Cardiovascular Health of Retired Field-Based Athletes

A Systematic Review and Meta-analysis

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Background: Retirement from elite sport participation is associated with decreased physical activity, depression, obesity, and ischemic heart disease. Although engagement in physical activity through sport is recognized as cardioprotective, an estimated one-quarter of deaths in American football players are associated with cardiovascular disease (CVD), predominately in players classified as obese.

Purpose: To systematically investigate the cardiovascular health profile of retired field-based athletes.

Study Design: Systematic review; Level of evidence, 4.

Methods: This review was conducted and reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and preregistered with PROSPERO. Four databases (PubMed, CINAHL, Embase, and Web of Science) were systematically searched from inception to October 2018 using MeSH terms and keywords. Inclusion criteria were retired field-based athletes, age >18 years, and at least 1 CVD risk factor according to the European Society of Cardiology and the American Heart Association. Review articles were not included. Control groups were not required for inclusion, but when available, an analysis was included. Eligible articles were extracted using Covidence. Methodological quality was assessed independently by 2 reviewers using the AXIS tool. The accuracy of individual study estimates was analyzed using a random-effects meta-analysis.

Results: This review yielded 13 studies. A total of 4350 male retired field-based athletes from 2 sports (football and soccer; age range, 42.2-66 years) were included. Eight studies compared retired athletes with control groups. Retired athletes had elevated systolic blood pressure in 4 of 6 studies; approximately 50% of studies found greater high-density lipoprotein, approximately 80% found lower triglyceride levels, and all studies found greater low-density lipoprotein for retired athletes compared with controls. The prevalence and severity of coronary artery calcium and carotid artery plaque were similar to controls. Retired linemen had double the prevalence of cardiometabolic syndrome compared with nonlinemen.

Conclusion: The overall findings were mixed. Inconsistencies in the reporting of CVD risk factors and methodological biases reduced the study quality. Retired athletes had a comparable CVD risk profile with the general population. Retired athletes with an elevated body mass index had an increased prevalence and severity of risk factors. Significant gaps remain in understanding the long-term cardiovascular effects of elite athleticism.

Keywords: cardiovascular; heart disease; retired athletes; field-based; evidence-based review; risk factors

Regular physical activity is recommended for the optimization of cardiovascular health and the reduction of all-cause mortality, whereas obesity is an established risk factor for cardiovascular disease (CVD).[12,25,65,71] Field-based athletes from sports such as American football and rugby present with a greater body mass index (BMI) along with superior aerobic fitness.[11,25,43,60,68,75] However, the cardiovascular health of these athletes after retirement is unclear. Premature mortality from CVD has become a prominent topic of discussion for field-based athletes, particularly during the transition into retirement.[3] Athletes are typically perceived as a healthy cohort, with evidence to support that fitness provides protection against known health risks of obesity[12,36] and relevant comorbidities.[54,59] Research also demonstrates that although exercise has beneficial cardioprotective qualities, it does not necessarily translate into immunity from cardiovascular risk.[28] An estimated one-quarter of football players' deaths are associated with CVD, predominately in those classified as obese.[24] Furthermore, when compared with retired baseball players, retired football players are more than twice as likely to die before the age of 50 years.[24] A study from the

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US National Institute for Occupational Safety and Health (NIOSH) found that although overall mortality from CVD in retired football players was 46% lower than in the general population, linemen had a 52% greater risk.[3] It has been suggested that this may, in part, reflect increased cardiovascular risk factors associated with a greater body size.[3,26] The BMI of football players often falls into the obesity range.[11,25,42,68,75] However, the applicability of BMI in this cohort is widely criticized because of the players' high muscle mass, leading to an overestimation of body fat percentage.[48,49,50,62] However, it is unknown if BMI remains inapplicable following retirement from elite athleticism.

To our knowledge, there has been no published review on the evidence concerning cardiovascular health in retired field-based athletes. The long-term cardiovascular health risks for professional athletes remain largely unclear. Therefore, the primary purpose of this review was to systematically collate and appraise the evidence on the cardiovascular health and the prevalence of CVD risk factors in retired field-based athletes. Furthermore, this review aimed to investigate the prevalence of factors that influence mortality from CVD, including obesity,[29,32] hypertension,[40] dyslipidemia,[58] glucose intolerance,[17] cardiometabolic syndrome (CMS),[17] coronary artery calcium (CAC),[61,67] and sleep-disordered breathing (SDB).[56,66]

METHODS

This review was conducted and reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (www.prisma-statement.org)[45] and was registered with PROSPERO, a registry of systematic reviews https://www.crd.york.ac.uk/prospero; registration No. CRD42017077885). Articles were retrieved via online database search engines including CINAHL, Embase, PubMed, and Web of Science. The reference lists of all reviews related to cardiovascular health and articles meeting the eligibility criteria were reviewed manually for suitability.

Keywords and MeSH terms were searched alone and in combination. The following keywords were included: CVD, cardiovascular health, blood pressure, lipids, cholesterol, cardio-metabolic syndrome, hypertension, glucose intolerance, body composition, body mass index, body fat percentage, low-density lipoprotein, high-density lipoprotein, triglycerides, total cholesterol, sleep-disordered breathing, field-based athlete, American football, baseball, field hockey, rugby, Gaelic football, and soccer. The inclusion criteria consisted of retired athletes from a field-based sport older than 18 years and studies that investigated at least 1 known risk factor for CVD according to the European Society of Cardiology (ESC)[54] and American Heart Association (AHA).[72] The search was not limited by language or publication status, and no date restriction was implemented. Articles were excluded if the study design was a review paper and if retired athletes with a prior cardiovascular event were included. The inclusion of controls was not required.

A 3-step screening strategy was implemented to identify appropriate relevant articles using Covidence (www.covidence.org) (Figure 1). Titles and abstracts were screened by 2 authors (C.M., F.W.) blinded to each other's selection, in accordance with the aforementioned inclusion criteria. Then, reviewers independently screened full texts (Appendix Table A1). A third reviewer (K.H.) was consulted to make a final decision when a consensus was not reached between the 2 reviewers. Manual searches were performed of reference lists of the selected articles. The search methodology and process are described in Figure 1. Eligible articles were critically appraised, and quality was assessed with full-text screening using the AXIS tool for the critical appraisal of cross-sectional studies (Table 1).[14] When studies were agreed upon, 1 reviewer extracted data from selected studies to create an evidence table using STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.[70]

We assessed the precision and accuracy of individual study estimates by conducting a random-effects meta-analysis to examine the overall effect. Heterogeneity between studies was determined by the I^2 statistic[27] as an indicator of the proportion of the total variation in estimates that is caused by heterogeneity. I^2 values of 25%, 50%, and 75% correspond to low, moderate, and high degrees of heterogeneity, respectively. Where high levels of heterogeneity were detected ($I^2 > 75\%$), a sensitivity analysis was conducted. Findings from the random-effects meta-analysis are represented through forest plots. Studies removed during the sensitivity analysis are represented by 0.0% weight in forest plot figures.

RESULTS

Overall, 1816 articles (after the removal of 12 duplicates from the original 1828 articles) were retrieved. After screening the titles and abstracts based on our inclusion criteria, 1583 articles were excluded. This left 233 articles for full-text screening, from which 76 were excluded because study participants were current athletes, 132 were excluded because of the studies' primary outcomes not being relevant to a traditional cardiovascular health assessment, 10 were excluded because of the study design

