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REVIEW

Orthopedic consequences of modern gladiators: a systematic review of lower extremity musculoskeletal issues in retired NFL players

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ABSTRACT

Objectives: The stressors that National Football League (NFL) athletes face are well-described and documented with regard to multisystem afflictions and injury prevalence. However, the majority of literature discusses the short-term effects rather than long-term outcomes of playing professional football. The purpose of this study was to characterize the long-term musculoskeletal issues in the retired NFL population.

Methods: Publications from CENTRAL, Scopus, Medline, PubMed, Embase, and Google Scholar were searched from database inception to February 2021. A total of 9 cohort studies evaluating lower extremity arthritis in retired NFL athletes were included for review. Two reviewers extracted data from the individual studies, including demographic information (age, body mass index, length of career, position), injury descriptions (location of injury, number of injuries, diagnoses), and procedure (total knee and or hip arthroplasty) frequency.

Results: Arthritis in retired NFL players was more than twice as prevalent than the general United States male population (95% CI: 2.1–2.3). Ankle osteoarthritis was directly correlated with the number of foot and ankle injuries. Players <50 years of age had a 16.1 and 13.8 times higher risk of undergoing TKA and THA, respectively, when compared to the general population. In older age groups, this trend held with retired NFL players being at least 4.3 and 4.6 times more likely than members of the general population to undergo TKA and THA, respectively.

Conclusion: This review demonstrates that the effects of NFL-related lower extremity injuries extend beyond the players' careers and present a higher risk for early-onset osteoarthritis and overall frequency of undergoing total knee and hip arthroplasty.

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KEYWORDS
NFL; national football league; osteoarthritis; total knee arthroplasty; total hip arthroplasty; orthopedic injury

Introduction

Professional American football is a physically demanding vocation. Demands from intense weightlifting, cardiovascular conditioning, rapid deceleration, and head-on collisions may have long-term, multisystem medical sequelae. Although these stressors are not new to the public, the literature delving into long-term effects has only recently gained traction. The most frequently cited conditions in the retired NFL population include cardiac, neurologic, and orthopedic diagnoses [1,2]. The majority of the literature covering the chronic effects focus on neurologic morbidities including concussions and chronic traumatic encephalopathy. Few studies to date have investigated the long-term musculoskeletal consequences of an NFL career.

Contact sports, such as American Football and Rugby, are associated with ligamentous, soft tissue, and osseous injuries [1,3]. Tackle football is associated with the highest rates of injury among all organized team sports in the US, and studies have reported between 300,000 to 1.2 million football related injuries annually among high school players alone [4]. Both contact and non-contact risk factors such as high-speed collisions and rapid changes of direction contribute to these high rates of injury [4]. In a study summarizing the extent of orthopedic injuries of professional football players, lower extremity injuries were found to be the most common [5]. About 70% of players at the NFL combine had a history of ankle injury, particularly in special teams players, wide receivers, and offensive linemen; followed by knee injuries at 50%. It was also shown that 50% of players at the combine had a history of shoulder injuries, often from passing plays that led to direct trauma to the shoulder. Interestingly, hip injuries only made up about 3% of all NFL injuries. These consisted of mostly muscle strains and were the most common in defensive backs, wide receivers, and offensive linemen. Other injuries that were less common were trunk and spinal injuries which made up 7% of all NFL injuries. Most of the spinal injuries were to the cervical spine and involved offensive linemen and defensive players [5]. Many of these injuries have been linked to early onset, post-traumatic osteoarthritis (OA) regardless of operative or non-operative treatment [6,7].

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OA is the most prevalent form of arthritis, affecting approximately 15% of the general population [8]. With an aging population and increased rates of obesity, the incidence of OA is increasing. Recent estimates from US data have shown that the prevalence of clinical hand, hip, and knee OA increased from 21 million US adults aged 25 years or older in 1995 to 27 million adults in just over a decade [9]. With high rates of injury and the potential development of post-traumatic OA, retired NFL players are at an even greater risk for developing OA compared to the general population. Compounding the long-term impact of the previously mentioned injuries is the high bodyweight of many retirees, given 49.2% are categorized as obese [10,11]. Such a combination of factors can lead to long-term joint pain and the need for arthroplasty [12].

To date, there are no publications consolidating the long-term orthopedic outcomes in former NFL players. The purpose of this systematic review is to better appreciate the chronic orthopedic manifestations of this demanding profession. Our hypothesis is that retired football athletes have a higher frequency of OA and undergo joint arthroplasty at a higher rate compared to the general population.

Materials and methods

This systematic review was performed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 27-item checklist [13]. The data from the included manuscripts were organized into one of three groups: (1) injury prevalence data, (2) osteoarthritis prevalence data, and (3) hip or knee arthroplasty prevalence data.

Eligibility criteria

The inclusion criteria were as follows: (1) study population consisted of retired NFL players and (2) outcomes included injuries or musculoskeletal issues continuing into retirement. Only studies published in full and in English were considered. Case reports and reviews were excluded.

Data sources

A search for systematic reviews on the orthopedic morbidities of retired NFL players yielded no results in the PROSPERO or PubMed databases. The searches for qualified publications in CENTRAL, Scopus, Medline, PubMed, Embase, and Google Scholar were completed in February 2021.

Searches

The algorithm used to search PubMed was '("Retirement"[Mesh] OR "Retire*"[tiab] OR "Retirement age"[tiab]) AND ("NFL"[tiab] OR "National Football League"[tiab] OR "Football"[Mesh] OR "Football/injuries"[Mesh] OR "football"[tiab]) AND (("Orthopedics"[Mesh] OR "orthopedic*"[tiab]) OR ("wounds and injuries"[Mesh] OR Trauma[tiab] OR wound*[tiab] OR "injure*"[tiab] OR "fracture*"[tiab])).' The designation 'tiab' specified the search to title and abstract. Embase, Google Scholar, CENTRAL, Scopus, and Medline were searched with the terms 'retired(retirement),' 'NFL,' 'orthopedic,' 'morbidity,' 'injury,' and 'pain.'

