Scaphoid Fracture Repair Does Not Significantly Diminish Short-Term Participation in the National Football League

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Received: 4 July 2018/Accepted: 19 September 2018/Published online: 5 November 2018
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Abstract *Background:* Fixation of scaphoid fractures is recommended in elite athletes to hasten healing and return-to-sport times. Complications such as nonunion negatively affect athletic performance. *Questions/Purposes:* The purpose of this study was to examine the prevalence and impact of scaphoid repair on National Football League (NFL) participation during athletes' first season in the NFL, while identifying significant predictors for development of carpal arthritis and scaphoid nonunion. *Methods:* A total of 1311 football athletes invited to the NFL Scouting Combine from 2012 to 2015 were evaluated for history of scaphoid fracture repair. Athlete demographics, surgical history, and imaging and physical examination findings were recorded. Future NFL participation based on draft status, games played, and

games started during athletes' first season were gathered using publicly available databases. *Results:* Nineteen (1.4%) athletes underwent 24 operations for scaphoid repair. Limitations in wrist range of motion or strength were present in 47.4% of athletes with a history of repair. Arthritic changes were present in 32% of wrists, while radiographic nonunion was present in two athletes following scaphoid fracture. Defensive backs were observed to have a higher incidence for arthritic changes following repair compared to other positions. No significant difference in prospective NFL participation was found in athletes with a history of scaphoid repair than in those without. *Conclusions:* Athletes with a history of scaphoid repair are not at significant risk for diminished participation during their first season in the NFL.

Level of Evidence: Level II, prognostic study

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11420-018-9640-6>) contains supplementary material, which is available to authorized users.

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Keywords scaphoid · fracture · football · athlete · nonunion · wrist

Introduction

The scaphoid is the most commonly fractured carpal bone in athletes, with up to 1% of collegiate American football athletes sustaining fractures annually [10, 26, 30]. During competition or practice, the scaphoid is susceptible to fracture from direct trauma during contact or a fall onto an extended wrist [22]. To ensure carpal stability and function, scaphoid fractures require quick recognition, diagnosis, and treatment to avoid the consequences associated with nonunion, including stiffness and decreased strength [24].

However, athletes who sustain a scaphoid fracture during competition may ignore pain and swelling, failing to report an injury in order to continue playing [17, 25]. Many fractures are discovered days to weeks after initial injury, increasing the risk of scaphoid nonunion due to disruption of the tenuous retrograde blood supply of the scaphoid [2, 8, 15, 16, 18]. Resultant nonunion places athletes at high risk

for long-term consequences involving wrist instability, progressive radiocarpal and pancarpal arthritis, and avascular necrosis [9, 14, 23]. Moatshe et al. evaluated 2285 players invited to the National Football League (NFL) Scouting Combine from 2009 to 2014 and found that 25% of athletes with a history of scaphoid fracture went on to nonunion, while 34% had evidence of degenerative changes and 15% of hardware complications including screw loosening, hardware breakage, and erosion of adjacent carpal bones [16]. Such complications effectively compromise playing ability, decreasing playing time, capability of returning to pre-injury level, and career length [20, 22, 24].

With 80% of fractures occurring in vulnerable portions of the proximal two-thirds of the scaphoid receiving retrograde blood flow, traditional methods of treatment with immobilization are seldom recommended [3, 20]. Instead, screw fixation is generally performed to ensure proper reduction and faster return to play, while minimizing complications [2, 20]. However, no investigation to date has examined outcomes after surgical repair of scaphoid fracture in elite collegiate football athletes.

The purpose of this study was to (1) establish the prevalence of scaphoid repair in elite collegiate American football players invited to the NFL Scouting Combine from 2012 to 2015; (2) ascertain the prevalence of post-operative limitations in range of motion and strength to the operative wrist; (3) determine the impact of scaphoid repair on first-season NFL participation among athletes with and without a history of scaphoid repair; and (4) define significant predictors for the development of carpal arthritis and scaphoid nonunion. We hypothesized that there would be only a small cohort of athletes with a history of scaphoid repair and that their future NFL participation would not be significantly compromised compared to athletes with no history of scaphoid repair.