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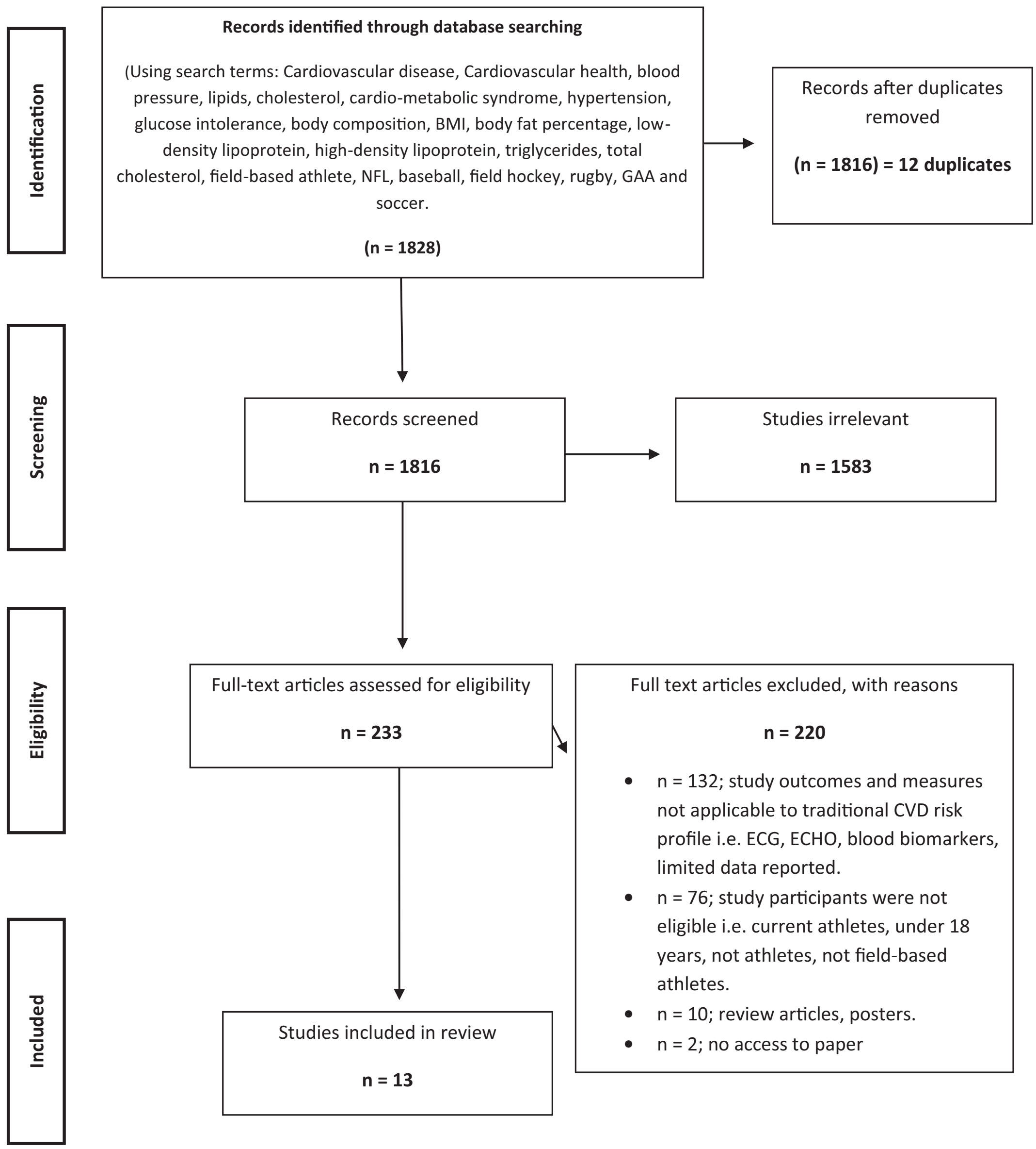

Figure 1. PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) flow diagram. BMI, body mass index; CVD, cardiovascular disease; ECG, electrocardiogram; ECHO, echocardiography; GAA, Gaelic Athletic Association; NFL, National Football League.

and insufficient data presented, and 2 were excluded because of no access to the full text. Overall, 13 studies were identified as relevant to cardiovascular health from 2 field-based sports (football and soccer).[‖]

Of the 13 relevant studies, 11 were cross-sectional, 1 observational, and 1 prospective in the study design. All participants were male and retired professional football (12/13)[¶] or professional soccer (1/13) players.[52] Twelve studies were conducted in the United States[#] and 1 in Greece[52] (Appendix Table A1). The included studies consisted of large (n = 948 athletes) and small (n = 12 athletes) cohorts. Studies compared athletes with age- and sex-matched controls, mainly derived from subsets of the following population cohorts: the National Health and Nutrition Examination Survey (longitudinal data collected in 1999-2006), the Coronary Artery Risk Development in Young Adults (CARDIA; study of cardiovascular risk development in young adults [n = 5116]), the Mayo Clinic (database of all patients who underwent a cardiovascular risk evaluation in 2006-2008), the Dallas Heart Study (DHS; probability-based cohort of Dallas County adults, oversampled for African Americans [n = 6101]), and the Aerobics Center Longitudinal Study (ACLS; longitudinal study of medical health). Participants were selected from a

[‖]References 1, 4, 7, 9, 30, 31, 34, 38, 39, 44, 52, 55, 69.
[¶]References 1, 4, 7, 9, 30, 31, 34, 38, 39, 44, 55, 69.
[#]References 1, 4, 7, 9, 30, 31, 34, 38, 39, 44, 55, 69.

TABLE 1
Critical Appraisal of Included Studies[a]

	Miller et al[44] (2008)	Panayiotoglou et al[52] (2017)	Basra et al[4] (2014)	Chang et al[9] (2009)	Hurst et al[30] (2010)	Hyman et al[31] (2012)	Albuquerque et al[1] (2010)	Carruthers et al[7] (2017)	Kelly et al[34] (2014)	Lynch et al[39] (2007)	Pokharel et al[55] (2014)	Virani et al[69] (2012)	Luyster et al[38] (2017)
Introduction													
Were the aims/objectives of the study clear?	N	Y	Y	Y	U	Y	N	N	Y	N	Y	Y	Y
Methods													
Was the study design appropriate for the stated aim(s)?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Was the sample size justified?	N	N	Y	Y	N	N	Y	N	N	N	N	N	Y
Was the target reference population clearly defined?	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Was the sample taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Y	Y	Y	Y	Y	N	Y	U	Y	Y	Y	Y	Y
Was the selection process likely to select participants who were representative of the target/reference population under investigation?	Y	Y	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y
Were there measures undertaken to address and categorize nonresponders?	N	N	N	N	N	N	U	N	Y	N	U	U	N
Were the risk factor and outcome variables measured appropriately to the aims of the study?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialed, piloted, or published previously?	Y	Y	Y	Y	Y	U	Y	U	Y	Y	Y	Y	Y
Is it clear what was used to determine statistical significance and/or precision estimates (eg, values, CIs)?	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y
Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y
Results													
Were the basic data adequately described?	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Does the response rate raise concern about nonresponse bias?	Y	Y	N	N	Y	Y	Y	U	N	Y	Y	N	N
If appropriate, was information about nonresponders described?	N	N	N	U	U	N	N	U	U	N	U	U	N
Were the results internally consistent?	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y
Were the results for the analyses described in the methods presented?	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Discussion													
Were the authors' discussions and conclusions justified by the results?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Were the limitations of the study discussed?	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Other													
Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	N	Y	N	N	N	N	N	N	N	N	N	N	N
Was ethical approval or consent of participants attained?	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y

[a]Colored text indicates the following: green, positive impact on quality of study; red, negative impact on quality of study; orange, unknown impact on quality of study. N, no; U, unsure; Y, yes.

subset of 5322 of a total 17,967 participants (Appendix Table A1).

An analysis was carried out to assess CVD risk factors according to the ESC and AHA guidelines to compare risk factors based on sport and playing position with control groups. The included studies evaluated cardiovascular health and the CVD risk in retired athletes under the following categories: body composition (BMI, body fat percentage, waist circumference, neck circumference, waist-to-hip ratio), blood pressure (BP), lipids (total cholesterol, high-density lipoprotein [HDL], low-density lipoprotein [LDL], triglycerides, total cholesterol/HDL ratio, triglyceride/HDL ratio), glucose, CMS,[23] CAC/carotid artery plaque (CAP),[22] and SDB.[64]

Body Composition

Eleven studies assessed BMI,[**] accounting for 3273 retired athletes (10 football, 1 soccer) with a mean BMI of 29.5 kg/m^2 (football: 31.7 kg/m^2; soccer: 27.3 kg/m^2). Football players had a greater mean BMI than controls.[1,7,9,38] Compared with controls, retired athletes had lower body fat percentages.[39,52] A lower waist circumference was reported for retired athletes compared with the DHS cohort, the CARDIA cohort, and a control group.[9,38,39] However, compared with the ACLS cohort, retired football players had a higher mean waist circumference (Table 2).[9] Conflicting waist-to-hip ratio findings were reported for retired football athletes.[9,39] The waist-to-hip ratio was found to be considerably lower for retired soccer players than for football players. Using BMI $\geq$30 kg/m^2, 67% of retired players were classified as obese compared with 10% when classifying body fat percentage $\geq$25% via dual-energy x-ray absorptiometry (DXA).[31]