Study selection

Two authors reviewed the titles and abstracts to detect eligibility and potential of meeting the inclusion criteria. These criteria were followed closely, and the papers that did not meet them were excluded. Discrepancies were resolved by consensus. References of the included articles were also searched for eligibility with the inclusion criteria.

Statistics

Available demographic data was reported as pooled means. Data from papers that included cases of retired player hip or knee arthroplasty were extracted for comparison, and statistical analyses were conducted using SPSS (IBM SPSS version 27.0.1.0, IBM Corp., Armonk, NY, USA) when data was homologous between studies. Pearson Chi-Square tests were used to compare categorical variables of retired NFL populations with the general population. Relative risk was also calculated in order to compare the prevalence of arthritis in retired NFL players to age matched U.S. males.

Risk of bias

Two independent reviewers assessed the risk of bias using the Newcastle-Ottawa Scale (NOS) and graded each study [14]. The following domains were included in all of the risk-of-bias assessments of the cohort, cross-sectional, and case studies: (1) representativeness of the exposed cohort, (2) selection of the non-exposed cohort, (3) ascertainment of exposure from a secure record, (4) outcome was not present at the start of the study, (5) control for most important factor, (6) control for other factors, (7) assessment of outcome, (8) long enough follow-up period, (9) adequate follow-up rate. The following domains were included in grading the case-control studies: (1) adequate definition of the case, (2) representativeness of the cases, (3) selection of controls, (4) definition of controls, (5) control for main factor, (6) control for additional factors, (7) ascertainment of exposure from secure record, (8) same method of ascertainment for cases and controls, (9) non-response rate. A score of 0–3 is very high risk, 4–6 is high risk, and 7–9 is high quality.

Results

The literature search resulted in 163 non-duplicate studies. After abstract and title review, 151 studies were excluded for not meeting the established inclusion criteria. The most common causes for exclusion were data being reported on active NFL players or studies focusing on non-orthopedic outcomes. The remaining 12 manuscripts were subsequently reviewed, and 3 additional studies were excluded (2 did not meet inclusion criteria and 1 was a systematic review on NBA, NFL, and nonprofessional athletes). Thus, a final count of 9 studies published from 2005–2020 were included for systematic review (Figure 1).

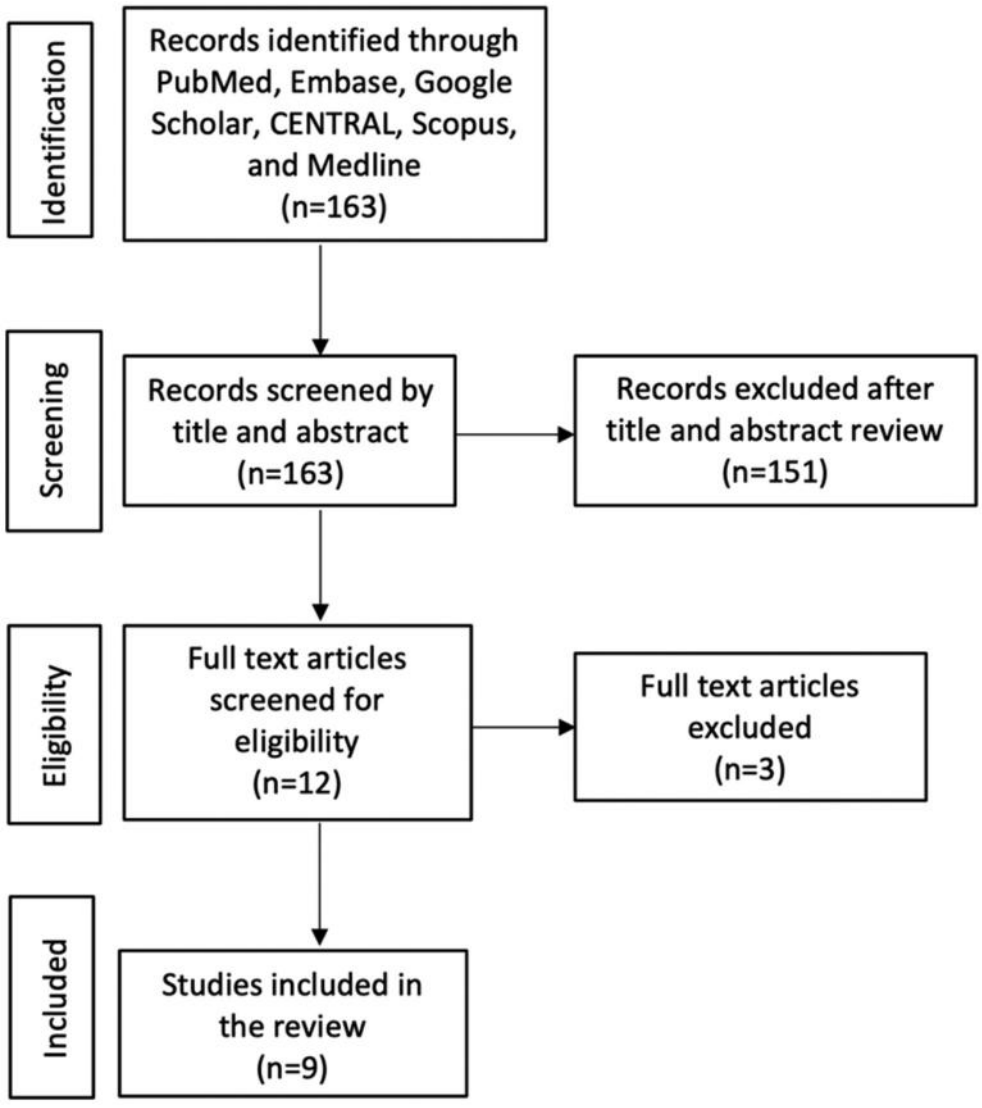

Figure 1. Literature selection algorithm. The records were excluded based on the inclusion/exclusion criteria as well as study methodology.

