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REVIEW

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Cardiovascular disease in retired NFL players: a systematic review

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ABSTRACT

Objective: Despite robust research endeavors exploring post-play health implications in former NFL players, the impact of former-player status on long-term cardiovascular health has not yet been elucidated. The purpose of this systematic review is to describe the available research on the cardiovascular health in former NFL players.

Methods: Relevant studies were included from the PubMed, Scopus, and Embase databases. Studies were evaluated in accordance with PRISMA guidelines. Two independent reviewers conducted the title/abstract screenings and risk of bias determinations. The results of the studies were extracted for inclusion in the review.

Results: Sixteen studies met inclusion criteria. Though evidence was discordant among studies, former NFL players appeared to possess more favorable metabolic profiles and decreased mortality compared to community controls. Of note, 90% of former players were found to be overweight or obese.

Conclusion: Though cardiovascular disease is the leading cause of death among former NFL players, they possess comparable metabolic and cardiovascular profiles to community controls. Further research is necessary to ascertain the impact of NFL play on cardiovascular health and develop tailored preventative care strategies for former players.

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Retired NFL players; cardiovascular disease; professional football; metabolic disease; cardiovascular abnormalities

Introduction

There have been multiple studies evaluating the health implications of playing football in the National Football League (NFL). In 2005, Omalu et al. published a case report detailing the postmortem pathologic report of a retired NFL player with extensive neurodegenerative disease [1]. Since then, numerous studies have examined the association between neurologic, psychiatric, and musculoskeletal pathologies with a history of professional football exposure. Neurologic and psychiatric studies have evaluated anatomic changes [2–5], psychiatric disease [6,7], and neurodegenerative disease [8,9] in this population. Musculoskeletal studies have investigated a wide variety of factors, ranging from the impact of environmental conditions on musculoskeletal injury prevalence [10] to long-term outcomes associated with ligament and joint injury in the NFL population [11–13].

Risk factors for cardiovascular disease include smoking, insufficient physical activity, hypertension, obesity, hypercholesterolemia, and hypertriglyceridemia [14]. Based on potential lower levels of activity after musculoskeletal injury [15], as well as high rates of obesity and diabetes [16,17], the retired NFL player population is an at-risk population for cardiovascular disease. This population may also experience health consequences such as obstructive sleep apnea [18]. This study provides a novel summary of the available literature describing the association between cardiovascular disease and a history of professional football play. The goal of this systematic review is to synthesize and examine current literature investigating the association between retired NFL football player status and cardiovascular disease.

Materials and methods

This systematic review was performed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 27-item checklist [19]. The data from the included manuscripts was organized into four groups: (1) weight gain and obesity, (2) mortality, (3) obstructive sleep apnea, and (4) cardiovascular disease. Studies pertaining to multiple categories were included in all applicable categories.

Eligibility criteria

The inclusion criteria were as follows: (1) study population consisted of retired NFL players, (2) outcomes included cardiovascular related diseases, (3) the studies were published in English, and (4) the studies were full-length publications. The exclusion criteria were: (1) non-English language studies, (2) case reports or case series, (3) commentaries or editorials, (4) unpublished