Methods

The study protocol was pre-approved by the NFL Research Committee and the institutional review board. Using the NFL Scouting Combine database, a retrospective review of all collegiate football athletes invited to the combine from 2012 to 2015 was performed; 2012 was the first year for which data from the combine was digitized into a centralized database, and 2015 was the last year for which data from the combine was available. Information collected included athlete position, race, combine year, age at the time of surgery, physical examination results, and surgical history. Prospective data regarding NFL participation during the athletes' first season in the NFL, based on draft status and number of games played and games started, was collected using the publicly available database at NFL.com.

Athletes with a history of isolated scaphoid fracture with repair prior to participation at the combine were included in the study for analysis. Athletes were excluded if they had no history of scaphoid fracture repair, had a history of wrist injury without clear evidence of isolated scaphoid repair based on history or imaging results, or

were still undergoing rehabilitation for scaphoid repair at the time of the combine.

Physical examination results were reviewed for the presence of any deficits in wrist range of motion (tested in flexion and extension, graded subjectively by physicians) or strength (based on grip or pinch strength). Discrepancies with the opposite wrist in range of motion or strength were recorded as positive findings. All athletes had radiographs of the operative wrist performed at the combine. Radiographs were independently reviewed by two senior authors to determine repair method, integrity of the repair, the presence and grade of arthritic changes in the carpus, and the presence of scaphoid nonunion. The extent of pancarpal arthritis was independently graded as stage I (normal), stage II (minimal joint-space narrowing), stage III (moderate joint-space narrowing), or stage IV (severe loss of joint space with osteophyte formation) by the senior authors using the classification system described by Weinstein et al. [28]. Scaphoid nonunion was defined by the presence of any visible fracture line extending through the scaphoid. Any disagreement between the senior authors regarding arthritic stage or the presence of scaphoid nonunion was reconciled through consultation with an independent musculoskeletal radiologist.

Statistical analysis was performed to assess our primary outcome examining the impact on short-term prospective NFL participation in athletes with a history of scaphoid repair compared to all other athletes invited to the NFL combine from 2012 to 2015. Continuous variables were compared using the independent *t* test, assuming unequal variance using the Satterthwaite method, and categorical variables were compared using the χ^2 test. Our secondary outcome measurement was to identify predictors for arthritic development (defined as stage II or greater) and scaphoid nonunion. We used athlete age, race, position, surgical history (bilateral repair, bone grafting, reoperations secondary to nonunion), and the presence of positive physical examination findings (decreased grip or pinch strength, limited range of motion) as potential predictor variables. Logistic regression was used to assess predictors of outcome in a unique univariable model for each outcome variable. A *p* value of <0.05 was used to determine significance. All statistical analysis was performed using SPSS, version 23 (IBM, Armonk, NY, USA).

Results

Review of the NFL combine database identified 19 athletes (1.4%) who underwent 24 operations for primary scaphoid repair (*n* = 22 procedures) or reoperation for symptomatic nonunion (*n* = 2 procedures) (Table 1). The highest incidence of scaphoid repair was in linebackers (*n* = 4; 21%). African American athletes, who comprised 79% (*n* = 1036 athletes) of the athletes, had a slightly higher prevalence of scaphoid fracture repair (*n* = 10; 53%) than Caucasian athletes. Mean age at surgery was 19.1 ± 2.4 years. Three athletes (16%) had a history of bilateral scaphoid repair. Three athletes (16%) underwent bone grafting at the time

Table 1 Prevalence of scaphoid fracture repair based on athlete position at NFL combine from 2012 to 2015

	DB	DL	LB	OL	PK	QB	RB	TE	WO	Total
No. of athletes participating in combine	230	223	138	212	45	68	140	79	176	1311
No. of athletes w/ surgical repair (% of combine position total)	3 (0.9%)	2 (0.9%)	4 (2.9%)	2 (0.9%)	1 (2.2%)	1 (1.5%)	1 (0.7%)	3 (3.8%)	2 (1.1%)	19 (1.4%)