Of the 9 studies, 6 included lower extremity injury prevalence of retired players [15–20], 3 focused on OA as their major outcome [18,21,22], and 3 papers examined total joint arthroplasty as their major outcome [15,19,23]. In terms of study strength, 3 of the 9 studies had a level of evidence of III [15,21,23], and 6 of the studies had a level of evidence of IV [16–20,22]. For risk of bias, 7 of the studies had a score of 7 (high quality) [15–22], 1 had a score of 8 (high quality) [16], and another had a score of 6 (high risk) (Table 1) [23].

Demographic characteristics

The 9 studies included a total of 16,593 retired football players with an average age of 54.6 years (range: 33.0–60.8 years) and BMI of 30.49 Kg/m^2 (range: 28.7–30.5 Kg/m^2). Players included represented a variety of positions including lineman, running backs, linebackers, wide receivers, defensive backs, quarterbacks, and special teams. The average length of NFL careers was 6.71 years (range: 1–26 years) (Table 2).

Lower extremity injury prevalence

The incidence of lower extremity injury was high after finishing a career in the NFL. In various studies that screened for these injuries, the percentage of players having one or more lower extremity injury ranged from 44.0% to 79.0% [15–21]. Due to differences in the types of injuries examined in each paper, many of the injury prevalence statistics could not be summarized. Nearly two-thirds (60.9%) of retired players reported at least one knee injury [15,19,20], 35.0% experienced isolated hip injuries, and 79.0% had either hip or knee injuries [15]. Domb and colleagues [17] observed that 76% of players who underwent magnetic resonance imaging (MRI) of the hip soon after retirement had a variety of soft tissue pathology including labral tears, chondral defects, and ligamentum teres tears (Table 3) [17].

Osteoarthritis

Among the three studies that included data on lower extremity OA, prevalence in the retired NFL player cohort was 37.2%

Table 1. Characteristics of included studies. LOE, level of evidence; Am J Sports Med, American journal of sports medicine; J athl train, Journal of athletic training; Orthop J Sports Med, Orthopedic journal of sports medicine; Med Sci Sports Exerc, Medicine and Science in Sports and Exercise; J Phys Act Health, Journal of physical activity and health.

authors	year	journal	loe	risk of bias	outcome measures	data source
Davies et al [7]	2019	Am J Sports Med	III	7	Musculoskeletal injury, total hip and knee replacement	Survey
Domb et al [10]	2014	Orthop J Sports Med	IV	8	Musculoskeletal injury	Institutional Database
Domb et al [11]	2014	Am J Sports Med	IV	7	Intra-articular hip lesions	Institutional Database
Golightly et al [16]	2009	J Phys Act Health	III	7	Osteoarthritis prevalence, musculoskeletal injury	Survey
Lynall et al [22]	2017	J Athl Train	IV	7	Osteoarthritis prevalence, concussion frequency	Survey
Nicholas et al [27]	2007	Am J Sports Med	IV	7	Osteoarthritis prevalence, knee musculoskeletal injury, joint replacement	Survey
Pietrosimone et al [30]	2015	Med Sci Sports Exerc	IV	7	Concussion frequency, knee and ankle musculoskeletal injury	Survey
Song et al [34]	2019	J Athl Train	IV	7	Ankle musculoskeletal injury, osteoarthritis prevalence	Survey
Tenforde et al [37]	2020	Am J Sports Med	III	6	Total hip and knee arthroplasty	Survey

Table 2. Player demographic characteristics. BMI, body mass index; RB, running back; LB, linebacker; WR, wide receiver; DB, defensive back; QB, quarterback.

Authors	n	Age, yr	BMI	Length of NFL Career (yrs) (range)	% Lineman	% RB or LB	% WR, DB, QB, Special Teams
Tenforde et al [37]	3913	52.4					
Lynall et al [22]	2696	60.8					
Golightly et al [16]	2538	53.8	30.5	6.6 (1–26)	41	25.5	28.5
Song et al [34]	2446				35.81	25.47	38.72
Davies et al [7]	2432	53.6	30.5	6.8 (3–10)	35.69	25.7	38.61
Pietrosimone et al [30]	2429	53.9	30.5	6.7 (1–26)	40.87	25.2	28.78
Domb et al [11]	65	33.5		7.5 (3–12)	24.62	27.69	47.69
Domb et al [10]	38	33		7 (3–12)	21		
Nicholas et al [27]	36	62	28.7				
Total	16,593						
Pooled Means	1,843.60	54.60	30.49	6.71	38.21	25.48	33.70

Table 3. History of lower extremity injuries in the retired NFL population. LE, lower extremity.

Paper	≥1 LE injury n/N (%)	≥1 knee injury n/N (%)			≥1 hip injury n/N (%)		
		Total	Left Knee	Right Knee	Total	Left	Right
Davies et al [7]	1921/2432 (79.0)	1747/2432 (71.8)			852/2432 (35.0)		
Domb et al [10]			35/65 (53.8)	37/65(56.9)		46/65 (71.0)	40/65 (62)
Lynall et al [22]	1930/2696 (71.6)						
Pietrosimone et al [30]	1744/2429 (71.8)	1213/2416 (50.2)					
Domb et al [11]					38/50 (76.0)		
Nicholas et al [27]	16/36 (44.4)	12/36 (33.3)					
Golightly [16]	1939/2511 (77.2)	1327/2511 (52.8)					

Table 4. Prevalence of osteoarthritis by age.

