

# The Epidemiology of Ankle Injuries Identified at the National Football League Combine, 2009-2015

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**Background:** American football is a leading cause of sports-related injuries, with the knee, ankle, and shoulder most commonly involved.

**Purpose/Hypothesis:** The purpose of this study was to describe the epidemiology, characteristics, and imaging findings of ankle injuries in football players at the National Football League (NFL) Combine and determine the relationship to player position. We hypothesized that there would be a high relative incidence of ankle injuries in these players compared with other sports and that there would be a direct correlation between the incidence of ankle injuries and player position.

**Study Design:** Cross-sectional study; Level of evidence, 3.

**Methods:** A retrospective chart review of data collected from NFL Combine participants between 2009 and 2015 was performed. Patient demographics, history, physical examination results, and imaging findings were reviewed.

**Results:** Of 2285 players, 1216 (53.2%) had a history of ankle injuries; of these, 987 (81.2%) had unilateral injuries, while 229 (18.8%) had bilateral injuries (total of 1445 ankles injured). This included 1242 ankle sprains (86.0% of ankle injuries): 417 (33.6% of sprains) high and 930 (74.9%) low. The most common soft tissue injuries were to the anterior talofibular ligament ( $n = 158$ , 12.7% of sprains) and syndesmosis ( $n = 137$ , 11.0%). Of all players at the NFL Combine with radiographs, 131 (10.9%) had evidence of an ankle fracture, all of which had healed. Magnetic resonance imaging (MRI) identified 66 players (28.9% of players at the combine who underwent MRI) with articular cartilage injuries: 62 involving the talus and 16 involving the tibia. Furthermore, 85 players (37.3% of players with MRI) with tendon injuries were identified: 26 Achilles, 55 peroneal, 3 flexor hallucis longus, and 19 posterior tibial. A total of 611 players (50.6% of players with radiographs) had signs of arthrosis on radiography. Running backs (61.9%), offensive linemen (60.3%), and tight ends (59.4%) had the highest rates of ankle injuries by position, while kickers/punters (23.3%) and long snappers (37.5%) had the lowest.

**Conclusion:** Prior ankle injuries were present in more than 50% of elite college football players attending the NFL Combine. The rate of these ankle injuries varied by player position: offensive linemen, running backs, and tight ends had the highest overall rates, while special teams players had the lowest. Additional prospective work is needed to determine the impact of prior injuries on future playing career.

**Keywords:** ankle injuries; football; college; NFL; ankle fracture; ankle sprain; low ankle sprain; high ankle sprain

American football is one of the most popular sports in the National Collegiate Athletic Association (NCAA), with over 60,000 collegiate male athletes playing the sport per year.<sup>19</sup> Participation in football is a leading cause of sports-related injuries, with the most common body parts involved being the knee, ankle, and shoulder.<sup>13,18,19</sup> It is estimated that 11% to 81% of American football players will sustain an

injury at some point during their career.<sup>27,34</sup> Hootman et al<sup>13</sup> evaluated the epidemiology of collegiate injuries for 15 sports and found that football had the highest rate of injuries during competition (35.9 injuries per 1000 athlete-exposures). Not only are football injuries frequent, they also often lead to loss of participation. In 2016, Steiner et al<sup>32</sup> evaluated all football injuries that occurred at their institution over a period of 4 years and found that 50% of football players were unable to participate for at least 1 day secondary to an injury sustained while playing. In general, practice injury rates in college football are lower than those

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during competition; however, the actual number of reported injuries is higher during practice, likely because there are more practices than games during the season and more players are involved with practices than formal competitions.<sup>6,18,30</sup> Additionally, practices tend to be well structured, with emphasis placed on skill development and game preparation, which may also contribute to the lower injury rate. Understanding the epidemiology of these injuries is important to physicians, athletic trainers, and athletes to improve diagnostic awareness when evaluating injured players in their sport.