DB defensive back, DL defensive linemen, LB linebacker, OL offensive linemen, PK placekicker, QB quarterback, RB running back, TE tight-end, WO wide-out

of primary surgery, and two athletes (11%) required revision surgery with bone grafting due to symptomatic nonunion following failed primary repair. Athletes without a history of scaphoid repair ($n = 1287$) and those with a history of wrist injury without clear evidence of isolated scaphoid repair based on history or imaging results ($n = 5$) were excluded. One athlete with prior scaphoid repair to the right wrist underwent subsequent repair to the left wrist 1 month prior to the combine and was undergoing rehabilitation at the time of the combine. This injury and surgery were excluded from analysis due to poor functional outcomes resulting from incomplete fracture healing.

Limitations in wrist range of motion or strength on physical examination were present in 47.4% ($n = 9$) of athletes with a history of scaphoid repair (Table 2). Decreased grip strength was present in eight athletes (42.1%) (mean loss: 16.75 pounds of force; mean, 92% of unaffected wrist) and decreased pinch strength in three athletes (15.7%) (mean loss: 4.7 pounds of force; mean, 95% of unaffected wrist). A decrease in wrist range of motion was present in four athletes (21%). Based on imaging reports, all fractures were

repaired using screw fixation. A total of 64% of wrists ($n = 14$ of 22) had no evidence of arthritic changes (stage I); 23% of wrists ($n = 5$ of 22) had stage II arthritis; 9% of wrists ($n = 2$ of 22) had stage III arthritis. Radiographic scaphoid nonunion was present in two athletes (11%), both playing the defensive back position, with a history of bilateral scaphoid repair. No athlete had evidence of screw malposition or breakage.

Prospectively, 53% ($n = 11$ of 19) of athletes with a history of scaphoid repair were drafted into the NFL, with no significant difference appreciated when compared to athletes without a history of isolated scaphoid repair ($p = 0.21$) (Table 3). Athletes with a history of isolated scaphoid repair did not experience a significant reduction in NFL games played ($p = 0.5$) or games started ($p = 0.65$) during their first NFL season compared to athletes with no history of scaphoid repair. Among athletes with scaphoid repair, defensive backs had a significantly higher incidence of arthritic changes in the wrist (stage II or greater) compared to all other positions ($p = 0.036$). No other outcome variables (age, race, history of bilateral repair, use of bone grafting,

Table 2 Demographics and physical exam findings of athletes with a history of scaphoid fracture repair

Athlete	Combine year	Position	Laterality	Bone grafting	Positive physical examination findings [†]	OA grading on X-ray
1	2012	PK	L	No	↓Grip: 5 lbs.	Stage 1
2	2012	DB	R	No	None	Stage 2
3	2012	WO	L	No	↓Grip: 10 lbs.; ↓Pinch: 6 lbs.	Stage 1
4	2012	QB	R/L	No	Left: ↓Grip: 10 lbs.; ↓Pinch: 2 lbs.	R: Stage 1; L: Stage 2
5	2013	LB	L	No	↓Grip: 40lbs.; ↓Pinch 6 lbs.; ↓Flexion/Extension: 10°	Stage 1
6	2013	OL	L	No	None	Stage 1
7	2013	LB	L	Yes	None	Stage 1
8	2013	OL	L	No	None	Stage 1
9	2013	TE	L	No	None	Stage 1
10	2014	DB	R/L	Yes on R	Left: ↓Extension: 15°	R: Stage 3 with nonunion; L: Stage 1
11	2014	TE	L	No	↓Grip: 20 lbs.	Stage 2
12*	2014	DB	R/L	Yes on R	Right: ↓Grip: 30 lbs.	R: Stage 2; L: Stage 3 with nonunion
13*	2014	DL	R	Yes	↓Grip: 10lbs.; ↓Flexion: 10°	Stage 1
14	2015	LB	L	No	None	Stage 1
15	2015	RB	R	No	None	Stage 1
16	2015	LB	R	No	None	Stage 1
17	2015	WO	R	No	None	Stage 3
18	2015	DL	L	Yes	↓Grip: 9 lbs.; ↓Flexion/Extension: 10°	Stage 2
19	2015	TE	R	No	None	Stage 1