Age	Prevalence of arthritis in US males [16]		Prevalence of arthritis in retired NFL Players		Arthritis Prevalence Ratio Prevalence Ratio (95% CI)
	n/N	%	n/N	%	
Golightly et al [16]					
≤55	950/8730	10.9%	514/1317	39.0%	3.4 (3.3–3.9)
>55	1569/3806	41.2%	585/1213	48.2%	1.17 (1.1–1.3)
Total:	2533/13,110	19.5%	1099/2530	43.4%	2.2 (2.1–2.3)

[18,21,22]. This statistic includes OA found anywhere in the body. The average age reported for players in these studies ranged from 53.8 to 60.8 years old. Golightly et al's [21] findings indicate that general arthritis is twice as prevalent among retired NFL athletes when compared to average U.S. males, and it is 3.4 times as prevalent when comparing members of these groups that are younger than 55 years of age [21]. However, when comparing the retired athletes to males in the general population, arthritis was defined as having a diagnosis of OA, rheumatoid arthritis, degenerative arthritis, or fibromyalgia. This comparison reflects the trend that one would expect OA to have with the general population, however it is separate from the study's numbers on OA specifically (Table 4). Similarly, Lynall et al [18] demonstrated that 33.9% of players under the age of 55 had OA, and 39.6% of players over the age of 55 had OA. This study defined OA as a diagnosis of OA or degenerative arthritis (Table 5) [18].

In a study investigating OA prevalence and lower extremity injury, Lynall et al [18] identified that disease prevalence rose by 70% after ≥2 lower extremity injuries [18]. Similarly, Song et al [22] found that the frequency of OA in those without a history of foot/ankle surgery increased by 24% following 3–5 injuries and 29% after enduring ≥6 injuries [22]. Athletes with a history of ankle surgery experienced an even greater prevalence of OA, with a 66% increase after 1–2 foot/ankle

Table 5. Combined osteoarthritis by age.

Age	Osteoarthritis n/N	%
Golightly et al [16]		
Lynall et al [22]		
≤55	996/2875	34.6%
>55	938/2343	40%
total:	1934/5218	37.1%

injuries and over 100% increase with ≥6 injuries [22]. The prevalence of OA for the two previously described studies are summarized in Table 6. Both Lynall [18] and Song [22] measured OA as total body OA that is not specific to any joint.

Arthroplasty

Of the 9 studies reviewed, 3 included data on joint arthroplasty. Two studies [15,23] examining the prevalence of total knee arthroplasties (TKA) and total hip arthroplasties (THA) were combined and compared to general population data [24]. Retired NFL players <50 years old had a 16.1 and 13.8 times higher risk of undergoing TKA and THA, respectively, when compared to the general U.S. populace. In older age groups, this trend held with retired NFL players being 4.3 and 4.6 times more likely than members of the general population to undergo TKA and THA, respectively.

Nicholas et al [19] included joint replacement data in a smaller cross-sectional study of 36 retired NFL players that was not stratified by age as in Table 7. Of these individuals, 7 (19.4%) had TKAs (5 of which were bilateral), and 1 (2.8%) player had a THA [19]. In a separate study, it was shown that as the incidence of knee and hip injury increases, so does TKA and THA prevalence [15]. Players that reported having a history of 1 knee injury had a nearly 80% greater prevalence of TKAs (95% CI: 1.14–2.77), while those who reported ≥3 knee injuries had a more than a three-fold greater prevalence (95% CI: 2.33–5.09). The same pattern held true for hips, as players with a history of 1 hip injury or ≥3 hip injuries had THA prevalence ratios of 1.72 (95% CI: 1.05–2.80) and 2.44 (95% CI: 1.52–3.91), respectively [15].

Discussion

When compared to the studies on neurologic and cardiometabolic disease in the retired NFL population, long-term orthopedic morbidities have not been as well characterized. In this review, we found that retired NFL athletes develop OA and undergo arthroplasty earlier and at a greater rate than the general population.

The summative finding of higher rates of OA and joint replacement compared to the general population is consistent with systematic reviews involving other retired high-level athletes [25,26]. One study found nearly 70% of retired NBA players studied experience knee pain, and 34% of these players underwent knee surgery after they retired [25]. The Swedish Olympic Committee archives, which includes data on athletes in sports such as soccer, handball, and hockey, highlighted that hip OA and arthroplasty were more prevalent in former athletes as compared to controls (14.2% Vs. 7.9% for OA and 8.3% Vs. 3.8% for THA) [26]. Athletes of other sports not only present with similar levels of OA and joint replacement, but they also represent a population that is dissatisfied because of the similar morbidities. In a 2019 systematic review, Filbay and colleagues [27] assessed the physical and mental wellbeing of retired soccer and American football athletes, with studies utilizing the Optum SF™ Health Survey [27]. The group found that musculoskeletal injuries played a large role in former athlete dissatisfaction. In particular, OA was the largest contributor of lower physical component scores (PCS), which assesses physical function and pain, for former professional athletes. However, OA had mixed results for the mental component score (MCS), which evaluates mental health and social wellbeing.

Joint injury and obesity are variables associated with early-onset OA, and both are prevalent among retired NFL players [11,28]. As many as 79% of retired NFL athletes report having at least one hip or knee injury during their careers [15]. Severe trauma to these joints can lead to post-traumatic OA [28]. In the setting of ligamentous knee injury, patients are at a 10-fold greater risk for developing OA [6]. The NFL retiree studies from Lynall [18] and Song [22] indicated that having >2 knee or ankle injuries increased the prevalence of OA by 20–100% [18,22]. In addition to injury, obesity has also been associated with developing OA [11]. Retired NFL players have a higher prevalence of obesity compared to the general population.

Table 6. Prevalence of osteoarthritis by number of lower extremity injuries OA, osteoarthritis.