A subgroup analysis found that retired linemen had elevated measures of body composition compared with retired nonlinemen: a higher BMI[4,30,38,44] and higher body fat percentages.[44] Conflicting findings were reported on the waist circumference between retired linemen and retired nonlinemen.[4,38]

Hypertension and Blood Pressure

A greater incidence of hypertension was reported in retired athletes compared with controls.[1,4,30,38] Retired linemen had a higher prevalence of hypertension compared with retired nonlinemen, although not significantly (Table 3).[4,30,38,44] Most studies found higher resting systolic BP in retired football players compared with controls (Table 3).[1,7,9,30,38,39] Conflicting findings were reported for the subgroup analysis in football players (Table 3).[4,30,38,44]

Lipid Profiles

Eleven studies analyzed measures of lipid profiles.[††] A greater prevalence of hyperlipidemia was reported for retired athletes compared with controls and population norms.[9,30] The mean total cholesterol for retired athletes was 194.3 mg/dL. Mixed findings were reported for mean total cholesterol for retired athletes compared with control groups; 3 studies reported lower values[1,9,30] and 3 reported higher values (Table 3).[9,38,39] Most studies examining retired football athletes found higher HDL values compared with controls.[1,7,9,30,38,39] The mean LDL for retired football and soccer players was 123.9 mg/dL and 134 mg/dL, respectively, both above recommended levels.[1,4,9,21,30,38,39,55,69] All studies reported higher LDL values for retired athletes compared with controls.[1,9,30,38,39] Five of 6 studies reported lower triglyceride values in retired athletes.[1,9,30,39,52] One of 3 studies investigating the total cholesterol/HDL ratio reported lower values in retired athletes compared with controls.[30,39,52]

A subgroup analysis based on prior playing position for football showed that retired linemen had higher total cholesterol values in 3 studies[4,30,44] and equal values in 1 study.[38] Four studies found higher HDL values in retired linemen compared with nonlinemen.[4,30,38,44] Conflicting findings for LDL were reported; 2 reported higher values for nonlinemen,[4,30] and 1 showed higher values for linemen (Table 3).[38] Inconsistencies were found for triglyceride levels; 2 studies reported higher levels for linemen,[30,44] and 2 reported higher levels for nonlinemen.[4,38]

Glucose

The prevalence of diabetes was reported to be between 7% and 8%.[1,4,9,31,44,55,69] Conflicting reports on fasting glucose were reported for retired football players; 3 studies found lower values for retired football players, and 2 found higher levels compared with comparators.[1,9,30,38,39] Higher glucose values were reported for former linemen compared with nonlinemen.[4,30,38,44]

Biomarkers

Four studies measured high-sensitivity C-reactive protein (hs-CRP).[4,9,55,69] Chang et al[9] reported conflicting findings: lower values in retired athletes compared with the DHS cohort but higher values compared with the ACLS cohort. Two studies found no association between hs-CRP levels and CAP or subclinical atherosclerosis.[4,69] hs-CRP was found to be significantly higher in retired National Football League (NFL) players with pre-existing CMS.[69]

Cardiometabolic Syndrome

Six studies reported on the prevalence of CMS in retired football players.[4,9,30,34,44,55] A substantial variance was found, ranging from 19.7% to 50%. Compared with the DHS cohort, a significantly lower incidence of CMS was reported; however, compared with the ACLS cohort and controls, a higher prevalence was reported for retired football players.[4,9] Retired linemen had almost double the prevalence of CMS compared with nonlinemen (Table 3).[4,30,44] Three of the component criteria, BMI $\geq$30 kg/m^2, reduced HDL cholesterol, and raised fasting glucose, were

**References 1, 4, 7, 9, 30, 34, 38, 39, 44, 52, 55.
††References 1, 4, 7, 9, 30, 38, 39, 44, 52, 55, 69.

TABLE 2
Body Composition Measures[a]

Author (Year)	BMI, kg/m^2	WC/NC, cm	BF%	WHR
Miller et al[44] (2008)	LM vs NLM: 34.9 (4.9) vs 30.7 (4.0)[b]		LM vs NLM: 31.4% vs 27.4%[b] BF% >28%: LM vs NLM: 111 (67.7%) vs 145 (41.9%)[b]	
Panayiotoglou et al[52] (2017)	Soccer vs control: 27.3 ± 2.8 vs 27.4 ± 2.7, NS		Soccer vs control: 24.5 ± 4.5 vs 27.0 ± 3.9, NS	Soccer vs control: 0.96 ± 0.05 vs 0.97 ± 0.01, NS
Basra et al[4] (2014)	LM vs NLM: 33.6 (30.5-37.9) vs 30.3 (27.7-33.0)[b]	LM vs NLM: 109.2 (99.1-119.4) vs 99.1 (91.4-106.6)[b]		
Chang et al[9] (2009)	NFL vs DHS: 31.5 ± 4.2 vs 31.4 ± 4.0, NS NFL vs ACLS: 31.7 ± 4.7 vs 28.6 ± 3.1[b]	NFL vs DHS: 103.8 ± 11.5 vs 107.4 ± 10.9, NS NFL vs ACLS: 105.7 ± 12.7 vs 98.4 ± 8.9[b]		NFL vs DHS: 1.08 ± 0.85 vs 0.98 ± 0.05[b] NFL vs ACLS: 1.06 ± 0.73 vs 0.93 ± 0.05[b]
Hurst et al[30] (2010)	NFL vs Mayo: 31.5 ± 4.5 vs 31.0 ± 2.7, NS LM vs NLM: 34.2 ± 4.5 vs 30.5 ± 4.0[b]			
Hyman et al[31] (2012)	BMI ≥30 = 89 (67%) BMI correlated with LM[b]		BF% ≥25% = 13 (10%)	
Albuquerque et al[1] (2010)	NFL vs control: 32.3 ± 0.3 vs 30.0 ± 0.1[b]			
Carruthers et al[7] (2017)	NFL vs DHS: 32.5 (5.4) vs 29.3 (5.4)[b]			
Kelly et al[34] (2014)	33.8 ± 6 BMI = 30: 45 (66.2%)			
Lynch et al[39] (2007)	NFL vs control: 29.4 ± 2.8 vs 30 ± 3, NS	NFL vs control: 101.2 ± 6.8 vs 106.1 ± 8.0, NS	NFL vs control: 23 ± 4 vs 32 ± 7[b]	NFL vs control: 0.95 ± 0.05 vs 0.98 ± 0.06, NS
Pokharel et al[55] (2014)	31 (29-35)	WC: 40 (37-44) NC: 17 (16-18)		
Virani et al[69] (2012)		WC: 39.4 ± 10.6		
Luyster et al[38] (2017)	NFL vs CARDIA: 30.3 ± 3.8 vs 29.9 ± 4.0, NS LM vs NLM: 29.8 ± 2.9 vs 30.5 ± 4.1, NS BMI ≥30: NFL vs CARDIA: 60 (49.2%) vs 51 (41.8%), NS BMI ≥30: LM vs NLM: 13 (38.2%) vs 47 (53.4%), NS	NFL vs CARDIA: 95.2 ± 22.0 vs 98.1 ± 10.2, NS LM vs NLM: 92.6 ± 19.7 vs 96.2 ± 22.8, NS		

[a]Data are reported as mean ± SD, median (interquartile range), or n (%). ACLS, Aerobics Center Longitudinal Study; BF%, body fat percentage; BMI, body mass index; CARDIA, Coronary Artery Risk Development in Young Adults; DHS, Dallas Heart Study; LM, linemen; Mayo, Mayo Clinic; NC, neck circumference; NFL, National Football League; NLM, nonlinemen; NS, not significant; WC, waist circumference; WHR, waist-to-hip ratio.
[b]$P < .001$.

significantly greater in retired linemen compared with nonlinemen.[44]

