as the ME of a kickoff occurring at the 35-yard line plus the league specific rule changes ME

We test the hypothesis that the addition of these two ME's for each league are equal to zero, implying a meaningful change

Note: First Row for each column and league is the Chi-Squared Value, the second row is the Chi-Squared probability

APPENDIX TABLE 8—MARGINAL EFFECTS OF RULE CHANGES ON TOUCHBACK PROBABILITY - ALTERNATIVE SAMPLE SELECTION

	(1)	(2)	(3)	(4)
Key Variables				
Kickoff from 35-yard line	0.2544	0.1905	0.2664	0.1997
	(0.0080)	(0.0089)	(0.0115)	(0.0118)
2011 NFL Rule Change	-0.0189	0.0270	-0.0385	0.0262
	(0.0132)	(0.0151)	(0.0157)	(0.0187)
NCAA	-0.0429	-0.0669	-0.0454	-0.0691
	(0.0062)	(0.0063)	(0.0068)	(0.0070)
2012 NCAA Rule Change	-0.0749	-0.0305	-0.0881	-0.0296
	(0.0096)	(0.0110)	(0.0123)	(0.0143)
Conference Game				
Conf Game (NFL = Division)	0.0164	0.0122	0.0171	0.0115
	(0.0038)	(0.0039)	(0.0038)	(0.0039)
Point Differential	0.0005	0.0002	0.0005	0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Time Remaining in Game	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Home Game	0.0247	0.0139	0.0249	0.0138
	(0.0033)	(0.0034)	(0.0033)	(0.0034)
Game Month				
August	0.0414	0.0144	0.0356	0.0149
	(0.0140)	(0.0157)	(0.0150)	(0.0168)
September	0.0136	0.0284	0.0092	0.0313
	(0.0047)	(0.0051)	(0.0063)	(0.0070)
October	*ref.*	*ref.*	*ref.*	*ref.*
November	-0.0428	-0.0426	-0.0386	-0.0456
	(0.0044)	(0.0044)	(0.0059)	(0.0059)
December	-0.0774	-0.0756	-0.0711	-0.0795
	(0.0058)	(0.0053)	(0.0083)	(0.0080)
January	-0.0492	-0.0557	-0.0422	-0.0608
	(0.0156)	(0.0148)	(0.0177)	(0.0165)
Team Win Percentage	0.0251	0.0163	0.0252	0.0160
	(0.0054)	(0.0060)	(0.0054)	(0.0060)
Opponent Win Percentage	-0.0098	-0.0109	-0.0099	-0.0109
	(0.0054)	(0.0062)	(0.0054)	(0.0062)
Quarter Trend	0.0040	0.0034	0.0000	0.0061
	(0.0004)	(0.0004)	(0.0037)	(0.0040)
Pseudo R2	0.0817	0.0873	0.0820	0.0875
Observations	63,998	54,316	63,998	54,316

Robust standard errors in parentheses

<u>Notes:</u>

(1) - Initial sample basic logit specification

(2) - No 'Power Conference' teams sample basic logit specification

(3) - Initial sample season fixed effects logit specifications

(4) - No 'Power Conference' teams sample season fixed effects logit specifications

Season marginal effects are included for models (3) and (4) but the marginal effects are not reported in Table I so as to truncate the reported results. See the corresponding Appendix table for the full table including the marginal effects for each season respectively.