Lower extremity injuries, No.	OA, (n/N)	OA, (%)	P-values	Prevalence Ratio (95% CI)
Lynall et al [22]				
0	200/766	26.1%		1.00 (referent)
1	157/530	29.6%	0.164	1.13 (0.95–1.35)
2+	621/1399	44.4%	<0.001	1.70 (1.49–1.94)
Song et al [34]				
No history of ankle or foot surgery				
0	340/1026	33.1%		1.00 (referent)
1–2	255/689	37.0%	0.099	1.12 (0.98–1.27)
3–5	152/370	41.1%	0.006	1.24 (1.07–1.44)
≥6	88/206	42.7%	0.008	1.29 (1.08–1.54)
History of ankle or foot surgery				
1–2	45/82	54.9%	<0.001	1.66 (1.34–2.05)
3–5	15/37	40.5%	0.348	1.22 (0.82–1.82)
≥6	25/36	69.4%	<0.001	2.10 (1.66–2.65)

This is particularly true for retired lineman with rates of obesity reaching as high as 85.4%. Even non-linemen have a high obesity rate of up to 50.3% compared to a 34.8% among non-NFL age-matched men [29]. The average retiree in this review had a body composition consistent with obesity (BMI = 30.49). It's not surprising that compounding these two factors in OA development results in a roughly 15-fold greater risk of undergoing THA and TKA in NFL athletes aged <50 years.

With the knowledge that NFL players develop OA and undergo arthroplasty at an earlier age, questions arise on the possible ramifications this premature progression has on former athletes. In the general population, primary hip and knee prostheses have a reported 25-year survival of 58% and 82%, respectively [30,31]. As such, the literature indicates that arthroplasty is not ideal for those younger than 50, as they are twice as likely to outlive their prosthesis. However, if an individual undergoes arthroplasty at the age 62 years or older, the prosthesis usually lasts until the patient's death [32]. The combination of obesity and early joint replacement in this population, is an unfavorable scenario that may set the stage for more revision arthroplasty procedures than the general population [33–36]. Beyond the physical toll of undergoing lower extremity joint replacement, arthroplasty earlier in life can cause potential financial challenges. With nearly 60–80% of retired NFL players being either bankrupt or under financial stress, many of these individuals continue working after retiring from the NFL, and their musculoskeletal morbidities may serve as an additional financial hurdle [37]. With these burdens in mind, improved chronic pain management and non-operative treatments are increasingly important. In a systematic review describing the most effective methods for pain control of osteoarthritis, Geenen et al [38] describe the recommended treatment sequence. The first step involves a comprehensive evaluation from a physician including acquisition of the patient's needs, previous pain management, pain characteristics, social factors, joint damage and inflammation, obesity, and the patient's knowledge of their own pain. The patient should then receive a personalized plan based on their individualized needs of the most effective treatments. These include patient education, physical therapy, orthotics and braces, psychological and social interventions (possible antidepressant pharmacotherapy), sleep therapy, weight therapy, and pharmacological or joint treatment such as injections [38]. A review article out of Hong Kong found that exercise and weight management were two of the most effective treatments [39]. They found that obesity increases the risk for knee osteoarthritis fivefold and an overweight habitus increases the risk twofold [39]. Because the prevalence of obesity is so high among retired NFL players, lifestyle management and exercise must be made a priority to decrease the need for arthroplasty. Pharmacotherapy such as steroid injections were not found to be effective long term chronic pain relief [39]. The results of injections vary from patient to patient, and frequent use of steroids can lead to long term joint damage and increased risk of infections. Opioids are very effective with short term management; however, they are not recommended for the treatment of chronic pain due to addiction and tolerance [39].

It is apparent that the downstream musculoskeletal consequences from professional American football are significant. Given the high incidence of ligamentous knee injuries in NFL players [40] and their association with post-traumatic OA [3,6,7,41], prevention strategies should be a focus of research. However, the majority of injury prevention programs have been conducted with soccer athletes. The Prevent Knee Injury and

Table 7. Prevalence of TKA and THA by age in retired NFL populations and the general population. TKA, total knee arthroplasty; THA, total Hip arthroplasty.

	Davies et al [7]		Tenforde et al [37]		Combined		Kremers, 2015 (General Population) [24]			
Age of Retiree (yrs)	n	%	n	%	n	%	n	%	P value	Relative Risk (95% CI)
TKA										
<50										
Replacement	10	1.1	24	1.5	34	1.3	85,195	0.1	<0.001	16.4 (11.7–22.9)
Total	956		1620		2576		105,709,894			
50–59										
Replacement	42	6.1	69	7.6	111	7.0	245,935	1.2	<0.001	5.8 (4.9–7.0)
Total	684		908		1592		20,512,532			
60–69										
Replacement	66	14.4	180	23.1	246	19.9	510,244	3.6	<0.001	5.5 (5.7–6.1)
Total	460		778		1238		14,029,131			
70+										
Replacement	70	21.1	170	37.0	240	30.3	541,038	7.3	<0.001	4.3 (3.9–4.8)
Total	332		460		792		7,447,964			
THA										
<50										
Replacement	14	1.5	27	1.7	41	1.6	122,401	0.1	<0.001	13.8 (10.2–18.7)
Total	956		1611		2567		105,709,894			
50–59										
Replacement	30	4.4	68	7.5	98	6.2	205,995	1.0	<0.001	6.1 (5.1–7.4)
Total	684		904		1588		20,512,532			
60–69										
Replacement	21	4.6	104	13.5	125	10.2	295,869	2.1	<0.001	4.8 (4.1–5.7)
Total	460		768		1228		14,029,131			
70+										
Replacement	48	14.5	90	19.7	138	17.5	280,383	3.8	<0.001	4.6 (4.0–5.4)
Total	332		457		789		7,447,964			

Enhance Performance (PEP) Program investigated neuromuscular approaches centered on stretching and proprioception exercises that focus on proper landing technique. Over a two-year period in more than 1000 high school female soccer players, there was an 88% ACL injury reduction in the first year and a 74% reduction the following year [42]. Similar findings in over 1100 male elite soccer players were identified with a 50% overall reduction in the rate of serious knee injury, particularly the medial and lateral collateral ligaments [43]. Although these study populations are not representative of NFL athletes, the principles utilized may be redirected toward American football-specific drills to serve as a powerful tool in reducing non-contact ACL injuries as these remain a common source of ligamentous damage [40]. Rule changes are another area of research that can potentially improve the safety of players. However, the data on the effects of these rules are mixed. Over the past decade, there have been many rule changes in the NFL, such as shifting the kickoff line forward, that have not made significant changes to player safety [44]. A study that recorded injuries over the past decade showed that despite rule changes, injury rates have not decreased, with a slight increase in arm injuries over the past decade [44]. An opposing study specifically on the initiation of the chop-blocking rule found a slight decrease in injuries [45]. They found the relative risk reduction of knee injuries to be 16% from the 2014–2015 and 2015–2016 seasons to the 2016–2017 and 2017–2018 seasons after the rule was implemented [45]. Due to the physical nature of football, even drastic rule changes have failed to make irrefutable differences in overall injury prevalence.