Legend: *Athletes requiring revision surgery prior to the combine due to symptomatic nonunion; †findings on physical examination considered positive with any limitations in range of motion or strength in the operative wrist compared to the opposite wrist; ↓indicates a decrease in wrist range of motion or strength when compared to contralateral wrist; OA osteoarthritis, PK placekicker, DB defensive back, WO wide-out, QB quarterback, LB linebacker, OL offensive linemen, TE tight-end, DL defensive linemen, RB running back

Table 3 Prospective NFL participation of athletes invited to the NFL combine from 2012 to 2015

	Total number of athletes	Drafted	Games played [95% CI]	Games started [95% CI]
+ scaphoid fracture repair	19	11	8.6 [5.1, 12.1]	4.0 [1.0, 7.0]
– scaphoid fracture repair	1292	859	7.4 [7.1, 7.8]	2.7 [2.5, 2.9]
<i>p</i> value	–	0.21	0.5	0.65

Legend: +, athletes with a history of scaphoid fracture with repair; –, athletes without a history of scaphoid fracture repair

reoperation secondary to nonunion, grip strength, pinch strength, or limitations in range of motion) were predictive of pancarpal arthritis or the presence of scaphoid nonunion.

Discussion

This study's principle findings demonstrate a 1.4% prevalence of athletes with a history of isolated scaphoid repair among the 1311 athletes invited to the NFL combine between 2012 and 2015. Limitations in wrist range of motion or strength were present in 47.4% of athletes; however, athletes with a history of scaphoid repair were not at significant risk for diminished participation during their first NFL season when compared to other athletes. Radiographic evidence of scaphoid nonunion was found in 11% of athletes with a history of repair, while 32% of wrists showed arthritic changes. Lastly, defensive backs with a prior history of scaphoid repair had a higher incidence of pancarpal arthritis than athletes in all other positions.

This study was not without limitations. We depended on the accuracy of the information athletes and physicians entered into the database, inviting the possibility of recall bias, which may confound the accuracy of the clinical history. Moreover, details on the exact timing of injury and the time until treatment were sought, and the presence of any residual subjective symptoms were infrequently reported and thus excluded from analysis. We had no access to operative reports, limiting information on scaphoid fracture location and configuration, initial displacement, ligamentous instability, surgical technique (open versus percutaneous), concomitant fixation, or operative complications. Also, data regarding return-to-play timing after fracture fixation, hand dominance, and the type of dynamometer used to record strength was not available. No inter- or intra-observer reliability analysis was performed to assess our agreement on the extent of arthritic changes or the presence of scaphoid nonunion. To standardize athlete participation in the NFL, prospective data was collected only during the athletes' first NFL season, regardless of career length at the time of data analysis. We believe there is a degree of selection bias, in that some athletes with a history of scaphoid repair participating in the NFL were not invited to the NFL combine. Based on the small prevalence of athletes meeting inclusion and exclusion criteria, our study and the statistical analysis performed are limited due to small sample size. This study examines only elite American football athletes, and therefore the findings cannot be generalized to non-athletes in the general population. Lastly, an athlete's ability to remain on

an active NFL roster allowing for NFL participation is multifactorial and related to factors beyond a specific injury, including additional injuries, overall performance, and team roster decisions. A specific injury is thus only one component affecting an athlete's NFL participation.

Previous investigations have similarly found a low prevalence of scaphoid fracture in American football athletes, reported in approximately 1% of collegiate football athletes annually [21, 30]. Meanwhile, Moatshe et al. reported a 2% prevalence of repair in the 2285 collegiate athletes invited to the NFL combine over a 6-year period (2009 to 2014) [16]. During competition, scaphoid injury typically results from direct trauma to the extended wrist during tackling, blocking, and falling [19, 22]. To avoid lost playing time, athletes may ignore or delay reporting an injury until the end of the season or after sustaining additional, more significant injuries [15, 18, 22]. Thus, despite the low prevalence of scaphoid injury and repair found in this and other studies, the true prevalence of these injuries is likely much greater [2].