The National Football League (NFL) Combine is a week-long showcase where college football players entering the NFL draft undergo physical and mental testing to maximize their draft position. Participation in the combine is by invitation only, and up to 330 elite collegiate football players attend each year. Testing includes the 40-yd dash, bench press, vertical jump, broad jump, 20-yd shuttle, 3-cone drill, 60-yd shuttle, position-specific drills, interviews, physical measurements, injury evaluation, and drug screening.

The prevalence and severity of injuries are important to take into account when designing and implementing injury prevention strategies. Numerous studies have been performed to classify football injuries by body region (eg, head, neck, shoulder, knee, ankle). Collectively, these epidemiological studies have reported that knee injuries account for approximately 20% of football-related injuries, while the foot and ankle are involved in roughly 17% of cases.<sup>26,30,33,39</sup> Although these studies provide value by highlighting at-risk regions of the body, they do not account for the variety of injuries that can occur within a particular body region; hence, a more in-depth understanding might allow for the development of targeted interventions.<sup>21</sup> Alternatively, several studies have focused on specific foot and ankle injuries, including syndesmotic sprains<sup>15</sup> and tarsometatarsal dislocations.<sup>11,28</sup> These studies enhance our understanding of the mechanism of injury as well as the prevalence and severity; however, it is also important to be aware of how a specific injury fits within the broader scope of all injuries to that body region.

In 2011, Kaplan et al<sup>16</sup> published one of the few reports of football injuries within body regions. The authors evaluated the incidence and variance of foot and ankle injuries in college football players who participated in the NFL Combine in 2006. Of the 320 players evaluated, 231 (72%) had a history of foot and ankle injuries, with the 5 most

common injuries being lateral ankle sprains, syndesmotic sprains, metatarsophalangeal dislocations and turf toe, fibular fractures, and Jones fractures. The most commonly reported injury, ankle sprain, is important because of its frequency and potential for morbidity and recurrence. Additionally, the authors evaluated foot/ankle injuries by position and found that these injuries are most common in kickers/punters, special teams players, running backs, wide receivers, and offensive linemen.<sup>16</sup>

The purpose of this study was to describe the epidemiology, characteristics, and imaging findings of ankle injuries in football players at the NFL Combine between 2009 and 2015 and to determine the relationship of such injuries to player position. We hypothesized that there would be a high relative incidence of ankle injuries in these players compared with other sports and that there would be a direct correlation between the incidence of ankle injuries and player position.

## METHODS

Approval for this study was obtained from an institutional review board, the NFL Players Association, and the NFL Physicians Society. Approximately 320 elite college football players attend the NFL Combine voluntarily and provide written consent to give a detailed medical history and undergo a thorough physical examination by NFL team orthopaedic surgeons, with a focus on identifying previous injuries, treatment, and current status. The charts of all players who participated in the NFL Combine from 2009 to 2015 were reviewed. The data collected included demographics, history, physical examination results, plain radiographs, and magnetic resonance imaging (MRI) scans. Demographic information collected included player position, injury type, and whether surgery (open or arthroscopic) was performed. The musculoskeletal intake history on every player was reviewed to document the number of ankle injuries, position played, and whether the player had undergone surgery. All players who were deemed to have an ankle injury were included in the study. For players with bilateral ankle injuries, each injury was analyzed separately, but each player was only recorded once in the overall player count.

All players underwent imaging (ankle radiography and/or ankle MRI [3-T MRI scanner on site at the NFL Combine]) if they had any history of ankle injuries or history/examination findings consistent with an ankle injury.

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Ethical approval for this study was obtained from Partners HealthCare.

All imaging was performed and analyzed during each player's evaluation at the NFL Combine. Players who had ankle radiography and/or MRI performed were identified by searching the database, and these athletes comprised the study group. In total, 228 players underwent ankle MRI, 1207 underwent ankle radiography, and 1224 underwent either radiography or MRI during the study period. Images were reviewed by 2 fellowship-trained orthopaedic sports medicine surgeons (M.K.M., A.S.B.), and the findings were corroborated with a musculoskeletal radiologist. These findings were used to determine the final diagnosis of each injury.