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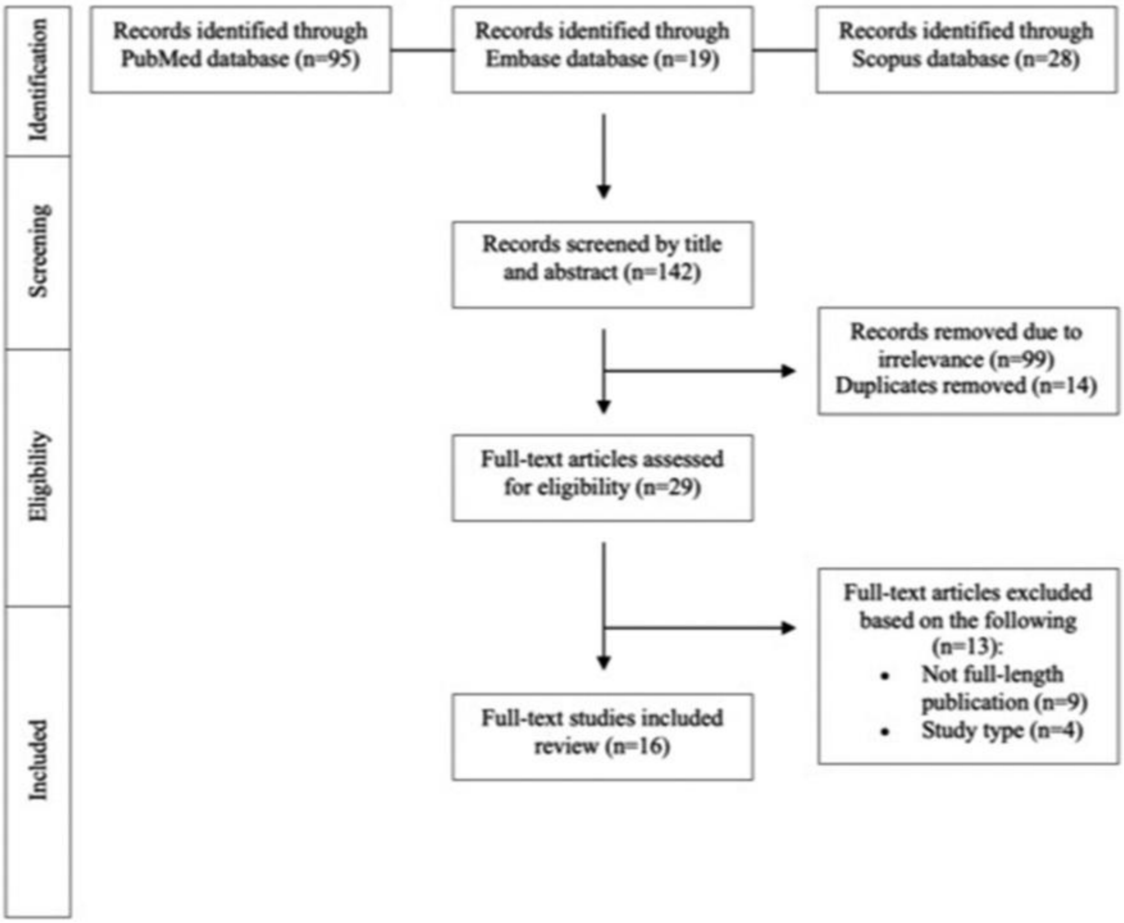

Figure 1. Literature selection algorithm. The records were excluded based on the inclusion/exclusion criteria as well as study methodology.

articles, (5) abstract only publications, (6) studies that did not assess former NFL players, (7) studies that included active NFL players in the cohort, and (8) studies that did not investigate cardiovascular disease incidence or prevalence.

Data sources

The searches for qualified publications in PubMed, Embase, and Scopus were completed in September 2021.

Study selection

Two authors (MS and NM) 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.

Risk of bias

Risk of bias was assigned independently by two different reviewers utilizing the validated Newcastle-Ottawa Quality Assessment Scale, which was adapted to this review [20,21]. Discrepancies among risk scoring were resolved by consensus. Cohort studies were evaluated based on (1) representativeness of the exposed cohort, (2) selection of the non-exposed cohort, (3) ascertainment of exposure from a secure record or structured interview, (4) outcome was not present at the start of the study, (5) controlled for most important factor, (6) controlled for other factors, (7) assessment of outcome, (8) long enough follow-up period, (9) adequate follow-up rate. Cross-sectional studies were evaluated based on (1) representativeness of the sample, (2) adequate sample size, (3) non-respondent comparability, (4) ascertainment of the exposure with valid measure, (5) control for most important factor (6) control for other factors, (7) assessment of outcome by blind assessment or record linkage, (8) statistical analysis appropriate and described, including confidence intervals and p-values. A score of 7–9 had a low risk of bias, 4–6 had a moderate risk of bias, and 0–3 had a high risk of bias.

