

Effect of Concussions on National Football League Quarterback Performance

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ABSTRACT

Background: Sports-related concussion (SRC) rates are higher in American football than any other sport; therefore, the effects of SRCs on professional football players is a prevalent topic. Previous research has shown that sustaining an SRC has negative financial and overall career outcomes for athletes and may cause performance decrements after an athlete returns to play, however, the results of previous research regarding athlete performance after returning from an SRC are mixed. While some studies found that player performance in the National Football League (NFL) was unaffected upon returning from an SRC, evidence also suggests significant scoring reductions in offensive players. Although previous research has found that NFL running backs and wide receivers perform at levels similar to their performance before sustaining an SRC, little is known about quarterback performance after an SRC. There is also evidence that SRCs decrease neurocognitive performance, a quality that is crucial, especially for quarterbacks. **Objective:** The purpose of this study is to examine changes in NFL quarterback performances upon return to play from an SRC. **Method:** Quarterback ratings (QBRs) and concussion data from 2012-2015 were used to determine if changes occurred in NFL quarterback performance following an SRC. **Results:** QBRs decreased by 13.3 points ($p = 0.014$) after quarterbacks return from an SRC. **Conclusions:** Changes in on-field performance for NFL quarterbacks after sustaining an SRC could be the result of neurocognitive decrements that impact quick reaction and decision-making skills, which may have greater impacts on quarterbacks than other positions.

Key words: Athletic Performance, Brain Concussion, Decision Making, Football, Return to Sport, United States

INTRODUCTION

Sports-related concussions (SRCs) have become a rising topic of concern. An SRC is defined as “a traumatic brain injury induced by biomechanical forces” (McCrory et al., 2017). American football has the highest reported number of SRCs compared to other sports (Daneshvar et al., 2011; Ianof et al., 2014; Wasserman et al., 2015). Over 600 concussions were reported in collegiate football over a four-year period (Wasserman et al., 2015), and more than 140 concussions are reported annually in professional football (Casson et al., 2010). In response, the National Football League (NFL) has implemented multiple policies and rule changes in attempts to make football safer (Gove, 2012). Despite efforts to decrease SRCs in football through changes in game rules, guidelines for actions following the occurrence of an SRC, increased protection of helmets, and education for coaches and players, the number of SRCs continues to rise (Gove, 2012; McCrory et al., 2017; NFL Head, Neck, and Spine Committee, 2018; Viano & Halstead, 2012).

While SRCs gained attention in the media and in research, studies examining the effects of SRCs on performance have yielded mixed results. Although there is evidence that

SRCs cause deficits in offensive performance in baseball (Wasserman et al., 2015), similar declines in offensive performance have not been seen in hockey (Kuhn et al., 2016). Additionally, Kumar et al. (2014) and Reams et al. (2017) found no evidence that sustaining an SRC impacted NFL player performance. Contrarily, Navarro et al. (2017) provided evidence that performance decreases for offensive skill position players in the NFL, including running backs and wide receivers, after returning from an SRC. However, a more recent study did not find performance differences for running backs and wide receivers following SRCs, relative to a control group (Jildeh et al., 2019). These findings reveal a need for more research and information on the relationship between SRCs and performance, especially research that examines performance relative to control groups. Furthermore, the relationship between SRCs and performance for quarterbacks remains understudied, especially considering the cognitive demands of the position.

SRCs cause decreases in neuropsychological performance in football (Collins et al., 1999), which would likely have a larger impact on quarterbacks than other positions. Quarterbacks are required to quickly process and react to

information with both physical and neurological skills; however, these may be impaired by sustaining an SRC (Collins et al., 1999; Wasserman et al., 2015). Thus, the purpose of this study is to examine how SRCs affect NFL quarterback performance by evaluating quarterback ratings (QBRs). NFL concussion data from 2012 to 2015 is used to compare QBRs before and after an SRC. Additionally, QBRs of quarterbacks who sustained SRCs are compared to QBRs of a control group: quarterbacks who did not sustain SRCs.