CAC/CAP

Three studies found a similar prevalence and severity of CAC between retired athletes and controls.[7,9,38] When controlled for ethnicity, no difference in CAC between retired players and the DHS cohort was reported (white: 67.2% vs 57.4%, respectively; African American: 31.5% vs 42.1%, respectively).[9] Conflicting findings were reported for the subgroup analysis of football players. Two studies reported a greater prevalence of CAC/CAP for nonlinemen.[30,38] However, Miller et al[44] reported that retired linemen were less likely to have an absence of CAC, a similar likelihood of mild CAC, and a greater likelihood of moderate to severe CAC compared with nonlinemen (Table 3). Furthermore, after adjusting for demographic and metabolic covariates, the lineman playing position remained independently associated with mild (odds ratio, 1.41 [95% CI, 1.05-2.2]) and moderate to severe (odds ratio, 1.67 [95% CI, 1.05-2.2]) subclinical atherosclerosis.[4]

Sleep-Disordered Breathing

A limited number of studies analyzed SDB. A self-reported presence of obstructive sleep apnea in retired football players was reported between 41% and 53%.[1,31] One study

TABLE 3
Risk Factors for Cardiovascular Disease[a]

Author (Year)	Blood Pressure	Lipids, mg/dL	CAC	CMS
Miller et al[44] (2008)	LM vs NLM: HT: 41 (25%) vs 71 (20.5%), NS SBP: 137.1 (21.3) vs 131.9 (17.4)[b] DBP: 79.2 (13.3) vs 78.5 (11.4), NS	LM vs NLM: HDL: 44.5 (14.2) vs 47.6 (14.9)[c] TC: 189.1 (43.9) vs 195.6 (38.6), NS TG: 128.5 (79.8) vs 116.1 (70.8), NS		LM vs NLM: 98 (59.8%) vs 104 (30.1%)[d] BMI ≥30: 140 (85.4%) vs 174 (50.3%)[d] Raised blood pressure: 111 (67.7%) vs 212 (61.3%), NS Reduced HDL: 69 (42.1%) vs 113 (32.7%), NS Raised fasting glucose: 99 (60.4%) vs 130 (37.6%)[d] Raised TG: 51 (31.1%) vs 83 (24.0%), NS
Panayiotoglou et al[52] (2017)		Soccer vs control: TG (mM): 1.1 ± 0.2 vs 1.6 ± 0.8, NS		
Basra et al[4] (2014)	LM vs NLM: HT: 38.8% vs 28.5%[b] SBP: 131 (122-144) vs 130 (120-143), NS	LM vs NLM: HDL: 45 (39-55.8) vs 48 (40-57)[b] LDL: 117.5 (98-143) vs 127 (104-151.8)[d] TC: 190 (167.5-214) vs 198 (173-227)[c] TG: 88 (62-141) vs 91 (66-140.5), NS	LM vs NLM: CAC = 0: 105 (33.88%) vs 259 (41.70%)[c] CAC = 1-100: 103 (33.22%) vs 198 (31.88%), NS CAC >100: 102 (32.90%) vs 164 (26.41%)[c]	LM vs NLM: 25.8% vs 16.5%[d]
Chang et al[9] (2009)	NFL vs DHS: SBP: 127.6 ± 16.7 vs 135.6 ± 17.0[d] DBP: 77.3 ± 11.2 vs 82.5 ± 10.4[d] NFL vs ACLS: SBP: 129.2 ± 17.0 vs 129 ± 16, NS DBP: 77.5 ± 11.1 vs 85.0 ± 9.8[d]	NFL vs DHS: HDL: 50.8 ± 16.8 vs 43.7 ± 10.9[d] LDL: 128.5 ± 36.0 vs 107.7 ± 37.5[d] TC: 197.8 ± 42.1 vs 176.8 ± 40.1[d] TG: 81 (61-115) vs 111 (74-160)[d] NFL vs ACLS: HDL: 49.4 ± 17.0 vs 46.4 ± 11.5, NS LDL: 126.0 ± 36.2 vs 124.7 ± 37.2, NS TC: 192.9 ± 41.9 vs 204.0 ± 41.6[d] TG: 83.5 (61-122) vs 127.5 (92-177)[d]	NFL vs DHS: 46.0% vs 48.3%, NS No statistically significant difference across CAC values for all groups	NFL vs DHS: significantly lower percentage of retired players with CMS compared with controls[c] NFL vs ACLS: 39.5% vs 23.0%[d]
Hurst et al[30] (2010)	NFL vs Mayo: HT: 38 (19%) vs 6 (7%) SBP: 128.7 ± 16.4 vs 123.7 ± 13.8[b] DBP: 78.7 ± 10.9 vs 78.4 ± 8.2, NS LM vs NLM: HT: 12 (20%) vs 9 (6%)[c] SBP: 128.8 ± 16.9 vs 128.6 ± 16.2, NS DBP: 79.2 ± 13.1 vs 78.6 ± 9.9, NS	NFL vs Mayo: HDL: 40.9 ± 16.5 vs 50.1 ± 13.5, NS LDL: 131.3 ± 25.6 vs 126.4 ± 35.5, NS TC: 198.8 ± 40.8 vs 207.2 ± 40.1, NS TG: 102.6 ± 64.6 vs 162.2 ± 128.3[d] LM vs NLM: HDL: 45.4 ± 18.4 vs 50.5 ± 15.6[c] LDL: 127.5 ± 30.1 vs 132.8 ± 37.7, NS TC: 197.7 ± 37.0 vs 199.2 ± 42.5, NS TG: 120.5 ± 64.4 vs 95.1 ± 63.4[b]	NFL vs Mayo: CAP: 67 (33%) vs 36 (29%), NS LM vs NLM: CAP: 16 (27%) vs 51 (36%), NS	LM vs NLM: 27 (46%) vs 32 (23%)[d]

(continued)

TABLE 3 (continued)

Author (Year)	Blood Pressure	Lipids, mg/dL	CAC	CMS
Hyman et al[31] (2012)	HT: 55 (42.6%)			
Albuquerque et al[1] (2010)	NFL vs control: HT: 37.8% vs 21.4%[d] SBP: 133.5 ± 1.1 vs 126.5 ± 0.5[d] DBP: 80.0 ± 0.7 vs 72.7 ± 0.3[d]	NFL vs control: HDL: 44 ± 0.8 vs 47 ± 0.3[d] LDL: 121.4 ± 2.3 vs 117.0 ± 1.3, NS TC: 183.4 ± 4.1 vs 195.3 ± 1.5, NS TG: 149.8 ± 12.7 vs 168.0 ± 4.7[d]		
Carruthers et al[7] (2017)	NFL vs DHS: SBP: 136.1 (17.2) vs 132.7 (17.0)[c]	NFL vs DHS: HDL: 55.9 (16.6) vs 48.9 (12.9)[d]	NFL vs DHS: CAC (median [95% CI]): 0.5 (0-45.2) vs 1.8 (0-73), NS <5% risk: CAC = 0: 23 (60%) vs 120 (64%), NS CAC = 1-100: 12 (32%) vs 56 (30%) CAC >100: 3 (8%) vs 11 (6%) 5%-7.5% risk: CAC = 0: 15 (65%) vs 61 (48%)[c] CAC = 1-100: 3 (13%) vs 53 (41%) CAC >100: 5 (22%) vs 14 (11%) >7.5% risk: CAC = 0: 14 (32%) vs 83 (27%)[b] CAC = 1-100: 21 (49%) vs 116 (38%) CAC >100: 8 (19%) vs 104 (34%)	
Kelly et al[34] (2014)				34 (50%)
Lynch et al[39] (2007)	NFL vs control: SBP: 130 ± 19 vs 133 ± 20, NS DBP: 79 ± 8 vs 82 ± 13, NS	NFL vs control: HDL (mM): 1.30 ± 0.23 vs 0.95 ± 0.19[d] LDL (mM): 3.10 ± 0.48 vs 3.04 ± 0.61, NS TC (mM): 4.93 ± 0.52 vs 4.75 ± 0.76, NS TG (mM): 1.17 ± 0.69 vs 1.71 ± 0.67[c]		
Pokharel et al[55] (2014)	HT: 267 (32%) SBP: 130 (121-142) DBP: 80 (74-87)	HDL: 47 (39-56) LDL: 125 (103-148) TC: 196 (171-223) TG: 89 (64-141)		
Virani et al[69] (2012)	HT: 309 (34.7%)	HDL: 49 ± 14 LDL: 127 ± 38 TC: 199 ± 41 TG: 89 ± 77	CAP detected in 41% of players	187 (19.7%)