Plain radiographs (anteroposterior, lateral, and mortise views of the ankle) from all players with imaging performed at the NFL Combine were reviewed. The radiographs were utilized to diagnose previous ankle fractures and obvious osteochondral lesions of the talus (OLTs) and/or tibia, to evaluate for tibiotalar or subtalar osteoarthritis (OA, classified according to the Kellgren-Lawrence classification system),<sup>17</sup> and to measure other radiographic parameters (eg, medial clear space, tibia-fibula overlap). Fractures were typically diagnosed based on the presence of hardware from a previous open reduction and internal fixation procedure or evidence of a healed fracture.

MRI that included a dedicated ankle series with an ankle extremity coil was used to diagnose tendon, ligament, and cartilage injuries. Physical examination findings (eg, range of motion, instability, strength) were used to further define the extent of injury and impairment. Any osteochondral lesions present on MRI were documented. Defect sizes were measured on coronal and sagittal images using a ruler in a picture archiving and communication system. Tendon injuries were also diagnosed through MRI, while os trigonum was diagnosed using a combination of plain radiographs and MRI scans. Ankle sprains were diagnosed through a history and physical examination, and MRI, when available, was used to determine the specific ligaments involved.

## Statistical Analysis

All injury data, including imaging history, injury type, location and nature of injury, surgical history, and player position, were compiled and entered into an Excel (Microsoft) spreadsheet. These data were then stratified by injury type and location, and percentages were calculated using formulas in Excel. Specific injuries were further classified by player position. The proportion of injuries per position, as well as the percentage of players at the combine who suffered each injury by position, was calculated.

## RESULTS

Of 2285 NFL Combine participants from 2009 to 2015, there were 1445 ankle injuries in 1216 players (53.2%). Of the 1216 players with ankle injuries, 229 (18.8%) sustained injuries to both ankles. Ankle injuries are broken down by specific injury in Table 1 and by position in Table 2. Offensive linemen, running backs, and tight ends had the

highest injury rates of all position groups, with an ankle injury diagnosed in roughly 60% of combine participants for those positions. Special teams players (ie, kickers/punters and long snappers) had the lowest rates of ankle injuries at 23.3% and 37.5%, respectively.

The overwhelming majority of ankle injuries were sprains, including high ankle sprains, low ankle sprains, or both. A total of 1242 sprains were documented, comprising 86.0% of the reported ankle injuries. Of the ankle sprains, there were 417 (33.6% of sprains) isolated high ankle sprains, 930 (74.9%) isolated low ankle sprains, and 105 (8.5%) ankles that sustained both high and low ankle sprains. MRI data were available for a total of 257 (11.2%) ankles, allowing for the delineation of specific ligament injuries in this subgroup. Among players with high ankle sprains, MRI confirmed 121 (47.1% of players with MRI) anterior inferior tibiofibular ligament injuries, 114 (44.4%) interosseous ligament injuries, 115 (44.7%) posterior inferior tibiofibular ligament injuries, and 137 (53.3%) complete syndesmotic injuries. Low ankle sprains were composed of 158 (61.9%) injuries to the anterior talofibular ligament, 112 (43.6%) to the calcaneofibular ligament, and 12 (4.7%) to the posterior talofibular ligament. Among ankles with a history of sprains, associated injuries included 34 (2.7%) ankles with fractures, 611 (49.2%) with OA, 76 (6.1%) with tendon injuries, 50 (4.0%) with peroneal tendon injuries, 54 (4.3%) with cartilage lesions, and 30 (2.4%) with os trigonum.