Football is the sport with the highest number of reported SRCs (Daneshvar et al., 2011), and despite efforts to increase safety within the sport, the number of concussions continues to rise (Gove, 2012). Although the NFL has implemented multiple rule changes to limit concussive injuries, concussion prevalence in the NFL remains high (Gove, 2012; McCrory et al., 2017; Viano & Halstead, 2012). More than 140 concussions are reported in the NFL each season; thus, there is approximately one concussion per team every five games (Casson et al., 2010). Quarterbacks are also at higher risk for sustaining an SRC than other positions in the NFL, likely because they are often struck at high velocities and may be unaware of the oncoming hit (Brophy et al., 2007; Pellman et al., 2004). Additionally, certain offensive playing styles may increase SRC risks, as players involved in pass plays sustain more SRCs than players involved in running plays (Teramoto et al., 2015). There is also evidence that players on teams using a West Coast offensive style consisting of short horizontal passes sustain the highest number of SRCs, putting quarterbacks at even higher risk of sustaining an SRC because they are more open and therefore more likely to be tackled (Teramoto et al., 2015).

Despite the high prevalence of SRCs in the NFL, SRC occurrences are likely higher due to underreporting (Kroshus et al., 2015; Meier et al., 2015; Reams et al., 2017). Over half of the athletes in the NFL admit to hiding a concussion to continue playing (Reams et al., 2017). Further, Kroshus et al. (2015) found that over 25% of athletes who experience head trauma are pressured to continue playing. Therefore, many concussions occur that are never reported. Additionally, self-reported symptoms are part of SRC assessment and management, and once an athlete is no longer reporting symptoms, a clinician can allow them to return to play (Meier et al., 2015). To return to play sooner, athletes often under-report symptoms; thus, many athletes return to play before they fully recover (Meier et al., 2015). It is also possible for athletes to attribute concussive symptoms to another injury, such as stress or dehydration (Fazio et al., 2007). Athletes who sustain an SRC often miss at least one game, which could affect an athlete's income or position on their team; therefore, underreporting of an SRC or its symptoms could be the result of external pressure from coaches or internal pressure from the athlete to continue playing (Fazio et al., 2007; Ochs et al., 2018).

Quarterbacks are simultaneously the most glorified and scrutinized position in football (Farmer, 2012). Although quarterbacks may not be the strongest or fastest players on the field, they are often considered the most important offensive player because of the physical abilities, leadership

skills, and mental acuity they must possess (Kissel, 2013). In addition to having the athletic skills needed for the physical demands of the position, quarterbacks are required to quickly process information and make decisions (Kissel, 2013). Mental acuity encompasses neurocognitive function through memory, focus, understanding, and concentration (Brennan & Daly, 2009); therefore, a successful quarterback must possess the mental acuity to accurately analyze and react to situations (Kissel, 2013).

In the NFL, results on the impacts of SRCs on performance are mixed. When comparing performance between players of any position who returned to play in less than seven days to players who missed at least one game following an SRC, Kumar et al. (2014) found no difference in performance upon return-to-play between the two groups. All players analyzed participated in at least four games after return-to-play during the same season as their injury, during which no performance differences were found between players who missed a game after an SRC and those who did not (Kumar et al., 2014). Similarly, when comparing NFL players who suffered an SRC to players with other head and neck injuries, Reams et al. (2017) found no differences in the performance between the two groups at return-to-play. Additionally, players returning from an SRC performed at levels similar to baseline (Reams et al., 2017).

Interestingly, when examining outcomes for NFL players of any position who sustained an SRC, Navarro et al. (2017) found that SRCs led to significantly greater financial losses and shorter careers overall in the five years following an SRC. Further, performances of offensive scoring players, including tight ends, running backs, wide receivers, and quarterbacks, were significantly lower during their post-concussion careers than their pre-concussion careers (Navarro et al., 2017). Contrarily, Jildeh et al. (2019) found that NFL running backs and wide receivers had no significant changes in power ratings upon returning from an SRC compared to a control group of players of the same position who had not experienced an SRC. These players were also analyzed for three years after returning to play following an SRC (Jildeh et al., 2019), thus there are mixed results regarding how SRCs affect NFL player performances both short- and long-term.