(continued)

TABLE 3 (continued)

Author (Year)	Blood Pressure	Lipids, mg/dL	CAC	CMS
Luyster et al[38] (2017)	NFL vs CARDIA: HT: 36 (29.5%) vs 35 (28.7%), NS SBP: 125.3 ± 13.9 vs 120.4 ± 13.2[b] DBP: 80.1 ± 10.3 vs 75.0 ± 11.2[d] LM vs NLM: HT: 9 (26.5%) vs 27 (30.7%), NS SBP: 124.6 ± 16.9 vs 125.6 ± 12.7, NS DBP: 81.4 ± 9.7 vs 80.0 ± 9.7, NS	NFL vs CARDIA: HDL: 49.9 ± 11.5 vs 44.9 ± 12.0[d] LDL: 126.5 ± 39.7 vs 110.5 ± 31.7[d] TC: 197.9 ± 43.5 vs 183.4 ± 35.9[b] TG: 140.3 ± 96.5 vs 140.2 ± 92.4[c] LM vs NLM: HDL: 47.9 ± 11.9 vs 50.8 ± 11.3, NS LDL: 135.0 ± 48.7 vs 122.9 ± 34.9, NS TC: 198.1 ± 55.8 vs 197.9 ± 37.6, NS TG: 105.3 ± 75.1 vs 120.5 ± 104.3, NS	NFL vs CARDIA: CAC presence: 37 (30.3%) vs 37 (30.3%), NS CAC distribution: NS CAC = 0: 87 (71.3%) vs 87 (71.3%) CAC = 1-99.99: 29 (23.8%) vs 28 (23%) CAC ≥100: 6 (4.9%) vs 7 (5.7%) LM vs NLM: CAC presence: 8 (23.5%) vs 29 (33.0%), NS	

[a]Data are reported as mean ± SD, median (interquartile range), or n (%). ACLS, Aerobics Center Longitudinal Study; BMI, body mass index; CAC, coronary artery calcium; CAP, carotid artery plaque; CARDIA, Coronary Artery Risk Development in Young Adults; CMS, cardiometabolic syndrome; DBP, diastolic blood pressure; DHS, Dallas Heart Study; HDL, high-density lipoprotein; HT, hypertension; LDL, low-density lipoprotein; LM, linemen; Mayo, Mayo Clinic; NFL, National Football League; NLM, nonlinemen; NS, not significant; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride.

[b]$P < .01$.

[c]$P < .05$.

[d]$P < .001$.

reported that retired football players had double the prevalence of high-risk sleep apnea compared with the CARDIA cohort.[38] Retired soccer players reported fewer days of snoring per week than controls.[52]

Smoking

Retired athletes were reported to have a lower prevalence of smoking (past or present) in all studies.[1,7,9,30,38,44,52] Conflicting findings were identified based on playing position in football. Two studies reported a lower prevalence of smoking history in linemen compared with nonlinemen,[38,44] whereas 1 study reported a greater prevalence in linemen.[30]

Meta-analysis

A meta-analysis using random effects and a sensitivity analysis indicated that the overall effect of prior engagement in football had a positive effect on fasting glucose levels, finding a mean difference of –4.66 (95% CI, –7.71 to –1.62; $I^2 = 55\%$) when compared with controls (Figure 2). Prior engagement in football had a negative effect on systolic BP, with a mean difference of 3.07 (95% CI, 0.78-5.36; $I^2 = 44\%$) in favor of controls (Figure 3). A wide confidence interval was identified for triglycerides of athletes; a mean difference of –19.07 (95% CI, –34.96 to –3.19; $I^2 = 59\%$) in favor of retired athletes was found for triglycerides (Figure 4). Retired players had a higher mean LDL value compared with control groups, with a mean difference of 5.00 (95% CI, 1.54-8.47; $I^2 = 42\%$) (Figure 5).

Risk of Bias

Studies were critically appraised using the AXIS tool (Table 1).[14] Overall, studies were of moderate quality, with common issues identified in several domains. Where an “unsure” response was assigned, it was most commonly associated with a lack of clarity in reporting. Many studies did not provide justification for the sample size because of their cross-sectional and observational study design. Studies did not address the issue of nonresponders, provide information, or categorize. Samples of convenience were most commonly sought, and it was not addressed how representative these samples were to the true population.

DISCUSSION

This review evaluated 13 studies examining the cardiovascular health profile of retired field-based athletes. The variance in study objectives provides a broad understanding of the cardiovascular health and CVD risk profile of retired contact-sport athletes and how this compares with the general population.

The synthesis of the studies suggests that retired athletes with an elevated BMI have a similar risk for future adverse cardiovascular events to obese nonathletes from the general population. The Framingham study in 2008 indicated that men and women who are obese have a lifetime risk of CVD of 66.8% and 46.7%, respectively.[18] Obesity as measured by BMI was common among retired

Study or Subgroup	Retired athletes Mean	SD	Total	Controls Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Hurst 2010	102.6	64.4	200	162.2	128.3	122	0.0%	-59.60 [-84.05, -35.15]
Lynch 2007	103.5	61	16	151.3	59.2	16	11.2%	-47.80 [-89.45, -6.15]
Panayiotoglou 2017	97.3	17.6	12	141.5	70.7	12	11.4%	-44.20 [-85.42, -2.98]
Albuquerque 2010	149.8	12.7	257	168	4.7	1539	48.0%	-18.20 [-19.77, -16.63]
Luyster 2017	140.3	96.5	108	140.2	9.4	122	29.4%	0.10 [-18.18, 18.38]
Total (95% CI)			**393**			**1689**	**100.0%**	**-19.07 [-34.96, -3.19]**

Heterogeneity: Tau² = 136.13; Chi² = 7.32, df = 3 (P = 0.06); I² = 59%
Test for overall effect: Z = 2.35 (P = 0.02)

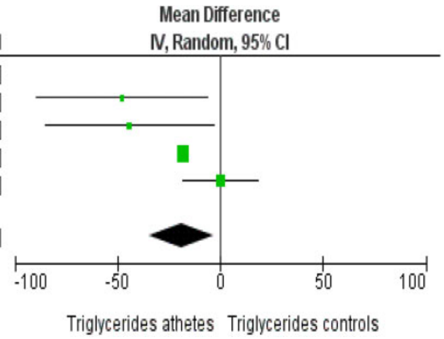

Figure 2. Forest plot of systolic blood pressure. IV, instrumental variable.

Study or Subgroup	Retired Athletes Mean	SD	Total	Controls Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Albuquerque 2010	133.5	1.1	257	126.5	0.5	1539	0.0%	7.00 [6.86, 7.14]
Carruthers 2017	136.1	17.2	104	132.7	17	618	22.2%	3.40 [-0.17, 6.97]
Chang 2009	129.2	17	200	129	16	400	27.8%	0.20 [-2.63, 3.03]
Chang 2009b	127.6	16.7	150	135.6	17	150	0.0%	-8.00 [-11.81, -4.19]
Hurst 2010	128.7	16.4	201	123.7	13.8	122	23.9%	5.00 [1.66, 8.34]
Luyster 2017	125.3	13.9	122	120.4	13.2	122	23.4%	4.90 [1.50, 8.30]
Lynch 2007	130	19	16	133	20	16	2.7%	-3.00 [-16.52, 10.52]
Total (95% CI)			**643**			**1278**	**100.0%**	**3.07 [0.78, 5.36]**

Heterogeneity: Tau² = 2.84; Chi² = 7.14, df = 4 (P = 0.13); I² = 44%
Test for overall effect: Z = 2.62 (P = 0.009)

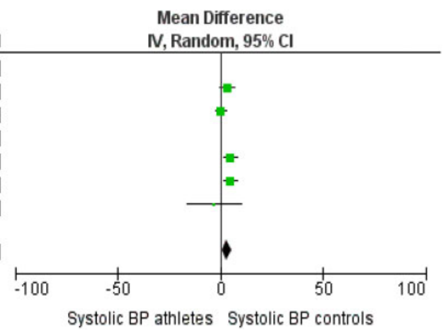

Figure 3. Forest plot of glucose. IV, instrumental variable.