Results

The initial search yielded 142 results among PubMed, Embase, and Scopus, which were then screened by title and then by abstract for relevance. Duplicates were excluded. Title, abstract, and duplication screening yielded 29 publications. Of those, 16 met inclusion criteria (Figure 1). Study characteristics are detailed in Table 1. The number of participants included in the studies ranged from 122 to 3506, all of whom were male. The studies were all conducted in the United States.

Table 1. Characteristics of included studies and player demographics.

Authors	Year	Journal	Risk of Bias	Outcome Measures	Data Source	n	Age, yr	BMI	Length of NFL Career (yrs) (range)	% Lineman
Churchill et al. (Values presented as mean for age, BMI and NFL career)	2018	Am J Med	4	Incidence of cardiovascular disease, cardiometabolic disease, sleep apnea, neurocognitive impairment, chronic pain	Survey	3506	52.8	32.2	6.8 (3.1–10.5)	36.2%
Venkataramani et al. (Values presented as mean for age and BMI, median for NFL career)	2018	JAMA	9	All-cause mortality	PFR Database	2933	52.7	29.7	5 (2–8)	30%
Luyster et al. (Values presented as mean; age and BMI)	2017	Nat Sci Sleep	6	Sleep apnea prevalence	Screening[a]	122	45.3	30.3	NR	27.9%
Chang et al	2009	Am J Cardiol	7	Coronary artery calcium and CRP levels, waist and hip circumference, BP, cholesterol, lipoprotein, lipid levels, diabetes prevalence	Survey and Screening[a]	300, 600	DHS: 51.2 average ACLS: 53.4 DHS: 51.2 NFL, 51.1 DH ACLS: 55.2 NFL, 52.5 ACLS control	DHA: 31.5 average NFL: 31.5, DHS:31.4 ACLS: 29.6 average NFL: 31.7, ACLS control: 28.6	NR	DHS: 29.3% ACLS: 57.5%
Miller et al. (Values calculated as means; age, BMI, years in NFL)	2008	Am J Cardiol	5	BMI, % body fat, prevalence of metabolic syndrome, blood pressure, fasting HDL cholesterol, triglycerides, and plasma glucose levels	Survey and Screening[a]	510	53.7 54.0 for linemen ($n = 164$), 53.5 for nonlinemen($n = 346$)	32.1 34.9 L, 30.7 NL	6.3 6.8 L and 6.0NL	32.2%
Pokharel et al. (Values reported as medians; age and BMI)	2014	Clinical Cardiol	5	Coronary artery calcium and CRP levels, waist and hip circumference, neck circumference, BP, cholesterol, lipoprotein, lipid levels, diabetes prevalence	Survey and Screening[a]	845	54	31	NR	NR
Singh Basra et al. (values reported as median; age and BMI)	2014	Am J Cardiol	7	Coronary artery calcium and CRP levels, waist and hip circumference, BP, cholesterol, lipoprotein, lipid levels, diabetes prevalence	Survey and Screening[a]	931	54	32	NR	33.3%
Pokharel et al. (Values reported as median; age and BMI)	2014	South Med J	7	CAC levels	Survey and Screening[a]	926	54	31	NR	NR
Croft et al. (Values reported as mean; age, BMI, years in NFL)	2008	Am J Cardiol	6	Cardiac posterior wall thickness, septal wall thickness, LV end diastolic diameter, and LA area	Survey and Screening[a]	487	54.2	31.8	6.1	30.2%
Virani et al. (values reported as mean; age)	2012	Atherosclerosis	6	LDL levels, non-HLD cholesterol levels, CRP levels	Survey and Screening[a]	948	53.5	NR	NR	33.7%
Pokharel et al. (Values reported as median; age, BMI)	2014	Atherosclerosis	7	$LpPLA_2$ mass, CAC burden, CAP burden	Survey and Screening[a]	832	54	31.3	NR	33.7%
Baron et al. (Values reported as medians; age, BMI, years in NFL)	2012	Am J Cardiol	7	Cause of mortality	Survey and Database	3439	54	29	8 (5–25)	33.7%
Albuquerque et al. (Values reported as mean; age, BMI)	2010	J Am Coll Cardiol	7	SDB prevalence	Survey and Screening[a]	257	53.9	32.3	NR	NR

(Continued)

Table 1. (Continued).