Ankle fractures were diagnosed using a combination of history and radiographic findings. In all, 137 ankle fractures (9.48% of ankle injuries) were identified, including 27 (19.7% of ankle fractures) of the fibular shaft, 46 (33.6%) of the lateral malleolus, 16 (23.2%) of the medial malleolus, 2 fractures (1.46%) involving both medial and lateral malleoli, and 10 (7.3%) fractures of the posterior malleolus. All fractures were healed on imaging.

Cartilage injuries were diagnosed using MRI. Of the 257 ankles with MRI, 69 (26.8%) were found to have articular cartilage injuries of either the talus ( $n = 65$ , 94.2% of ankles with cartilage lesions), distal tibia ( $n = 16$ , 23.2%), or both. Of the 65 players with OLTs, 44 (67.7% of ankles with OLTs) were located laterally, 17 (26.2%) were located centrally, and 4 (6.2%) were located medially. Of the osteochondral lesions of the distal tibia, 8 (50%) were on the central tibial plafond, 5 (31.3%) were on the medial tibia, and 3 (18.8%) were on the lateral tibia, making up 16 lesions in total. Some players sustained multiple ankle cartilage injuries. Of the 69 ankles with chondral lesions, 54 (78.2%) were diagnosed with an ankle sprain.

Tendon injuries were diagnosed using MRI. Of the 257 ankles with MRI, 95 (37.0%) had tendon injuries, some of which involved multiple tendons. There were 30 ankles (31.6% of all tendon injuries) with Achilles tendon lesions, 26 (27.4%) with tendinopathy, and 4 (4.2%) with complete ruptures. Fifty-two ankles (54.7%) suffered from tendinopathy of the peroneal tendons, 4 (4.2%) had tears, and 2 (2.1%) had tendon subluxations. Additionally, there were 20 ankles (21.1%) with posterior tibial tendinopathy and 3 (3.2%) with flexor hallucis longus injuries. Using MRI and/