Study or Subgroup	Retired athletes Mean	SD	Total	Controls Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Luyster 2017	89.4	36.4	122	101.7	19.6	122	12.2%	-12.30 [-19.64, -4.96]
Chang 2009b	101.4	14.1	150	110.4	47.7	150	10.9%	-9.00 [-16.96, -1.04]
Albuquerque 2010	101.1	1.8	257	109.6	1	1539	0.0%	-8.50 [-8.73, -8.27]
Hurst 2010	97.8	10.5	201	102.1	7.8	118	35.6%	-4.30 [-6.32, -2.28]
Chang 2009	102.3	17	200	104.5	20.5	400	29.4%	-2.20 [-5.30, 0.90]
Lynch 2007	97.2	10.8	16	97.2	10.8	16	11.9%	0.00 [-7.48, 7.48]
Total (95% CI)			**689**			**806**	**100.0%**	**-4.66 [-7.71, -1.62]**

Heterogeneity: Tau² = 5.72; Chi² = 8.89, df = 4 (P = 0.06); I² = 55%
Test for overall effect: Z = 3.00 (P = 0.003)

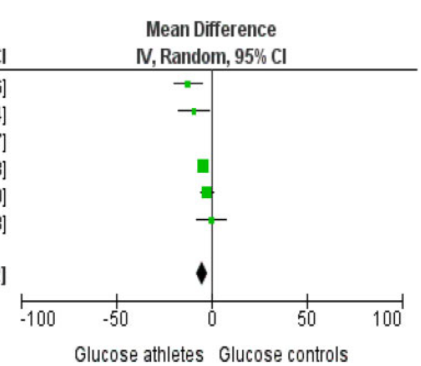

Figure 4. Forest plot of triglyceride. IV, instrumental variable.

Study or Subgroup	Retired athletes Mean	SD	Total	Controls Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chang 2009	126	36.2	200	124.7	37.2	400	19.3%	1.30 [-4.90, 7.50]
Lynch 2007	119.6	18.5	16	117.3	23.5	16	5.0%	2.30 [-12.35, 16.95]
Albuquerque 2010	121.4	2.3	257	117	1.3	1539	50.1%	4.40 [4.11, 4.69]
Hurst 2010	131.3	25.6	176	126.4	35.5	116	15.0%	4.90 [-2.59, 12.39]
Luyster 2017	126.5	39.7	107	110.5	31.7	118	10.6%	16.00 [6.55, 25.45]
Chang 2009b	128.5	36	150	107.7	37.5	150	0.0%	20.80 [12.48, 29.12]
Total (95% CI)			**756**			**2189**	**100.0%**	**5.00 [1.54, 8.47]**

Heterogeneity: Tau² = 6.22; Chi² = 6.84, df = 4 (P = 0.14); I² = 42%
Test for overall effect: Z = 2.83 (P = 0.005)

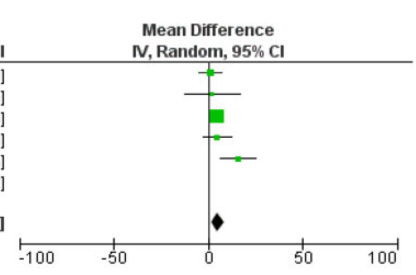

Figure 5. Forest plot of low-density lipoprotein (LDL). IV, instrumental variable.

football players and was found to be more prevalent in 5 of 6 studies (83%) compared with comparators.[1,7,9,30,38] There is an argument that because BMI does not consider the increased muscle mass in current athletes, as a measure of body composition, BMI may overestimate the prevalence of obesity in current athletes. Despite a 3-fold greater engagement in physical activity during young adulthood (20-34 years), after the age of 65 years, former athletes (66 ± 6 years) and sedentary individuals (67 ± 5 years) have similar levels of physical activity.[39] The errors associated with using BMI during an active athletic career are most likely not as significant during retirement; therefore, using BMI as a measure of obesity during retirement is more appropriate, as epidemiological research has consistently reported an increased risk of cardiovascular death with increased BMI.[13,35,51,57]

Retired linemen were found to have elevated measures of body composition compared with nonlinemen in all but 1 study.[4,30,38,44] Luyster et al[38] suggested that at an average of 25 years after retirement, nonlinemen have an equal probability of becoming obese to that of linemen. Similarly, Miller et al[44] reported that 50% of retired nonlinemen had a BMI $\geq$30 kg/m^2. The mean age of retired NFL players was 57.1 years, falling in line with the estimated 37.7% prevalence of obesity (BMI $\geq$30 kg/m^2) in male patients between the ages of 40 and 59 years from the general population.[19] Despite known limitations, BMI remains the most widely used measure of obesity, with 92% (12/13) of studies in this review applying it. It is postulated that waist circumference and waist-to-hip ratio are more accurate indicators of obesity and future risk of CVD for athletes than BMI.[8,41] Interestingly, when matched for BMI, both Luyster et al[38] and Chang et al[9] (DHS) reported a lower waist circumference.

This highlights the need for more reliable measures of body composition beyond BMI, waist circumference, and waist-to-hip ratio, such as DXA. DXA provides an in-depth analysis of body composition, identifying lean mass, fat mass, and visceral adipose tissue (VAT). In current field-based athletes, an elevated BMI often reflects greater lean muscle mass.[2,20,33,37,46] Findings from this review suggest that the same may not be the case in retired players. This generates speculation that persistent reporting of an elevated BMI found in retired athletes reflects an increase in fat mass compared with the increased lean mass found in current athletes. No study analyzed VAT in this review. Epidemiological research has consistently reported links between VAT and systemic inflammation.[16,53,63,76] It remains unclear if an elevated BMI during retirement diminishes the benefits gained from an individual's past elite athleticism.

The cause of the long-term risk of elevated BP and hypertension in retired field-based athletes is unclear. In current football athletes, there is an increased prevalence of hypertension (13.8%) compared with age- and sex-matched controls (5.5%).[68] A 1994 study by the NIOSH reported that deaths among linemen were almost exclusively attributable to hypertension and ischemic heart disease.[3] According to the AHA, the risk of death from ischemic heart disease and stroke doubles with every 20–mm Hg systolic BP increase or 10–mm Hg diastolic BP increase among people aged 40 to 89 years.[72] The mean systolic BP was 130.6 mm Hg in this review, 10 mm Hg above recommended target levels.[6,72]

Where elevated BP was reported, concomitant increases in body composition were typically reported.[1,7,30] When matched for BMI, results on BP are conflicting. Compared with the DHS cohort, retired football players had lower BP[9]; however, Hurst et al[30] and Luyster et al[38] reported higher BP. No study controlled for smoking, alcohol intake, or dietary intake; therefore, it was not possible to identify the cause of higher mean BP in retired players. Furthermore, studies comparing retired NFL players based on positions reported similar or increased BP for linemen.[4,30,38,44]

This finding suggests that body composition in linemen might offset some benefits of exercise on BP. In retired soccer players, the mean BMI was $\leq$30 kg/m^2 (27.3 kg/m^2); however, according to the European Society of Hypertension guidelines,[15] 66% had BP exceeding the upper range of grade 1 hypertension. This corresponds to statistics from age- and sex-matched individuals from the general population.[73] While nonlinemen overall had a statistically similar BMI to linemen (29.8 vs 30.5 kg/m^2, respectively) but a greater percentage of African American athletes (47.7% vs 26.4%, respectively; P = .03), the incidence of hypertension was higher for nonlinemen (26.5% vs 30.7%, respectively).[38] The meta-analysis identified moderate statistical heterogeneity (I^2 = 44%) (Figure 3). A possible cause for the high level of heterogeneity in these studies is the significant difference in smoking history and BMI between retired players and controls, along with measures that were not controlled for.