Authors	Year	Journal	Risk of Bias	Outcome Measures	Data Source	n	Age, yr	BMI	Length of NFL Career (yrs) (range)	% Lineman
Hurst et al. (values reported as mean; age BMI)	2010	Am J Cardiol	7	Carotid arterial plaque levels, age, weight, BMI, height, body surface area, lineman status, metabolic syndrome prevalence, smoking status, HTN, BP, HLD, LDL, HDL, TG, Total Cholesterol, Glucose levels	Survey and Screening[a]	201	50.8	31.5	NR	29.4%
Trexler et al. (values reported as means; age, BMI and years in NFL)	2018	Med and Sci in Sports and Exercise	5	Prevalence of CHD, diabetes, and HBP; change in BMI since retirement	Survey	2062	53.6	30.6	15.1 (5–33)	35.9%
Hyman et al. (values reported as means)	2012	J of Occupational and Envi Med	4	Prevalence of HTN, OSA, LVH, GERD, DM; BMI and % Body Fat	Referral and Chart Review	129	42.2	NR	8 (1.0–20.0)	48.8%

[a]NFL Player Care Foundation Cardiovascular Health/Living Heart Foundation Screening Program; LOE, level of evidence; PFR: Pro Football Reference; BMI, body mass index; NR, Not Reported; Chang et al. compared Living Heart Foundation screenings against two sets of controls: the Dallas Heart Study participants and Aerobics Center Longitudinal Study participants (2nd). Data from Croft et al. and Miller et al. are included as the sum of two means. Basra et al. presented data as medians for age and BMI, a median of medians. An average of the medians was calculated. Baron et al. presented data as medians for age, BMI, and years in NFL (an average of the medians was calculated).

Eleven out of the 16 studies utilized the NFL Player Care Foundation Cardiovascular Health/Living Heart Foundation Screening Program (LHFSP) as their data source [16,18,22–30]. Churchill et al. generated a survey that was distributed to living former NFL players from 1960 to 2018 [17]. Trexler et al. administered a survey to former NFL players by mail or phone and sent a follow-up survey to 25 respondents, 24–36 months afterward, to determine concordance [31]. Hyman et al. collected data from a population of former NFL players referred to a medical practice [32]. Venkataramani et al. utilized data from the National Death Index and Pro Football Reference Database [33]. Baron et al. compiled data from the NFL pension fund death records and National Death Index [34].

Weight gain/obesity

The seven relevant studies qualified as low or moderate bias risk. Studies investigated factors such as weight gain [17,31], cardiovascular disease risk factors compared to community controls [22], the impact of player position [16], and neck and waist circumference [23,25].

Two of the studies focused on the impact of weight gain over time on subsequent comorbidities. The first study described a statically significant weight gain in each timeframe: high school to college (23.3 ± 18.2 lbs., $p \leq 0.0001$), college to professional career (11.3 ± 13 lbs., $p \leq 0.0001$), and professional career to the time of the study (5.9 ± 35 lbs., $p \leq 0.001$) [17]. The weight gain from high school to college was significantly associated with cardiovascular disease (OR 1.08), chronic pain (OR 1.09), and sleep apnea (OR 1.13). The weight gain from college to professional career was significantly associated with cardiovascular disease (OR 1.11), neurocognitive impairment (OR 1.11), and sleep apnea (OR 1.19) [17]. The second study found an association between BMI changes from retirement to the time of the study and the prevalence of diabetes and elevated blood pressure [31].

Several studies extended the investigation to compare the former NFL population to community controls. One commonality among several studies was comparing the prevalence of metabolic syndrome, though the evidence appeared discordant. In a study comparing former NFL players to community controls matched for age, ethnicity, and BMI, NFL players had significantly lower prevalence of smoking and diabetes ($p < 0.01$), sedentary lifestyles ($p < 0.05$), and metabolic syndrome ($p < 0.05$). NFL players did have a significantly higher prevalence of impaired fasting glucose compared to community controls ($p < 0.01$) [22]. A different study comparing the prevalence of metabolic syndrome in former NFL players to adult males in the US determined the prevalence of metabolic syndrome in non-linemen, linemen, and the adult US population [16]. Nearly 60% (59.8%) of former linemen met criteria for metabolic syndrome, compared to 30% of former non-linemen and 24% of males in the United States (US) [16]. Another study posed the question of whether BMI was the most appropriate measure to study in a population that may have significant muscle mass. This study suggested that measuring percent body fat may better capture the obesity rates in the former NFL population [32].