TABLE 1  
Rates of Specific Ankle Injuries<sup>a</sup>

Injury Type and Location	No. of Players Affected	No. of Bilateral Injuries	No. of Ankles Affected	% of Players at Combine With Imaging	% of All Ankle Injuries or Injury Subgroup
Ankle injury	1216	229	1445	53.2 <sup>b</sup>	100
Sprain	1055	187	1242	<b>46.2<sup>b</sup></b>	<b>86.0</b>
High	367	50	417	16.1 <sup>b</sup>	33.6
AITFL	113	8	121	49.6 <sup>c</sup>	47.1
IOL	106	8	114	46.5 <sup>c</sup>	44.4
PITFL	109	6	115	47.8 <sup>c</sup>	44.7
Complete syndesmotic	126	11	137	55.3 <sup>c</sup>	53.3
Low	789	141	930	34.5 <sup>b</sup>	<b>74.9</b>
ATFL	147	11	158	64.5 <sup>c</sup>	<b>61.9</b>
CFL	103	9	112	45.2 <sup>c</sup>	43.6
PTFL	11	1	12	4.8 <sup>c</sup>	4.7
ATFL + CFL	95	9	104	41.7 <sup>c</sup>	40.5
ATFL + CFL + PTFL	6	0	6	2.6 <sup>c</sup>	2.3
High and low	101	4	105	4.4 <sup>b</sup>	8.5
Medial (deltoid)	50	2	52	2.3 <sup>b</sup>	4.2
Fracture	131	6	137	10.9 <sup>d</sup>	9.5
Lateral malleolus	45	1	46	3.7 <sup>d</sup>	<b>33.6</b>
Medial malleolus	16	0	16	1.3 <sup>d</sup>	11.7
Bimalleolar	2	0	2	0.2 <sup>d</sup>	1.5
Posterior malleolus	9	1	10	0.7 <sup>d</sup>	7.3
Fibular shaft	27	0	27	2.2 <sup>d</sup>	19.7
Unavailable	36	0	36	—	—
Cartilage lesion	66	3	69	28.9 <sup>c</sup>	26.8
Talus	62	3	65	27.2 <sup>c</sup>	<b>94.2</b>
Medial	4	0	4	1.8 <sup>c</sup>	6.2
Lateral	42	2	44	18.4 <sup>c</sup>	67.7
Central	16	1	17	7.0 <sup>c</sup>	26.2
Distal tibia	16	0	16	7.0 <sup>c</sup>	23.2
Central tibia	8	0	8	3.5 <sup>c</sup>	50.0
Medial tibia	5	0	5	2.2 <sup>c</sup>	31.3
Lateral tibia	3	0	3	1.3 <sup>c</sup>	18.8
Osteoarthritis	611	84	695	50.6 <sup>d</sup>	57.2
Tibiotalar	606	83	689	50.2 <sup>d</sup>	<b>47.7</b>
Grade I	503	59	562	41.7 <sup>d</sup>	<b>81.6</b>
Grade II	112	11	123	9.3 <sup>d</sup>	17.8
Grade III	3	0	3	0.2 <sup>d</sup>	0.4
Grade IV	3	0	3	0.2 <sup>d</sup>	0.4
Subtalar	82	8	90	6.8 <sup>d</sup>	6.2
Grade I	64	4	68	5.3 <sup>d</sup>	<b>75.6</b>
Grade II	19	3	22	1.6 <sup>d</sup>	24.4
Grade III	0	0	0	0.0 <sup>d</sup>	0.0
Grade IV	0	0	0	0.0 <sup>d</sup>	0.0
Tendon injury	85	10	95	37.3 <sup>c</sup>	37.0
Achilles	26	4	30	11.4 <sup>c</sup>	31.6
Tendinitis	22	4	26	9.6 <sup>c</sup>	27.4
Partial tear	0	0	0	0.0 <sup>c</sup>	0.0
Complete tear	4	0	4	1.8 <sup>c</sup>	4.2
Peroneal tendon	55	3	58	24.1 <sup>c</sup>	<b>61.1</b>
Tendinitis	49	3	52	21.5 <sup>c</sup>	54.7
Tear	4	0	4	1.8 <sup>c</sup>	4.2
Subluxation	2	0	2	0.9 <sup>c</sup>	2.1
Posterior tibial tendinitis	19	1	20	8.3 <sup>c</sup>	21.1
Flexor hallucis longus	3	0	3	1.3 <sup>c</sup>	3.2
Os trigonum	206	30	236	19.3 <sup>c</sup>	16.3

<sup>a</sup>Isolated injuries are not reported but rather the total number of players with each injury; not all percentages will sum to 100%. Select highest values are emphasized in bold. AITFL, anterior inferior tibiofibular ligament; ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; IOL, interosseous ligament; MRI, magnetic resonance imaging; NFL, National Football League; PITFL, posterior inferior tibiofibular ligament; PTFL, posterior talofibular ligament.

<sup>b</sup>All players at the NFL Combine (N = 2285).

<sup>c</sup>Players with MRI (n = 228).

<sup>d</sup>Players with radiographs (n = 1207).

<sup>e</sup>Players with MRI or radiographs (n = 1224).

TABLE 2  
Rates of Specific Ankle Injuries by Position<sup>a</sup>

Position	Any Ankle Injury					Sprain				
	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position
QB	63	11	126	50.0	5.1	53	9	126	42.1	5.0
RB	148	29	239	<b>61.9</b>	12.3	135	26	239	<b>56.5</b>	13.0
WR	165	28	308	53.6	13.4	142	21	308	46.1	13.1
TE	79	19	133	59.4	6.8	71	15	133	53.4	6.9
OL	223	57	370	60.3	<b>19.4</b>	191	47	370	51.6	<b>19.2</b>
DL	207	35	384	53.9	16.8	181	30	384	47.1	17.0
LB	118	20	239	49.4	9.6	103	14	239	43.1	9.4
DB	193	28	405	47.7	15.3	165	23	405	40.7	15.1
K	17	2	73	23.3	1.3	13	2	73	17.8	1.2
LS	3	0	8	37.5	0.2	1	0	8	12.5	0.1