An increased prevalence of hyperlipidemia and fasting glucose in retired linemen was reported in 2 studies.[9,30] Results were conflicting for LDL and HDL concentrations.[1,7,9,30,38,39,52] Higher levels of HDL in retired athletes coincided with higher levels of total cholesterol.[7,9,38,39] This may be attributed to their physically active and high caloric diet past. Where lower levels of HDL were reported in retired players, elevated measures of body composition were reported.[1,30] This suggests that size matters, and early cardiovascular risk factor screening and maintenance of physical activity levels in early retirement are needed.[1,9,30,44] Multiple studies reported that hyperlipidemia is associated with coronary atherosclerosis, CAP, and CMS.[9,39,44,69] All studies reported that retired players had a higher LDL concentration compared with controls; this may be caused by a high caloric diet during their career or the change in body composition that occurs during retirement.[1,9,30,38,39] Increasing body fat percentage coincides with a decrease in physical activity levels, similar to that of obese sedentary controls after the age of 65 years.[39]

A lower prevalence of diabetes was reported for retired athletes, despite the indication of a 3-fold higher prevalence of impaired fasting glucose.[1,9,38] When stratified by ethnicity, African American athletes had a significantly greater prevalence of impaired fasting glucose, whereas white athletes failed to reach significance.[9] The high percentage of African American athletes in retired football player groups provides a possible understanding for the difference in impaired fasting glucose levels between retired athletes and controls, warranting further investigations. All studies reported linemen to have a higher impaired fasting glucose concentration than nonlinemen.[4,30,38,44] Although the cardiovascular risks affiliated with CMS and increased body size are inevitable during early retirement, engagement in physical activity during a professional sporting career may slow the progression from impaired fasting glucose to diabetes mellitus and decreases the risk of developing an atherogenic lipoprotein profile. An initial meta-analysis of glucose identified a high level of heterogeneity ($I^2 = 86\%$). The removal of the study by Albuquerque et al[1] reduced heterogeneity to a moderate level ($I^2 = 55\%$), indicating a significantly lower level of fasting glucose for retired players. However, insufficient methodological information prevents an investigation into possible causes.

CMS, an established risk factor for CVD,[54] was shown to be highly prevalent among retired athletes.[34,44,52,55] The lineman position was associated with, and in some studies doubled, its prevalence compared with nonlinemen and comparators.[4,30,44] Three components of CMS, BMI $\geq$30 kg/m^2, increased fasting glucose, and decreased HDL, were significantly more prevalent in linemen.[44] This is further supported by an association between CMS and increased weight gain.[9,52] Athletes playing in the lineman position are exposed to an increased likelihood of developing CMS after retirement. However, the classification of CMS may overestimate the cardiovascular risk in larger retired players, as previously discussed; BMI is a poor indicator of body composition in this cohort.[50] The mean age of retired athletes in this review was 57.1 years; therefore, it is debatable how long into retirement BMI remains an inapplicable measure because of prior elite athleticism. Identification of the high prevalence in retired athletes is important, as many of the components of CMS are reversible with lifestyle changes, physical activity, and diet.

As measures of subclinical atherosclerosis, CAP and CAC are strongly and independently associated with adverse cardiovascular events.[5,74] Despite high levels of physical activity throughout their athletic career, after retirement, former athletes have a prevalence and distribution of subclinical atherosclerosis similar to those of the general population matched for age, sex, and BMI.[7,9,30,38,39] The presence of CAP and CAC is a sign of advanced atherosclerosis and has significant diagnostic implications. The prevalence of CAC was consistently reported in at least one-third of retired players.[9,30,38,55] CAC <100 was present in 76% of retired players, posing a concern[9]; the risk of an adverse cardiovascular event increases several-fold higher with CAC $\geq$100.[10] Retired linemen were more likely to have a moderate to severe presence of CAC and less likely to have an absence of CAC compared with nonlinemen.[4,30] Possible explanations for a higher risk of moderate to severe CAC include an increased prevalence of obesity, hypertension, CMS, and SDB. However, it is difficult to rule out factors beyond those measured in these studies, including but not limited to steroid use, race, and socioeconomic status. These findings suggest that former athletes have not benefited from their athletic past, despite the well-documented cardioprotective benefits associated with prolonged engagement in exercise.[47]

Limited data suggest that obstructive sleep apnea may be more prevalent after retirement, possibly explained by the previously discussed elevated BMI and increased prevalence of obesity.[1,31,38] Retired soccer players' lower mean BMI of 27.3 kg/m^2 was associated with a lower incidence of obstructive sleep apnea compared with controls and retired football players.[52] However, Luyster et al[38] reported that despite similar levels of obesity, the sleep apnea risk was twice that for retired football players compared with controls, giving plausibility to other possible causes for an increased prevalence, beyond BMI.

This review is limited by several factors. First, studies included were cross-sectional, observational, or prospective; therefore, inferences on temporality and causality cannot be made from the observed findings. Results should be viewed as hypothesis generating only. Second, 12 of the 13 studies included were based on retired football players; therefore, caution is needed when interpreting conclusions to all retired field-based athletes. It is worth noting that all studies included male athletes who were retired from professional sports; therefore, the applicability to amateur and female athletes is limited. A high proportion of retired athletes, primarily football players, were African American, limiting the generalizability of results. Caution is needed when interpreting findings, given the disproportionate percentage of African American retired football players who have a higher predisposition for increased BP and hypertension.[40] Because of the limited amount of research in this area, a control group was not implemented into our inclusion criteria to widen the number of studies that could be analyzed. All studies recruited participants from open health screening events, allowing for self-selection bias; however, this applies to all participants: linemen, nonlinemen, and retired soccer players. There are possible unknown causes for findings; for example, the previous use of anabolic androgenic steroids could have multiple deleterious effects on the cardiovascular system, altering lipid profiles, promoting atherosclerosis, enhancing thrombogenesis, and altering body composition.

Other possible confounding factors include years in retirement, diet, alcohol use, socioeconomic status, education, genetics, and medication use. The use of self-reported screening tools for obstructive sleep apnea without objective assessments precludes the confirmation that participants who scored in the high-risk range had obstructive sleep apnea. Therefore, the proportion of high-risk participants may be overestimated or underestimated. Finally, it was difficult to acquire a similar comparator population. The general population and cohorts from larger studies were used; however, not all studies matched controls for ethnicity, race, and body composition.

CONCLUSION

There is inconsistency in the screening and reporting of CVD risk factors in retired field-based athletes. Most studies have focused on retired football players, with only 1 study examining retired soccer players. There is a need for research in field-based athletes from other sports, particularly in sports that emphasize a greater body mass. There is also a need for research on cardiovascular risks in female athletes from similar sports. This current synthesis of studies has demonstrated that heavier retired field-based athletes are at a risk of elevated BP, hypertension, increased LDL, SDB, CMS, and the development of CAP and CAC. It can be inferred that this risk is comparable with obese nonathlete counterparts. BMI might not be an appropriate measurement of cardiovascular health in retired field-based athletes, and other measures of body composition may be more valuable. Further research is needed, focusing on retired athletes of other field-based sports such as rugby, hockey, and soccer, as well as retired female athletes, to gain clear insight into the cardiovascular health of all field-based sports.

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APPENDIX

TABLE A1
Study Details[a]

Author (Year)	Study Design	Primary Aims	Setting	Participants	Variables	Risk Factor Prevalence
Miller et al[44] (2008)	Cross-sectional prevalence	To assess the prevalence of CMS in athletes; to assess the prevalence of CMS based on playing position	Living Heart Foundation health screening, 2004-2006	NFL; n = 510; male; mean age: 53.8 y; sex-matched controls from NHANES; LM vs NLM	BMI, BF%, SBP, DBP, HT, TC, TG, HDL, LDL, fasting glucose, CMS, smoking, DM	CMS was more prevalent in LM than NLM (59.8% vs 30.1%, respectively; P = .001); elevated BMI and impaired fasting glucose and reduced HDL were more prevalent in LM than NLM
Panayiotoglou et al[52] (2017)	Cross-sectional case-control	To determine the risk and prevalence of CMS in retired professional soccer players	Greece	Soccer; n = 12; male; mean age: 46.7 y; age-, sex-, and BMI-matched nonathletic controls	BMI, BF%, WHR, blood pressure, snoring, smoking, TG, TC/HDL, non-HDL/HDL	Prevalence of CMS was not different between groups; retired players with CMS gained significantly more weight since retirement
Basra et al[4] (2014)	Cross-sectional	To evaluate the presence and severity of subclinical atherosclerosis; to evaluate whether the lineman position is independently associated with an increased risk of subclinical atherosclerosis	Living Heart Foundation health screening, 2007-2009	NFL; n = 931; male; mean age: 54 y; no comparators; LM vs NLM	BMI, WC, SBP, hs-CRP, TC, HDL-C, LDL-C, TG, fasting glucose, CMS, HT, DM, smoking, CAC	LM were less likely to have absence of CAC (33.8% vs 41.7%, respectively; P = .02) and had greater likelihood of moderate to severe CAC (32.9% vs 26.4%, respectively; P = .04)