The final studies addressing obesity in the former NFL population assessed correlations between obesity and neck or waist circumference. The presence of coronary artery calcium was not associated with BMI increases but was associated with waist circumference in unadjusted models [25]. After adjusting for demographic factors such as age, race, blood pressure, and metabolic syndrome components, the association was reversed; BMI was associated with a 31% increase in coronary artery calcium prevalence (OR 1.31, 95% CI 1.11–1.56), but waist circumference was not significantly associated with coronary artery calcium prevalence [25]. Neck circumference was not associated with levels of coronary artery calcium or plaques [23].

Mortality

Each of the two relevant studies qualified as low bias risk. Both studies identified cardiovascular/cardiometabolic disease as the leading cause of death in former NFL players. The first study compared mortality causes and rates among players who debuted between 1982 and 1992 with controls, who were players that played exclusively during the 1987 strike period (weeks 4 to 6 were played by replacement players) and therefore had limited exposure to professional play. The leading cause of death in both groups was cardiometabolic disease. The difference in all-cause mortality between the two groups did not reach statistical significance. Adjusting for birth year, BMI, height, and position group, the absolute risk difference was 1.0% (95% CI – 0.7 to 2.7; $p = 0.25$) [33]. The second study used a national database to compare NFL player mortality to the US population. Of importance, 90% of the former NFL player cohort had overweight-range BMI (>24.9 kg/m^2), and an increase in cardiovascular disease mortality risk was observed in players with an obesity-range BMI (>29.9 kg/m^2) during their years of professional play compared to other players. Overall mortality comparison between the two groups indicated an overall decrease in mortality in the former NFL player cohort compared to US controls [34].

Obstructive sleep apnea

One of the relevant studies qualified as low risk of bias while the other was moderate risk. The first study compared former NFL players to community controls, matching for age, BMI, and race [18]. Based on questionnaire results, they found a significantly larger percentage of participants that qualified as high risk for sleep apnea among the former NFL players than among the controls (27% vs 11.5%, respectively; $p = 0.002$) [18]. The second study parsed out rates of sleep apnea among different playing positions. They found that former lineman had a higher prevalence of sleep-disordered breathing than non-linemen (61.3% vs. 46.6%; $p = 0.02$), though this portion of the study did not control for BMI or age [28].

Cardiovascular disease

The eight relevant studies qualified as low or moderate bias risk. The studies focused primarily on cardiovascular disease risk factors, differences among player positions, structural heart changes, and atherosclerotic vascular burden. Four studies compared cardiovascular disease risk factors, such as cholesterol levels, triglyceride levels, and blood pressure, among former NFL players and community controls. The studies utilized data from the LHFSP, though their control groups differed. Two matched controls based on age, race, and BMI [18,22], another matched based on age and BMI [28], and the final study matched based on age bracket, gender, and cardiovascular disease categories [29]. Study results varied, as detailed in Tables 2 and 3. Chang, Luyster, and Albuquerque all found that former NFL players were less likely to be former smokers [18,22,28].

In addition to the aforementioned studies, several studies within this category did not employ community controls but evaluated cardiovascular disease risk factors, atherosclerotic disease, and comparisons based on player position status, specifically linemen versus non-linemen. Two used regression models to adjust for factors such as age, BMI, and hypertension [24,26]. The first study compared left ventricular structural

Table 2. Cardiovascular morbidity risk factors.