Based on previous research, NFL players in general do not seem to exhibit performance declines following SRCs (Kumar et al., 2014; Reams et al., 2017). However, there is evidence that offensive scoring players who sustain an SRC do exhibit performance declines for the remainder of their careers (Navarro et al., 2017). Contrarily, the performances of running backs and wide receivers were unaltered in the three seasons following an SRC (Jildeh et al., 2019). Therefore, it is possible that the effects of SRCs on NFL player performance differ by position or over time. While the short-term effects of performance after an SRC have been studied in running backs and wide receivers (e.g., Jildeh et al., 2019), the short-term performance outcomes for quarterbacks after an SRC remain largely unknown. Although SRCs appear to impact quarterback performances long-term (Navarro et

al., 2017), it is possible that the effects of SRCs on quarterback performance are obvious short-term as well, especially given the increased neurocognitive demands of quarterbacks compared to other positions. Thus, we present the following hypothesis:

Athletic performance is lower for quarterbacks in the season after sustaining SRCs than it will be for quarterbacks who did not sustain SRCs.

METHOD

Participants and Study Design

To examine the relationship between SRCs and NFL quarterback performance, a correlational research design was used. QBRs of NFL quarterbacks were examined based on whether the quarterback had sustained an SRC from 2012 to 2015. Quarterbacks were separated into an experimental and a control group based on whether they sustained an SRC during the sample period. The control group consisted of quarterbacks who had not experienced a reported SRC during a playing season, and quarterbacks who had experienced a reported SRC were placed in the experimental group. There was no Institutional Review Board (IRB) approval, as the research did not involve interaction with human participants and all data used is publicly available.

The dependent variable of interest is a player's QBR for the next season (*Future QBR*). QBR is recorded on a scale of zero to 100, where higher numbers are indicative of better performance and lower numbers are indicative of worse performance (Burke, 2016). Quarterback actions that help the team overall, such as completed passes and running yards, increase QBR, whereas quarterback actions that negatively impact game outcomes for their team, such as turnovers and interceptions, decrease QBR (Burke, 2016).

Three independent variables are used as predictors of the dependent variable in this analysis. A player's QBR from the season prior to the SRC (*Previous QBR*) is used as a baseline for predicting future performance (i.e., performance in the year following the SRC). A dichotomous variable indicating whether a quarterback sustained a concussion (*Concussion*) is also included in the model, where quarterbacks are assigned the value of 0 if they had no reported SRC during that year or the value of 1 if they experienced an SRC. Lastly, to account for increases in each quarterback's age, the age of the quarterback when they sustained the SRC (*Age*) is included in the model.

Data Procedure

QBRs were obtained from <http://pro-football-reference.com>, and concussion data were collected from *PBS Frontline's Concussion Watch*. Only quarterbacks who started in at least eight games of a season (i.e., half of the NFL season) were included in the sample. There were 129 observations of 56 quarterbacks who played at least eight games of a season during the sample period. Twenty of the 129 observations included rookies, previously injured players, or players who were not on an NFL roster in the previous season. Similarly,

five more quarterbacks did not return the following season. Therefore, 25 of the 129 observations were excluded from the sample due to missing data. The final sample included 40 quarterbacks and 104 observations.

Statistical Analysis

Data were analyzed using Stata 15 (Stata Press, College Station, TX, USA). Ordinary least squares (OLS) regression was used to analyze the effects of concussions, previous quarterback rating, and quarterback age on future quarterback rating. Based on the dependent and independent variables, the OLS model takes the following form:

$$\text{Future QBR} = \beta_0 + \beta_1(\text{Concussion}) + \beta_2(\text{Previous QBR}) + \beta_3(\text{Age})$$

RESULTS

Table 1 reports the summary statistics of the mean, standard deviation, minimum, median, and maximum values for each variable. Although 15 quarterbacks in the sample suffered SRCs, only nine played during the following NFL season. Thus, 8.7% of quarterbacks included in the regression analysis sustained an SRC. *Previous QBR* varies from 5.2 to 84.5 with a mean of 57.361. *Future QBR* varies from 0 to 79.7 with a mean of 54.389. The mean age in the sample is 29.4, and ranges from 23 to 38.