Scaphoid repair alone was not found to significantly compromise athletic participation during athletes' first NFL season when compared to no history of scaphoid repair. Limited data exists analyzing the impact of scaphoid fracture repair on prospective performance in elite American football athletes. Brophy et al. [4] investigated the impact of carpal fractures on the likelihood of athletes playing in the NFL and career length by player position. While not specifically investigating isolated scaphoid fractures, the authors found that relative to all other positions, offensive linemen with carpal fractures participating at the combine from 1987 to 2000 had significantly lower odds of playing in the NFL ($p = 0.02$). Specifically, of six offensive linemen who underwent surgery, only 17% ($n = 1$) played in the NFL, likely due to difficulty in blocking secondary to injury. However, the number of athletes undergoing surgical repair was not reported. Therefore, while a history of scaphoid repair does not appear to be a limiting factor at the professional level, the ability to determine the contribution of a single injury on the current status or level of NFL participation is not possible.

We found deficits in range of motion and strength in a number of athletes with prior scaphoid surgery at the NFL combine, plus a high number of athletes with radiographic arthritic changes in the wrist. Moatshe et al. similarly reported high rates of limitations in range of motion (28%), grip strength (31%; mean, 91% of unaffected wrist), and pinch strength (52%; mean, 96% of unaffected wrist), as well as degenerative changes (34%) following scaphoid fracture in

football athletes; however, not all athletes were treated with operative fixation [16]. In their investigation examining clinical ($n=35$ patients) and radiologic ($n=28$ patients) outcomes after scaphoid fracture repair in non-athletes, Dias et al. found a mean grip and pinch strength of 96% of the contralateral wrist, with arthritis present in 11% ($n=3$) of patients [6]. Consequently, despite comparable restoration of strength rates among athletes and non-athletes, the higher rate of arthritic development in football athletes could be related to a delay in initial injury diagnosis, early return to play, or stress on the healed repair site with continued elite competition [1, 18, 22]. Moreover, studies have shown that treating scaphoid fractures with screw fixation results in early scaphotrapezial arthritis [27]. We found that relative to all other positions, defensive backs had a higher incidence of arthritic changes in the wrist following scaphoid repair. This may reflect the high contact forces defensive backs encounter due to the open-field nature of the position, resulting in increased stress to the wrists during high-speed collisions.

Scaphoid nonunion was appreciated radiographically in 11% of athletes with a history of scaphoid repair—two defensive backs who had undergone bilateral repair. Previous investigations have reported healing rates for acute scaphoid fractures of 75 to 100%, with nonunion reported in 5% of operatively treated fractures among NFL combine athletes [7, 11, 12, 16, 29]. While we could not determine the exact timing of these injuries, returning to play prior to complete scaphoid healing has been shown to increase scaphoid nonunion in up to 50% of athletes [5, 13]. Physicians must therefore maintain a high degree of suspicion for scaphoid injury, enabling quick diagnosis and operative management when indicated, with return to play after rehabilitation to regain strength and range of motion [2].

In conclusion, despite their low prevalence at the NFL combine between 2012 and 2015, athletes with a history of scaphoid repair are at high risk for post-operative deficits in range of motion and strength in the operative wrist. Scaphoid nonunion was seen in 11% of athletes following repair. Athletes with a history of scaphoid repair showed no significant reduction in draft status or NFL participation the year after the combine. When compared to all other positions, defensive backs were at highest risk for the development of pancarpal arthritis.

Compliance with Ethical Standards

Conflict of Interest: Derrick M. Knapik, MD, Leigh-Anne Tu, MD, Joseph Sheehan, ATC, and Kevin J. Malone, MD, declare that they have no conflicts of interest. James E. Voos, MD, reports being a paid consultant for Arthrex, Stryker, and Linvatec during the conduct of this study. Michael J. Salata, MD, reports being a paid consultant for Smith & Nephew during the conduct of this study.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

Informed Consent: Informed consent was obtained from all patients for being included in this study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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