Given the significant frequency of musculoskeletal injury among retired NFL athletes, action must be taken to manage these ailments sooner. To our knowledge there is no literature on standardized evaluation of athletes as they depart from the league. As such, it may be warranted to obtain imaging to catch injuries early on to limit the progression of insidious musculoskeletal injuries. Domb and colleagues [17] observed a variety of soft tissue pathology on imaging from 75% of recently retired NFL athletes with symptomatic hip pathology. Although incidental soft tissue lesions are commonly identified on MRI in middle-aged persons [46], the athletic background of these patients should rouse greater suspicion for serious pathology and prompt earlier conservative management strategies to delay the need for surgical intervention. In addition, given the high incidence of obesity and its link to OA, programs should be implemented for retired athletes to manage weight after the NFL, which may potentially decrease the progression of posttraumatic OA.

By controlling arthritis and pain earlier, many retired players may have overall improved quality of life. Schwenk et al [47] found that 14.7% of retired NFL players in their study suffer from moderate to severe depression and 47.6% suffer from chronic pain. They found that pain and depression have an important and complex connection, with reports of roughly half of the pain clinic patients meeting the criteria for major depressive disorder [47]. They hypothesized that chronic pain in retirement led to impaired activity and exercise leading to depression. Depression is much more likely to follow chronic pain than vice versa, and the severity of the pain correlates with the level of depression [47]. A similar study on longitudinal NFL health outcomes and the associations between pain and post-career opioid misuse found that 52% of players were prescribed opioids during their career, and 71% of this subset misused opioids, with the strongest predictor of misuse being undiagnosed concussion commonly found in offensive linemen [48]. Those who abused opioids during their career were also much more likely to misuse in retirement [48]. Addiction and depression due to opioid misuse is yet another potential outcome of musculoskeletal injuries in retired NFL players. Further research is needed to investigate prevention strategies for depression and opioid misuse, such as early arthritis treatment and mental health programs for retired NFL athletes.

Limitations

Like any systematic review, this paper is limited by the level of quality of the included literature. Studies included cohort, case series, case-control, and cross-sectional studies with levels of evidence of III and IV. Several studies lacked standardized protocols, generalizability, and sufficient sample sizes. Additionally, statistical analysis was only completed on arthroplasty data and minimal arthritis data due to lack of homogeneity of outcomes reported. Much of the data on OA referred to the entire body instead of a specific joint or the lower extremities. In addition, it is difficult to assess whether the included studies had any overlap in the patient populations. Also, we only investigated literature on professional American football. Including additional studies on other contact sports (Canadian Football League, rugby, etc.) or lower levels of American football (high school and collegiate) could provide additional evidence and a better appreciation for how the intensity and duration of play in impact sports can affect orthopedic health outcomes.

Conclusions

Retired football players from the NFL are at high risk for long-term musculoskeletal morbidities in the lower extremities with early-onset OA and arthroplasty presenting at a greater frequency than the general population. Due to the potential economic and psychological burden such injuries place on retired athletes, greater attention should be directed toward prevention and long-term follow-up support for these musculoskeletal issues.

Disclosure statement

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Eugene Willis Brabston, MD
Link Orthopaedics: Paid consultant
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Arthroscopy: Editorial or governing board
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Miach Orthopaedics: Paid consultant
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Geolocation Information

Longitude: −86.779633
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Joseph Elphingstone is a recent graduate of the Medical College of Georgia and current Family Medicine resident at the Phoebe Putney Memorial Hospital with a career goal of entering primary care sports medicine with academic interests in athlete injury prevention and orthobiologics.

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Achraf Jardaly graduated magna cum laude from the Lebanese American University, with a major in Biology and a minor in Chemistry and continued to earn his medical degree from the same university. To augment his studies and gain experience in the US healthcare system, Dr. Jardaly took a gap year in medical school to complete a research fellowship at the University of Alabama at Birmingham. Now that he has received his medical degree, he plans to spend a year at the Hughston Foundation, working with fellows, residents, and physicians to achieve their research goals. He is passionate about research, mentorship, and leadership and hopes to use these passions to help the Hughston Foundation grow its research program.

Eugene Brabston currently serves as an Assistant Professor in the shoulder and elbow and sports medicine sections. In addition to his clinical work, Dr. Brabston has ongoing research in shoulder surgery. He publishes and presents his research findings on a regular basis. Dr. Brabston has won numerous awards such as the John W. McDonald Memorial Award in Surgery, University of South Alabama 2008. He has experience in serving both high school and college-level teams as their Team Physician.

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Brent Ponce is a fellowship-trained shoulder surgeon who has published over 100 peer-reviewed scientific journals. He also serves on the editorial boards of several well-known medical journals. Further, Dr. Ponce presents his research at international and national meetings, and has won awards for his investigative studies, publications, and presentations at state, regional, and international levels. During his career, he has held academic appointments at the University of Alabama at Birmingham, to include Vice Chairman of Clinical Affairs and Professor for the Department of Orthopaedic Surgery as well as Director of the Orthopaedic Research Fellowship and Director of Orthopaedic Specialties Institute Skills Lab. At the Hughston Foundation he mentors sports medicine fellows and surgical residents and is the Chairman of Research at the Hughston Foundation.