OLS regression estimates for each independent and control variable are reported in Table 2. Quarterbacks who sustained an SRC had a significantly lower *Future QBR* than those who did not. In this sample, quarterbacks who sustained an SRC experienced a decrease in QBR by approximately 13 points ($p = 0.014$), a decrease of nearly one standard deviation from the mean. Additionally, *Previous QBR* is a significant predictor of *Future QBR*, resulting in approximately a 0.4-point increase in *Future QBR* for every one-point increase in *Previous QBR* ($p < 0.001$).

Table 1. Summary statistics

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
Future QBR	54.389	16.887	0	57.4	79.7
Concussion	0.087	0.283	0	0	1
Previous QBR	57.361	15.406	5.2	60.9	84.5
Age	29.404	3.905	23	29.5	38
Season	2013.529	1.114	2012	2013.5	2015

Table 2. OLS Regression estimates

Variable	Coefficient	Std. Err.	P-value
Concussion	-13.317	5.307	0.014
Previous QBR	0.407	0.102	<0.001
Age	0.352	0.396	0.376
Constant	21.831	11.482	0.060

DISCUSSION

The purpose of this study was to determine the effects of an SRC on NFL quarterback performance by examining the effect of sustaining an SRC on QBRs. Consistent with our hypothesis that sustaining an SRC would negatively impact a player's QBR, results indicate that QBRs significantly decreased after an athlete returns from an SRC. Because QBRs are based on pass completion rates, passing yards, touchdowns, and interceptions (Burke, 2016), this indicates a decrease in overall on-field performance after sustaining an SRC. More specifically, the overall on-field performance of quarterbacks decreases almost a full standard deviation (about 13.3 points) after sustaining an SRC. This finding is important because previous studies (a) have found limited evidence of performance declines following concussions, (b) examining post-concussion athletic performances have not always focused on positions with more neurocognitive demands, and (c) examined a variety of time spans to gauge performance following a concussion (e.g., total career fantasy points following a concussion; Navarro et al., 2017). Therefore, this study establishes a substantial effect of concussions on the performance of quarterbacks, whom have to process lots of information in a short period of time to perform effectively, and that effect is present in seasons that immediately follow the SRCs.

While the present study suggests that sustaining an SRC impairs on-field performance, Kumar et al. (2014) found no differences in NFL player performance after an SRC whether the player did or did not miss games before return-to-play. Likewise, Reams et al. (2017) found that NFL players performed at levels similar to their individual baseline levels upon return from an SRC. However, it is possible that these differences are the result of analyzing players of different positions. Unlike the current study, which analyzed the performances of only quarterbacks, Kumar et al. (2014) and Reams et al. (2017) both analyzed players of any position with a reported SRC. Further, Navarro et al. (2017) found that NFL athletes who suffer an SRC face significant financial losses and that the number of points scored by offensive NFL players after returning from an SRC was significantly lower than before the athlete sustained an SRC.

However, Jildeh et al. (2019) found that a high rate of NFL running backs and wide receivers were able to return to play after an SRC and that these players performed at a similar level in both acute and long-term periods after returning to play. Given the findings of the present study and those of Jildeh et al. (2019), it is possible that the effects observed in Navarro et al. (2017) could mostly be a result of the larger influence of quarterback salaries and on-field performance.

Furthermore, changes in on-field performance seen in quarterbacks but not in other offensive positions may indicate that performance changes following an SRC are caused by neurological deficits. Because of the increased neurological demands of quarterbacks compared to other positions, changes in quarterbacks' performances may be more visible than for other positions. Additionally, as quarterbacks have higher rates of SRCs than other positions (Brophy et al., 2007; Pellman et al., 2004), there may be more available

data and opportunities to study performance changes following an SRC in quarterbacks compared to other positions.

It is also possible that time-off after an SRC influences changes in performance. Quarterbacks tend to miss more games after sustaining an SRC than other positions (Heintz et al., 2020); therefore, quarterbacks may take longer than other positions to return to baseline performance levels. Missing more games may cause quarterback performance to decline more than players of other positions who return to practice and play sooner. This could also result in quarterbacks needing more time to return to preSRC performance levels once they return to play, leading to decreases in QBRs.