Authors	Coronary Artery Calcium Level	Fasting Glucose Levels	LDL Levels	HDL Levels	Triglyceride Levels
Hurst et al.	NR	97.8 ± 10.5 mg/dL[a]	131.3 ± 25.6 mg/dL[a]	40.9 ± 16.5 mg/dL[a]	102.6 ± 64.6 mg/dL[a]
Albuquerque et al.	NR	101.1 ± 1.8 mg/dL[a]	121.4 ± 2.3 mg/dL[a]	44.0 ± 0.8 mg/dL[a]	149.8 ± 12.7 mg/dL[a]
Pokharel et al. (10/2014)	1: 0.89 (0.76–1.04) 2: 0.85 (0.71–1.02)[c]	91 (84–98) mg/dL[b]	124 (102–148) mg/dL[b]	47 (44–56) mg/dL[b]	89 (64–141) mg/dL[b]
Virani et al.	NR	NR	127 ± 38 mg/dL[a]	49 ± 14 mg/dL[a]	89 (12–166) mg/dL[b]
Singh Basra et al.*	L = 105 (33.88%) NL = 259 (41.7%)	L: 92 (84–100) mg/dL[b] NL: 90 (83–97.3) mg/dL[b]	L: 117.5 (98–143) mg/dL[b] NL: 127 (104–151.8) mg/dL[b]	L: 45 (39–55.8) mg/dL[b] NL: 48 (40–57) mg/dL[b]	L: 88 (62–141) mg/dL[b] NL: 91 (66–140.5) mg/dL[b]
Pokharel et al. (07/2014)	a) 1.01 (0.88–1.16) b) 1.00 (0.87–1.15)[d]	91 (84–98) mg/dL[b]	125 (103–148) mg/dL[b]	47 (39–56) mg/dL[b]	89 (65–141) mg/dL[b]
Miller et al.*	NR	L: 104.6 ± 22.6 mg/dL[a] NL: 97.4 ± 15.7 mg/dL[a]	NR	L: 44.5 ± 14.2 mg/dL[a] NL: 47.6 ± 14.9 mg/dL[a]	L: 128.5 ± 79.8 mg/dL[a] NL: 116.1 ± 70.8 mg/dL[a]
Chang et al.	NR	101.4 ± 14.1 mg/dL[a] 102.3 ± 17.0 mg/dL[a]	128.5 ± 36.0 mg/dL[a] 126 ± 36.2 mg/dL[a]	50.8 ± 16.8 mg/dL[a] 49.4 ± 17.0 mg/dL[a]	81 (61–115) mg/dL[b] 83.5 (61–122) mg/dL[b]
Luyster et al.	37 (30.3%)	89.4 ± 36.4 mg/dL[a]	126.5 ± 39.7 mg/dL[a]	49.9 ± 11.5 mg/dL[a]	140.3 ± 96.5 mg/dL[a]

All values reported as either mean +/- standard deviation[a] or median with (IQR)[b].
[c]reported as odds ratio (95% confidence interval) – 1: adjusted for age, race, systolic BP, fasting blood glucose, BMI, 2: adjusted for model 1 + HDL, LDL, TG + high-sensitivity CRP. Both are an odds ratio associated with 1-standard deviation increase (80 ng/mL) in LpPLA2.
[d]a) association between neck circumference and subclinical atherosclerosis as an odds ratio per standard deviation increase in neck circumference (3–8 inches) b) association between neck circumference/BMI, as an odds ratio per standard deviation increase in NC/BMI (0.12398 inches x m^2/kg)
*L = linebacker status vs NL = non-linebacker status.

Table 3. Prevalence of atherosclerosis, metabolic syndrome, and obstructive sleep apnea.