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References

1. Dailey A, Harrop JS, France JC. High-energy contact sports and cervical spine neuropraxia injuries: what are the criteria for return to participation? Spine (Phila Pa 1976). Spine. 2010 Oct 1;35(21 Suppl):S193–201. PMID: 20881462.
2. Morris TP, McCracken C, Baggish A, et al. Multisystem afflictions in former national football league players. Am J Ind Med. 2019 Aug;62 (8):655–662. Epub 2019 May 27. PMID: 31134638; PMCID: PMC6640629.
3. Ball S, Halaki M, Orr R. Training volume and soft tissue injury in professional and non-professional rugby union players: a systematic review. Br J Sports Med. 2017 Jul;51(13):1012–1020. Epub 2016 Oct 8. PMID: 28525884.
4. Smart BJ, Haring RS, Asemota AO, et al. Tackling causes and costs of ED presentation for American football injuries: a population-level study. Am J Emerg Med. 2016;34(7):1198–1204.
5. Kluczynski MA, Kelly WH, Lashomb WM, et al. A systematic review of the orthopaedic literature involving national football league players. Orthop J Sports Med. 2019 Aug 20;7 (8):2325967119864356. PMID: 31457068; PMCID: PMC6702781.
6. Anderson DD, Chubinskaya S, Guilak F, et al. Post-traumatic osteoarthritis: improved understanding and opportunities for early intervention. J Orthop Res. 2011 Jun;29(6):802–809. Epub 2011 Feb 11. PMID: 21520254; PMCID: PMC3082940.
7. Tayfur B, Charuphongsa C, Morrissey D, et al. Neuromuscular function of the knee joint following knee injuries: does it ever get back to normal? A systematic review with meta-analyses. Sports Med. 2021 Feb;51(2):321–338. PMID: 33247378; PMCID: PMC7846527.
8. Guccione AA, Felson DT, Anderson JJ, et al. The effects of specific medical conditions on the functional limitations of elders in the Framingham study. Am J Public Health. 1994;84(3):351–358.
9. Lawrence RC, Felson DT, Helmick CG, et al. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II. Arthritis Rheum. 2008;58(1):26–35.
10. Luyster FS, Dunn RE, Lauderdale DS, et al. Sleep-apnea risk and subclinical atherosclerosis in early-middle-aged retired national football league players. Nat Sci Sleep. 2017 Feb 21;9:31–38. PMID: 28260958; PMCID: PMC5328609.
11. Wearing SC, Hennig EM, Byrne NM, et al. Musculoskeletal disorders associated with obesity: a biomechanical perspective. Obes Rev. 2006 Aug;7(3):239–250. PMID: 16866972.
12. Kerkhoffs GM, Servien E, Dunn W, et al. The influence of obesity on the complication rate and outcome of total knee arthroplasty: a