Results of this study may also provide additional evidence for prolonged neurological decrements, similar to those found in Collins et al. (1999). Although players may be cleared to return to play, it is possible that neurological symptoms of an SRC still persist after physical symptoms are no longer being displayed (Broglio et al., 2007; Moore et al., 2014). Therefore, performance changes in quarterbacks after returning from an SRC could be the result of changes in neurocognitive abilities. This could also indicate that players are returning to play before they have fully healed neurologically. While neurocognitive changes in quarterbacks may be more noticeable because of the increased neuropsychological demands of quarterbacks, it is likely that players in other positions have impaired neuropsychological abilities when returning from an SRC as well. However, because other positions do not have the same neurocognitive demands as quarterbacks, changes in performance caused by neurological impairments may not be as apparent.

Practical Applications

The present study provides evidence that on-field performances of NFL quarterbacks decrease following an SRC. Because similar decrements in performance have not been found in players of other positions, it is likely that these performance decrements are neurological, as quarterbacks have increased neurocognitive demands compared to other positions. However, it is also likely that other positions face similar decreases in neurocognitive performance following an SRC, although they may be less visible. Therefore, the findings from this study benefit not only NFL quarterbacks, but all NFL players, coaches, and management through a better understanding of how sustaining an SRC affects on-field performance, which could impact overall team success. Medical personnel and athletic trainers should take these findings into account when assessing players for return-to-play. Additionally, it may be necessary to increase monitoring of players before and during return-to-play, as some players may be returning before neurological symptoms of an SRC have healed. Finally, monitoring of neurological symptoms and neurocognitive testing should be implemented for all players after an SRC to ensure full recovery.

Limitations

Although this study found that NFL quarterbacks' performances significantly decreased after returning from an SRC,

the explanations for these findings remain unclear. Because this study analyzed only QBRs and whether the quarterback sustained an SRC, the results do not account for other factors that may have influenced performance, including time-off or additional injuries. For example, quarterbacks who sustained an SRC may have suffered other musculoskeletal injuries that could have caused decreases in performance. It is also possible that the amount of time-off a player receives after an SRC influences performance after returning to play. Additionally, QBRs were not compared to physical and neurological testing; therefore, more data is needed to attribute performance decreases to suffering an SRC. Furthermore, the data analyzed contains only reported SRCs, and with a high prevalence of underreporting (Reams et al., 2017), there are likely more SRCs that occurred but were excluded from the data because they were unreported. Finally, this study includes data from 2012-2015; however, more recent data and data from additional seasons would be beneficial to determine if similar trends occur in QBRs after returning from an SRC. Nevertheless, the methods of the present study are consistent with previous studies of athlete performance following concussions, though the results revealed additional insights.

Future Research

There are numerous directions for future research on quarterback performance following an SRC. First, accounting for or excluding quarterbacks who suffered additional injuries in conjunction with an SRC could help determine if sustaining an SRC is the cause of decreases in QBRs. Additionally, considering the amount of time-off a quarterback receives after sustaining an SRC could also provide insight on whether sustaining an SRC causes decreases in performance or if other factors influence performance outcomes. Including data from neuropsychological tests of quarterbacks would be beneficial for examining the effects of an SRC on physical and neurocognitive performance, which may influence overall performance differently for different positions. Likewise, studying the performances of each individual position would lead to a better understanding of how SRCs may impact different positions in different ways, as well as overall athletic performance. Examining changes in performance at different time points after an SRC would also be beneficial for determining how SRCs impact player performances throughout the remainder of their careers. Finally, including more recent data would determine if similar trends in performance still exist after a player returns from an SRC, which could influence future concussion protocols and provide insight on the effectiveness of current return-to-play protocols.

CONCLUSION

The results of this study indicate that QBRs significantly decrease after a player returns from an SRC in the NFL, showing decreases in quarterback performance after sustaining an SRC. These changes in performance could be the result of neurological impairments that cause decrements in

neuropsychological performance, which is likely more visible in quarterbacks compared to other positions.

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