  

Position	Fracture					Cartilage Lesion				
	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position
QB	7	0	60	11.7	5.1	3	0	12	25.0	4.4
RB	17	1	151	11.3	13.1	7	0	23	30.4	10.1
WR	17	2	164	10.4	13.9	5	0	25	20.0	7.3
TE	9	1	75	12.0	7.3	4	1	18	22.2	7.3
OL	23	1	226	10.2	17.5	15	0	53	28.3	<b>21.7</b>
DL	16	1	203	7.9	12.4	12	0	39	30.8	17.4
LB	11	0	120	9.2	8.0	9	1	18	<b>50.0</b>	14.5
DB	26	0	189	<b>13.8</b>	<b>19.0</b>	11	1	36	30.6	17.4
K	3	0	16	18.8	2.2	0	0	4	0.0	0.0
LS	2	0	3	66.7	1.5	0	0	0	0.0	0.0

  

Position	Osteoarthritis					Tendon Injury				
	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position	No. of Players Affected	No. of Bilateral Injuries	No. of Players at Combine With Imaging	% of Players at Combine With Imaging	% of Injuries in That Position
QB	23	3	60	38.3	3.7	7	1	12	<b>58.3</b>	8.4
RB	71	9	151	47.0	11.5	6	1	23	26.1	7.4
WR	78	8	164	47.6	12.4	12	2	25	48.0	14.7
TE	46	8	75	<b>61.3</b>	7.8	7	0	18	38.9	7.4
OL	129	21	226	57.1	12.6	19	2	53	35.9	<b>22.1</b>
DL	115	15	203	56.7	<b>18.7</b>	14	1	39	35.9	15.8
LB	54	9	120	45.0	9.1	6	2	18	33.3	8.4
DB	86	10	189	45.5	13.8	13	1	36	36.1	14.7
K	7	1	16	43.8	1.2	1	0	4	25.0	1.1
LS	2	0	3	66.7	0.3	0	0	0	0.0	0.0

<sup>a</sup>Positions with the highest rates of each specific injury, excluding kickers and long snappers, are emphasized in bold. DB, defensive back; DL, defensive lineman; K, kicker; LB, linebacker; LS, long snapper; OL, offensive lineman; QB, quarterback; RB, running back; TE, tight end; WR, wide receiver.

or radiographs, 236 ankles (16.3% of all ankle injuries) were found to have os trigonum.

OA of the ankle, which was diagnosed based on radiographs, was common in players at the NFL Combine. In total, 611 players (50.6% of all players with plain

radiographs) had some degree of arthrosis involving the tibiotalar joint, the subtalar joint, or both. Of these players, 84 (13.7%) showed signs of OA in both ankles. Among the 689 (99.1% of OA) ankles with tibiotalar OA, 562 (81.6%) showed grade I changes, 123 (17.8%) showed grade II

TABLE 3  
Surgical Management Decisions of Specific Injuries<sup>a</sup>

Injury	Total No.	Surgical Management	Open Surgery	Arthroscopic Surgery	Not Recorded
Sprain	1242	72 (6)	40 (56)	21 (29)	11 (15)
Fracture	137	78 (57)	78 (100)	0 (0)	0 (0)
Chondral injury	69	26 (38)	14 (54)	8 (31)	4 (15)
Osteoarthritis	695	64 (9)	46 (72)	13 (20)	5 (8)
Tendon injury	95	22 (23)	13 (59)	7 (32)	2 (9)
Os trigonum	236	24 (10)	19 (76)	4 (16)	1 (4)

<sup>a</sup>Values are reported as No. of ankles (% of subgroup) unless otherwise noted.

changes, 3 (0.4%) showed grade III changes, and 3 (0.4%) showed grade IV changes. Ninety (12.9%) ankles showed signs of subtalar OA on radiographs: 68 (75.6%) with grade I changes and 22 (24.4%) with grade II changes; none of these players had progressed to grade III or IV arthrosis. Of the 695 ankles with OA, 611 (87.9%) were diagnosed with an ankle sprain.