meta-analysis and systematic literature review. J Bone Joint Surg Am. 2012 Oct 17;94(20):1839–1844. PMID: 23079875; PMCID: PMC3489068.
13. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 2009 Jul 21;339:b2700. PMID: 19622552; PMCID: PMC2714672.
14. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010 Sep;25(9):603–605. Epub 2010 Jul 22. PMID: 20652370.
15. Davies MAM, Kerr ZY, DeFreese JD, et al. Prevalence of and risk factors for total hip and knee replacement in retired national football league athletes. Am J Sports Med. 2019 Oct;47(12):2863–2870. Epub 2019 Sep 9. PMID: 31498654.
16. Domb BG, Carter C, Finch NA, et al. Whole-person impairment in younger retired NFL players: the orthopaedic toll of a professional football career. Orthop J Sports Med. 2014May19;2(5):2325967114534824. PMID: 26535333; PMCID: PMC4555538.
17. Domb BG, Jackson TJ, Carter CC, et al. Magnetic resonance imaging findings in the symptomatic hips of younger retired national football league players. Am J Sports Med. 2014 Jul;42(7):1704–1709. Epub 2014 Apr 29. PMID: 24780892.
18. Lynall RC, Pietrosimone B, Kerr ZY, et al. Osteoarthritis prevalence in retired national football league players with a history of concussion and lower extremity injury. J Athl Train. 2017Jun2;52(6):518–525. PMID: 28653870; PMCID: PMC5488842.
19. Nicholas SJ, Nicholas JA, Nicholas C, et al. The health status of retired American football players: super bowl III revisited. Am J Sports Med. 2007 Oct;35(10):1674–1679. Epub 2007 May 21. PMID: 17517907.
20. Pietrosimone B, Golightly YM, Mihalik JP, et al. Concussion frequency associates with musculoskeletal injury in retired NFL players. Med Sci Sports Exerc. 2015 Nov;47(11):2366–2372. PMID: 25871466.
21. Golightly YM, Marshall SW, Callahan LF, et al. Early-onset arthritis in retired national football league players. J Phys Act Health. 2009 Sep;6(5):638–643. PMID: 19953841.
22. Song K, Wikstrom EA, Tennant JN, et al. Osteoarthritis prevalence in retired national football league players with a history of ankle injuries and surgery. J Athl Train. 2019 Nov;54(11):1165–1170. Epub 2019 Sep 25. PMID: 31553650; PMCID: PMC6863693.
23. Tenforde AS, Cortez B, Baker J, et al. Prevalence of total hip and knee arthroplasty in former national football league players: comparison with the general US population and other populations of professional athletes. BMJ Open Sport Exerc Med. 2020 Sep 7;6(1):e000833. PMID: 33062305; PMCID: PMC7520548.
24. Maradit Kremers H, Larson DR, Crowson CS, et al. Prevalence of total hip and knee replacement in the United States. J Bone Joint Surg Am. 2015 Sep 2;97(17):1386–1397. PMID: 26333733; PMCID: PMC4551172.
25. Khan M, Ekhtiari S, Burrus T, et al. Impact of knee injuries on post-retirement pain and quality of life: a cross-sectional survey of professional basketball players. HSS J. 2020 Dec;16(Suppl 2):327–332. Epub 2019 Nov 8. PMID: 33380964; PMCID: PMC7749878.
26. Tveit M, Rosengren BE, Nilsson JÅ, et al. Former male elite athletes have a higher prevalence of osteoarthritis and arthroplasty in the Hip and knee than expected. Am J Sports Med. 2012 Mar;40(3):527–533. Epub 2011 Nov 30. PMID: 22130474.
27. Filbay S, Pandya T, Thomas B, et al. Quality of life and life satisfaction in former athletes: a systematic review and meta-analysis. Sports Med. 2019 Nov;49(11):1723–1738. PMID: 31429036; PMCID: PMC6789047.
28. Thomas AC, Hubbard-Turner T, Wikstrom EA, et al. Epidemiology of posttraumatic osteoarthritis. J Athl Train. 2017 Jun 2;52(6):491–496. Epub 2016 May 4. PMID: 27145096; PMCID: PMC5488839.
29. Miller MA, Croft LB, Belanger AR, et al. Prevalence of metabolic syndrome in retired national football league players. Am J Cardiol. 2008 May 1;101(9):1281–1284. Epub 2008 Mar 7. PMID: 18435958.
30. Evans JT, Evans JP, Walker RW, et al. How long does a Hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet. 2019 Feb 16;393(10172):647–654. Epub 2019 Feb 14. PMID: 30782340; PMCID: PMC6376618.
31. Evans JT, Walker RW, Evans JP, et al. How long does a knee replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet. 2019 Feb 16;393(10172):655–663. Epub 2019 Feb 14. Erratum in: Lancet. 2019 Feb 20;: PMID: 30782341; PMCID: PMC6381229.
32. Wainwright C, Theis JC, Garneti N, et al. Age at Hip or knee joint replacement surgery predicts likelihood of revision surgery. J Bone Joint Surg Br. 2011 Oct;93(10):1411–1415. PMID: 21969444
33. Bhandari M, Smith J, Miller LE, et al. Clinical and economic burden of revision knee arthroplasty. Clin Med Insights Arthritis Musculoskelet Disord. 2012;5:89–94. Epub 2012 Dec 5. PMID: 23239930; PMCID: PMC3520180
34. Ong KL, Lau E, Suggs J, et al. Risk of subsequent revision after primary and revision total joint arthroplasty. Clin Orthop Relat Res. 2010 Nov;468(11):3070–3076. Epub 2010 May 25. PMID: 20499292; PMCID: PMC2947702
35. Sayed-Noor AS, Mukka S, Mohaddes M, et al. Body mass index is associated with risk of reoperation and revision after primary total Hip arthroplasty: a study of the Swedish hip arthroplasty register including 83,146 patients. Acta Orthop. 2019 Jun;90(3):220–225. Epub 2019 Apr 1. PMID: 30931664; PMCID: PMC6534237.
36. Vanhegan IS, Malik AK, Jayakumar P, et al. A financial analysis of revision Hip arthroplasty: the economic burden in relation to the national tariff. J Bone Joint Surg Br. 2012 May;94(5):619–623. PMID: 22529080.
37. PS T. How (and why) athletes go broke sports illustrated. [cited 2021 Sept 4]. Available from https://vault.si.com/vault/2009/03/23/how-and-why-athletes-go-broke
38. Geenen R, Overman CL, Christensen R, et al. EULAR recommendations for the health professional's approach to pain management in inflammatory arthritis and osteoarthritis. Ann Rheum Dis. 2018 Jun;77(6):797–807. Epub 2018 May 3. PMID: 29724726.
39. Kan HS, Chan PK, Chiu KY, et al. Non-surgical treatment of knee osteoarthritis. Hong Kong Med J. 2019 Apr;25(2):127–133. Epub 2019 Mar 28. PMID: 30919810.
40. Palmieri-Smith RM, Mack CD, Brophy RH, et al. Epidemiology of anterior cruciate ligament tears in the national football league. Am J Sports Med. 2021 Jun;49(7):1786–1793. Epub 2021 Apr 30. PMID: 33929907.
41. Smith MV, Nepple JJ, Wright RW, et al. Knee osteoarthritis is associated with previous meniscus and anterior cruciate ligament surgery among elite college American football athletes. Sports Health. 2017 May/Jun;9(3):247–251. Epub 2016 Dec 1. PMID: 27940573; PMCID: PMC5435150.
42. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am J Sports Med. 2005 Jul;33(7):1003–1010. Epub 2005 May 11. PMID: 15888716.
43. Krutsch W, Lehmann J, Jansen P, et al. Prevention of severe knee injuries in men's elite football by implementing specific training modules. Knee Surg Sports Traumatol Arthrosc. 2020 Feb;28(2):519–527. Epub 2019 Sep 20. PMID: 31541292.
44. Sheth SB, Anandayuvaraj D, Patel SS, et al. Orthopaedic and brain injuries over last 10 seasons in the national football league (NFL): number and effect on missed playing time. BMJ Open Sport Exerc Med. 2020 Apr 5;6(1):e000684. PMID: 32341797; PMCID: PMC7173995.

45. Baker HP, Varelas A, Shi K, et al. The NFL's chop-block rule change: does it prevent knee injuries in defensive players? Orthop J Sports Med. 2018Apr23;6(4):2325967118768446. PMID: 29780842; PMCID: PMC5954335.
46. Englund M, Guermazi A, Gale D, et al. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. N Engl J Med. 2008 Sep 11;359(11):1108–1115. PMID: 18784100; PMCID: PMC2897006.
47. Schwenk TL, Gorenflo DW, Dopp RR, et al. Depression and pain in retired professional football players. Med Sci Sports Exerc. 2007 Apr;39(4):599–605. PMID: 17414796.
48. Cottler LB, Ben Abdallah A, Cummings SM, et al. Injury, pain, and prescription opioid use among former national football league (NFL) players. Drug Alcohol Depend. 2011 Jul 1;116(1–3):188–194. Epub 2011 Jan 28. PMID: 21277121; PMCID: PMC3095672.