Authors	Prevalence of Atherosclerosis	Prevalence of Metabolic Syndrome	Prevalence of OSA
Churchill et al	NR	NR	NR
Venkataramani et al	NR	NR	NR
Luyster et al	NR	NR	27%
Chang et al	NR	NR	NR
Miller et al	NR	59.8% in linemen, 30.1% in nonlinemen	NR
Pokharel et al. (2014 Clinical Cardiol)	56%	21%	NR
Singh Basra et al	NR	NR	NR
Pokharel et al. (2014 South Med J)	NR	NR	NR
Croft et al	NR	NR	NR
Virani et al	41%	NR	NR
Pokharel et al. (2014 Atherosclerosis)	65%	NR	NR
Baron et al	NR	NR	NR
Albuquerque et al	NR	NR	61.3% in linemen, 46.6% in nonlinemen
Hurst et al	33.3% presence in all players; 27.1% in linemen, 35.9% in nonlinemen	45.8% in linemen, 22.5% in nonlinemen	NR
Trexler et al	NR	NR	NR
Hyman et al	NR	NR	41.1%

NR, Not Reported.

changes in linemen versus non-linemen. After adjusting for BMI and hypertension, the study found that in former players with a BMI < 35, left ventricular mass and mass/height ratio were significantly different between linemen and non-linemen. This association did not hold true in the BMI > 35 group. However, a substantial proportion of both linemen and non-linemen had left ventricular mass exceeding the upper limit of normal (52.3% of linemen, 23.7% of non-linemen) [26]. The next study compared prevalence of subclinical atherosclerosis in different playing positions. Linemen had 59% greater odds of having moderate to severe subclinical atherosclerosis compared to non-linemen after adjusting for demographic factors such as age, BMI, race, and diabetes [24]. There was no significant difference in odds of mild subclinical atherosclerosis between the two player position groups after the same demographic adjustments (OR 1.24, 95% CI 0.82–1.8; $p = 0.28$) [24].

Several studies evaluated levels of subclinical cardiovascular disease in former NFL players. Two studies found that retired NFL players had comparable prevalence of coronary artery calcium to community controls [18,22]. In one of the studies, detectable CAC was found in 46% of community controls and 48% of former NFL players [22]. The prevalence of coronary artery plaques in former NFL players varied among the studies, including 41% [27], 33% [29], and 65% [30]. A series of studies found no associations when investigating the relationship between neck circumference or lipoprotein (a biomarker for metabolic disease) levels and the presence of coronary artery calcium or plaque [23,30].

Discussion

The leading cause of death in both former NFL players and the US community is cardiovascular disease. Studies evaluating mortality indicate that NFL players suffer from lower overall mortality compared to the community. While many factors likely contribute to this finding, two important factors include the rigorous exercise regimens maintained during young adulthood and the lower smoking prevalence in the former player population [18,22,28]. One recent meta-analysis suggested that this lower mortality risk also extended into the area of mental health. In this study, former professional football players had a lower risk of mental health-related causes of mortality compared to the general population [35].

In addition to mortality considerations, cardiovascular morbidity associated with post-play health remains an important area of investigation. Numerous studies have examined the impact of professional football on neurologic and musculoskeletal health, but scant data exists on the cardiovascular impact of the sport. As the game of football continues to evolve, the body composition of professional players becomes increasingly delineated based on position. Whereas historically players may have been expected to play a variety of positions and were conditioned for versatility, modern players cultivate body compositions based on their positions' requirements for strength, speed, or agility [36]. This change is likely responsible for the disparity in cardiovascular risk between linemen and non-linemen [16,24]. The impact of eating habits on cardiovascular health at the professional football level has not been studied, though Abbey et al. suggested that eating habits may affect cardiovascular health at the college level [37]. Further study will continue to illuminate the cardiovascular health outcomes of different playing positions and dietary factors to delineate the most appropriate initiatives for post-play preventative medicine.

Recent studies have compared the cardiovascular health in former professional football players to community members. In several studies, the NFL population possessed a lower prevalence of cardiovascular disease risk factors, such as metabolic syndrome and diabetes, compared to community controls matched for age, race, and BMI. These findings likely reflect the vigorous exercise regimens maintained throughout pre-professional and professional play. These health benefits appear to diminish over time, however, and >90% of former NFL players are overweight or obese [34]. One study described an association between osteoarthritis and cardiovascular disease risk factors [38].

There may be a destructive chain of events, wherein obesity accelerates cartilaginous degeneration and osteoarthritic changes. This in turn increases the pain associated with mobility, leading to a disadvantageous cycle of decreased exercise, increased weight gain, and subsequent increases in cardiovascular disease risk.