(continued)

TABLE A1 (continued)

Author (Year)	Study Design	Primary Aims	Setting	Participants	Variables	Risk Factor Prevalence
Chang et al[9] (2009)	Cross-sectional	To assess the prevalence of CAC in retired NFL players compared with physically active controls; to evaluate retired players' true risk of an adverse cardiovascular event	Living Heart Foundation health screening, 2007	NFL; n = 201; male; mean age: 51.2 y; age-, sex-, BMI-, and ethnicity-matched participants from DHS and ACLS	BMI, WC, WHR, SBP, DBP, fasting insulin, fasting glucose, TC, HDL, LDL, TG, HbA1C, CMS, DM, smoking, CAC, HT, hs-CRP	There was no significant difference in CAC prevalence (46.0% vs 48.3%, respectively; $P = .69$) or distribution ($P = .11$) between retired players and controls
Hurst et al[30] (2010)	Cross-sectional	To evaluate subclinical atherosclerosis in retired NFL players; to assess the cardiovascular risk in professional football players	Living Heart Foundation health screening, 2006-2007	NFL; n = 201; male; mean age: 50.8 y; age-, sex-, BMI-, and smoking prevalence–matched controls from Mayo (2006-2007); LM vs NLM	BMI, smoking, HT, SBP, DBP, hyperlipidemia, TC, HDL, LDL, TG, TC/HDL, fasting glucose, CAP, CMS	Prevalence of CAP in players was not significantly different to BMI-matched controls (33.3% vs 29.3%, respectively; $P = .45$); CMS was more prevalent in LM than NLM (45.8% vs 22.5%, respectively; $P = .001$)
Hyman et al[31] (2012)	Observational	To validate the accuracy of BMI when measuring obesity in the retired NFL population; to investigate the correlation between obesity and several comorbidities in this population	Internal medicine practice, 5/2010-6/2011	NFL; n = 129; male; mean age: 42.2 y; no comparators; LM vs NLM	BMI, HT, obstructive SA, left ventricular hypertrophy, DM	BMI has poor specificity (0.36) in classifying obesity in retired football players; BMI/obesity was correlated with LM ($P < .0001$) and obstructed SA ($P = .0005$)
Albuquerque et al[1] (2010)	Cross-sectional	To assess the prevalence of SDB and HT; to compare the risk of CVD between retired NFL players and controls	Living Heart Foundation health screening, 2006	NFL; n = 257; male; mean age: 53.9 y; age-, sex-, and BMI-matched cohort from NHANES	BMI, SBP, DBP, HT, obesity, TC, TG, HDL, LDL, fasting glucose, DM, smoking, apnea-hypopnea, SDB	SDB was present in 52.3% of retired players; prevalence of HT and obesity ($P < .001$) was higher in retired players; LM were more likely to have SDB (61.3% vs 46.6%, respectively; $P = .02$) and obesity (83.5% vs 52.5%, respectively; $P < .001$) compared with NLM; retired players had lower TC, TG, HDL, and impaired fasting glucose than controls

(continued)

TABLE A1 (continued)

Author (Year)	Study Design	Primary Aims	Setting	Participants	Variables	Risk Factor Prevalence
Carruthers et al[7] (2017)	Cross-sectional	To assess the 10-y risk of atherosclerotic CVD in elite former athletes	Not specified	NFL; n = 104; male; mean age: 53.8 y; age- and sex-matched participants from DHS	BMI, SBP, non-HDL, HDL, median CAC, median atherosclerotic CVD risk, smoking	Compared with DHS, retired NFL players had no significant differences in odds of having CAC = 0 among participants with a high atherosclerotic CVD risk (OR, 1.37 [95% CI, 0.36-5.17]) or in odds of having high CAC (>100) among participants with a low atherosclerotic CVD risk (OR, 1.28 [95% CI, 0.64-2.54])
Kelly et al[34] (2014)	Prospective	To determine the rate of metabolic dysfunction in retired NFL players	Providence St John's Health Center; Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center	NFL; n = 74; male; mean age: 47.3 y; no comparators; non–hormone deficient vs hormone deficient	BMI, CMS, IGF-1	CMS was present in 50% of retired players; BMI increased significantly ($P <$ .001) for players during retirement
Lynch et al[39] (2007)	Cross-sectional	To determine if playing professional football as a young adult is associated with a more favorable cardiovascular risk profile and greater bone density and lean mass compared with their healthy peers	University of Maryland	NFL; n = 16; male; mean age: 66 y; sex-, BMI-, race-, and current physical activity–matched never-athletic comparators	BMI, WC, WHR, BF%, TC, LDL, HDL, TG, fasting insulin, fasting glucose, blood pressure	Retired players had a more favorable body composition and cardiovascular risk profile than controls: 37% higher HDL, 4-fold higher HDL2, 25% lower TC/HDL, and 31% lower TG ($P <$ .05 to $P <$ .001)
Pokharel et al[55] (2014)	Cross-sectional	To examine the association of NC with other markers of adiposity and components of CMS; to examine whether NC is independently associated with subclinical atherosclerosis as assessed by CAC and CAP	NFL Player Care Foundation; Living Heart Foundation; Boone Heart Institute	NFL; n = 845; male; mean age: 54 y; no comparators	HT, DM, SBP, DBP, BMI, NC, WC, fasting blood glucose, hs-CRP, TC, LDL, HDL, TG, CMS, CAC/CAP	21% had CMS, 62% had CAC, and 56% had CAP present; NC was not associated with CAC or CAP after adjusting for age, race, and cardiometabolic risk factors

(continued)

TABLE A1 (continued)

Author (Year)	Study Design	Primary Aims	Setting	Participants	Variables	Risk Factor Prevalence
Virani et al[69] (2012)	Cross-sectional	To assess whether LDL-P concentration and hs-CRP can identify subclinical atherosclerosis better than traditional cholesterol parameters; to assess if hs-CRP is associated with CAP in retired NFL players	Living Heart Foundation and Boone Heart Institute, 9/2007-11/2009	NFL; n = 948; male; mean age: 53.5 y; no comparators; CMS vs no CMS	HT, DM,CMS, WC, TC, LDL, non-HDL, TG, LDL-P, HDL, hs-CRP	CAP was common in retired players (41%) and strongly associated with LDL-P (OR, 3.71 [95% CI, 1.16-11.84]); 19.7% of retired players had CMS; hs-CRP was not associated with CAP (OR, 1.13 [95% CI, 0.71-1.79])
Luyster et al[38] (2017)	Cross-sectional	To compare the SA risk in young- to middle-aged retired NFL players with a community cohort; to compare the SA risk based on playing position	NFL Player Care Foundation Cardiovascular Health Screening Program, 2007-2012	NFL; n = 122; male; mean age: 45.3 y; age-, sex-, race-, and BMI-matched cohort from CARDIA	Smoking, WC, BMI, obesity, SBP, DBP, TC, HDL, LDL, TG, DM, fasting glucose, sleep duration, SA risk, CAC	Retired players had greater prevalence of high SA risk (27.0% vs 11.5%, respectively; P = .002) but similar prevalence of CAC compared with matched controls (30% vs 30%, respectively; P = 1)

[a]ACLS, Aerobics Center Longitudinal Study; BF%, body fat percentage; BMI, body mass index; CAC, coronary artery calcium; CAP, carotid artery plaque; CARDIA, Coronary Artery Risk Development in Young Adults; CMS, cardiometabolic syndrome; CVD, cardiovascular disease; DBP, diastolic blood pressure; DHS, Dallas Heart Study; DM, diabetes mellitus; HDL, high-density lipoprotein; HDL-C, high-density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein; HT, hypertension; IGF-1, insulin-like growth factor 1; LDL, low-density lipoprotein; LDL-C, low-density lipoprotein cholesterol; LDL-P, low-density lipoprotein particle number; LM, linemen; Mayo, Mayo Clinic; NC, neck circumference; NFL, National Football League; NHANES, National Health and Nutrition Examination Survey; NLM, nonlinemen; OR, odds ratio; SA, sleep apnea; SBP, systolic blood pressure; SDB, sleep-disordered breathing; TC, total cholesterol; TG, triglyceride; WC, waist circumference; WHR, waist-to-hip ratio.