Treatment decisions differed between injury groups in terms of both operative versus nonoperative intervention and open versus arthroscopic surgery. The prevalence of operative management for specific injuries ranged from 6% to 57%, with sprains being treated surgically least often and fractures being the most common injury to be treated operatively. All injuries were more likely to be treated with open surgery than with arthroscopic surgery, with fractures exclusively treated with open surgery. Surgical decisions are detailed in Table 3.

## DISCUSSION

The primary findings in our study are the high rate (53.2%) of ankle injuries in elite college football players and the variable distribution of these injuries by player position. Ankle injuries have been established as one of the most common injuries in football players at all levels, and this study demonstrates similar trends among NFL prospects. Although there have been many epidemiological studies on foot and ankle injuries,<sup>3,4,8,14,25,31</sup> this is the largest and most detailed study of ankle injuries in elite college football players. Here, we demonstrate that prospective NFL football players have much higher rates of ankle injuries than in other sports and classify these injuries by type, location, and rate of injuries per player position.

Of the 2285 players who participated in the NFL Combine during the 7 years studied, more than half had sustained an ankle injury. The injury rate of 53.2% reported in this study is higher than that in many other sports; in handball, floorball, and a group of athletes in many different sports, the prevalence was 7.5%, 21%, and 16%, respectively.<sup>10,29,35</sup> The higher injury rate can be attributed to several factors, including level of competition, the extensive medical evaluation that is performed at the NFL Combine, and the fact that our study potentially includes players with a remote history of injuries. However, this study strongly suggests that football leads to more ankle injuries than other sports.

In our breakdown by player position, we found distinct differences in rates of injuries, especially when stratified by specific injury. Running backs, offensive linemen, defensive linemen, and tight ends were most at risk for all types of ankle injuries and also had the highest rates of ankle sprains. These players are often playing within crowded spaces near the line of scrimmage, which may increase the risk of injuries, especially to their lower leg. However, offensive and defensive linemen had lower rates of ankle fractures than other positions, potentially explained by lower speeds of play and less force of injuries in the tight quarters near the line of scrimmage. Offensive linemen, defensive linemen, and tight ends also had substantially higher rates of ankle OA. It is worth noting that larger players typically play each of these positions, and they are often in a 3-point stance, both of which may be contributing factors to the development of OA, as prolonged loading on the flexed knee, especially in larger players, would presumably lead to arthritic changes.<sup>36</sup> Kickers/punters and long snappers had the lowest rates of ankle injuries of all players, likely because they play a lower percentage of snaps per game. They may also have a lower risk of injuries when they are on the field, as the NCAA rules provide additional protection for both types of players and kickers/punters are rarely involved in blocking or tackling.

Our injury profile was fairly consistent with the existing literature on ankle injuries. Ligamentous sprains were the most common diagnosis, making up 86.0% of all ankle injuries. Fong et al<sup>10</sup> reported on 32,509 sports-related ankle injuries in 70 different sports over a 28-year period and found that 84% of cases with injury information available were ankle sprains. They reported that the incidence of ankle injuries and ankle sprains was high in court games and team sports, such as rugby, soccer, volleyball, handball, basketball, field hockey, dancing, American football, netball, and lacrosse.<sup>10</sup> In a study of high school athletes in 9 different sports including basketball, football, and soccer, 83.4% of 905 ankle injuries were sprains with incomplete tears,<sup>23</sup> and in professional soccer players, sprains made up 80.4% of all ankle injuries incurred during a Major League Soccer season.<sup>22</sup> Understandably, other sports have a different injury profile owing to different common mechanisms of injury, such as snowboarding, where only 52% of ankle injuries were sprains.<sup>20</sup> Interestingly, high ankle sprains made up 33.6% of all sprains in our study, a similar figure to the 24.4% and 24.6% reported in other studies on