Preventing long-term health consequences requires research to quantify the problem and inform subsequent evidence-based health initiatives. One important consideration in future studies will be the most appropriate measurements to assess in former players. BMI has traditionally been used as the standard weight measure, but Hyman et al. raised the concern that this data may skew obesity rates in a population with substantial muscle mass [32]. This review sought to capture the expansive topic of cardiovascular disease as a whole, and thus approached the topic of measurement determination only nominally. Further studies may be required to delineate the measure most reflective of true obesity in the former NFL population.

Addressing obesity and cardiovascular disease in former NFL players requires both data-gathering and intervention programs. The Living Heart Foundation is promoting preventative healthcare measures through regular health screenings for former NFL players. Recognizing and addressing cardiovascular and metabolic disease is particularly salient in the at-risk population of former NFL players. Aggressive pursuit of patient education on the health consequences of obesity and the importance of lifestyle management may improve the long-term cardiovascular outcomes of former NFL players. Chang et al. suggest that age and lipid levels correlate with CAC levels [22]. Thus, interventions targeting the period during play or shortly thereafter may help prevent incremental increases in weight and corresponding accrual of cardiovascular disease risk.

This study has several limitations. We developed an expansive search strategy encompassing multiple databases. Nevertheless, the scope of this study is limited to the search criteria provided. Another limitation of this study is the homogeneity of data sources. Nearly all available studies are based on the data collected from a single survey and screening program (LHFSP). Despite the common data source in most of the literature, the results of analyses and conclusions among the studies diverge and often conflict. Very few studies utilized community controls to further parse out the impact of BMI, age, and race on results and conclusions. Inconsistencies in data reporting and controls limited this study's ability to pool data for statistical analysis. Conducting large-scale studies on the impact of playing professional football on cardiovascular health would allow for meta-analyses and subsequent evidence-driven healthcare recommendations for this population. Finally, all the studies included were cross-sectional or retrospective cohort studies. Consequently, results can only be used to identify associations, rather than causal relationships.

The former NFL population, like the US population, carries a tremendous burden of cardiovascular disease. As the leading cause of death in this population, cardiovascular disease requires vigilant monitoring and intervention in former NFL players. Several important questions have been posed by studies included in this review, including how the former NFL population compares to a general US control population and the best forms of measure in assessing the former NFL population. These questions will be central to future discussions and warrant further investigation. Moreover, it will be important for NFL stakeholders to implement appropriate mechanisms and programs to promote player care and health maintenance after players retire from the sport.

Conclusions

NFL players exhibit risk factors for cardiovascular disease, though the existing literature suggests they have more favorable overall cardiovascular and metabolic profiles when compared to community controls matched for BMI, ethnicity, and age. Lineman status was associated with a higher prevalence of metabolic syndrome and OSA compared to non-linemen. Further research is necessary to understand of the impact of NFL player status on longitudinal cardiovascular health, including robust comparisons to general population statistics and defining the optimal variables for long-term monitoring.

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Searches

The PubMed keyword search is as follows:

(“Cardiovascular Diseases”[Mesh] OR “Heart Diseases”[Mesh] OR “Vascular Diseases”[Mesh] OR “Cardiovascular Diseases”[tiab] OR “Heart Diseases”[tiab] OR “Vascular Diseases”[tiab] OR “cardiac morbidit*”[tiab]) AND ((“Football”[Mesh] OR “football”[tiab]) AND (“retirement”[Mesh] OR “retired”[tiab])) OR (“retirement”[Mesh] OR “retired”[tiab) AND (“National Football League”[tiab] OR “NFL”[tiab])

The Embase keyword search is as follows:

american AND football AND ('pensioner'/exp/mj OR 'retired worker' OR 'retiree' OR 'retirement' OR 'retired') AND ('cardiovascular disease'/exp/mj OR 'heart disease'/exp/mj OR 'vascular disease'/exp/mj)

The Scopus keyword search is as follows:

(“Cardiovascular Disease” OR “Heart Disease” OR “Vascular Disease”) AND (Football OR “National Football League” OR NFL) AND (retirement OR retired OR retirement OR retired)