ankle injuries in football players<sup>5,15</sup> but much higher than the 5.2% reported in male professional soccer players.<sup>37</sup> Ankle sprains, while managed nonoperatively and typically considered a minor injury, are significant injuries because of their frequent occurrence and potential for associated morbidity. Recurrence rates have been reported to be as high as 73%, with 59% of those athletes reporting significant disability and residual symptoms that led to impairment in athletic performance.<sup>38</sup>

Ankle fractures, although not as common as sprains, typically cause more disability and lost playing time.<sup>2</sup> Although ankle sprains have been reported to carry residual symptoms for months to years,<sup>1</sup> the vast majority of players are still able to return to sport within 6 weeks, despite pain or limited function.<sup>12</sup> Ankle fractures, in contrast, are typically the most severe ankle injuries and more likely to lead to retirement from sport.<sup>7</sup> We found that 9.4% of all ankle injuries were fractures, a higher incidence than seen in high school athletes (5.2%) and professional soccer players (2.0%) but much lower than the 44% reported in snowboarding.<sup>20,23,37</sup> We also found that lateral malleolus and fibular shaft fractures were more common than fractures of the medial and posterior malleoli and that OLTs were located laterally much more frequently than medially or centrally. Lateral OLTs are associated with trauma,<sup>9</sup> which may be exacerbated by the biomechanics of football, especially with planting and distributing force toward the lateral portion of the leg.

While this is the most complete study on ankle injuries in elite college football players, previous reports that focused more on specific ankle injuries (eg, syndesmotom injuries) in collegiate and NFL players are still useful for comparisons of the injury rate by position.<sup>15,24</sup> In these studies, linemen, both offensive and defensive, comprised 36.9% of all players who sustained syndesmotom injuries, whereas linemen accounted for 46.0% of syndesmotom injuries in our study. Linebackers suffered fewer syndesmotom sprains (7.3% vs 11.1%, respectively), but the remainder of our position analysis was consistent with previous studies.

This study has several limitations. First, this is a retrospective study and therefore carries all the limitations associated with this study design. Only about 10% of NFL Combine participants underwent ankle MRI, limiting our sample size and potentially introducing bias. We were not able to track statistics on each player's exposure to injuries, making a comparison with injury rates in other studies difficult. The location of fractures was not visible on radiographs for all players with a history of ankle fractures. Physical examination data were incompletely reported and therefore not included in our analysis. Further, we did not have reliable data on the timing of each injury, so we were not always able to distinguish acute from chronic injuries and may have included injuries that occurred in the distant past. Additionally, because radiographs and/or MRI scans were required for the diagnosis of certain injuries, it is possible that there were players with these injuries that were not diagnosed because necessary imaging was not performed. Information regarding the indications for surgery was not available in the orthopaedic notes generated at the combine and was therefore not included in the present

study; these details may have been informative for future treatment decisions in this cohort. Because treatment decisions are individually varied and surgical data were not available for all players, it is difficult to recommend any specific procedure for certain injuries.

Despite the limitations, this study maintains relevance in reporting the epidemiology of ankle injuries in elite college football players transitioning to the professional level. The prevalence of ankle injuries in this group is outlined and stratified by both specific injury and player position. We found that ankle injuries, especially ligamentous sprains, are commonly diagnosed in this cohort. The rates of overall ankle injuries and specific injuries were variable by player position, as detailed above.

## CONCLUSION

Prior ankle injuries, including both soft tissue and bony lesions, are present in more than 50% of elite college football players transitioning to the professional level. The rates of these ankle injuries varied considerably by player position: offensive linemen, running backs, and tight ends had the highest overall rates of ankle injuries, while special teams players had the lowest rates. Additional prospective work is needed to determine the impact of prior injuries on future playing career.

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