Long-term function, body composition and cardiometabolic health in midlife former athletes: a scoping review

Jena Heck Street,1 Zebadiah P Boos,1 Alissa Fial,2 Shannon L Lennon,3 Carolyn S Smith,1 Seth A Creasy,4 Sandra K Hunter,1 William B Farquhar,3 Jacob John Capin1,5

ABSTRACT

While sports medicine has traditionally focused on recovering from injury and returning athletes to sport safely after injury, there is a growing interest in the long-term health of athletes. The purpose of this scoping review was to (1) summarise the literature (methodologies and findings) on physical function, body composition and cardiometabolic health in midlife (age 40–65 years) former competitive athletes compared with non-athlete controls, (2) identify areas for future study in long-term health in athletes and (3) determine outcomes that could be evaluated in a future systematic review(s). We searched PubMed, CINAHL, Web of Science and SPORTDiscus for studies published between 2000 and 2022 evaluating former athletes and controls on physical function, body composition and/or cardiometabolic measures using MeSH terms. We identified 20 articles that met our criteria. Outcomes varied considerably across studies, most of which were cross-sectional and evaluated only males. Limited data suggest that former endurance athletes have leaner body compositions, higher aerobic capacity and better cardiometabolic indicators than controls; former athletes who maintain higher physical activity (ie, self-reported exercise) are healthier than those who do not; and former team sport athletes, who have higher injury prevalence, may have poorer functional performance than controls who were recreationally active in college. Studies rarely evaluated functional performance, did not control for prior injury or diet and seldom assessed current physical activity levels. Future research should include females and evaluate sex differences, control for prior sports-related injury (yes, no) and quantity physical activity, use standardised outcome measures including performance-based functional assessments and incorporate longitudinal designs.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Physical activity, exercise and sport confer many benefits across physical, cognitive and psychological domains.
⇒ Former elite athletes tend to live longer than non-athlete peers.
⇒ Former elite athletes, especially those with histories of lower extremity injury, have high rates of knee and hip osteoarthritis and joint replacement.
⇒ Former athletes report similar physical component quality of life scores and higher mental component quality of life scores compared with non-athlete controls.

WHAT ARE THE NEW FINDINGS

⇒ We identified 20 articles published since 2000 that evaluated at least one functional, body composition and/or cardiometabolic outcome in midlife former athletes compared with controls. Outcome measures varied considerably across studies, most of which were cross-sectional and evaluated only male participants. Studies did not control well for prior injury nor present behaviours such as physical activity patterns and dietary intake.
⇒ The available data suggest former national and international class endurance athletes may have leaner body compositions, higher aerobic capacity (ie, higher VO2 max) and better cardiometabolic indicators than non-athlete controls.
⇒ Data from a few studies suggest former athletes who maintain higher activity patterns (ie, self-reported exercise frequency) in midlife are healthier than former athletes who lead more sedentary lives and controls.
⇒ Though limited by very few studies and relatively small samples, former team sport athletes—who also have a much higher prevalence of former time-loss injury—may have poorer physical function and poorer cardiometabolic health than individuals who were recreationally active during young adulthood.

INTRODUCTION

Approximately 7.6 million high school1 and 480 000 collegiate2 athletes engage annually in competitive, organised sport in the USA alone. Participating frequently in competitive sports may have beneficial and harmful long-term health implications, as athletes often engage in vigorous intensity exercise and strength-training yet are also exposed to high training loads and musculoskeletal injury risk. Recently published studies suggest former athletes live longer than age-matched peers3–5 yet also have a higher risk for lower extremity osteoarthritis (OA) and joint replacement.6–8
A systematic review and meta-analysis of cardiovascular disease risk factors in male former team-sport athletes found inconsistencies in the reporting of cardiovascular disease risk factors and inconclusive results.\textsuperscript{9} Traditional sports medicine focuses on athletes’ health during or soon after their athletic careers and rarely evaluates health outcomes later in life. Describing the implications of competitive sports participation on long-term function, body composition and cardiometabolic health may guide how clinicians and coaches counsel athletes for life-time injury prevention and optimal health and elucidate areas for future research.

Several factors suggest sports are beneficial to function, body composition and cardiometabolic health that could have important implications for ageing former athletes in midlife and beyond. Athletes regularly participate in vigorous exercise, which is strongly linked to many health benefits across physical, cognitive and psychological domains.\textsuperscript{10–18} Factors such as greater strength and higher VO\textsubscript{2} max, common among athletes, may help preserve long-term cardiometabolic health and functional independence.\textsuperscript{19}

Participating in competitive sports may also come with a cost, as athletes are at substantially higher risk for musculoskeletal injury than non-athletes and novice athlete counterparts.\textsuperscript{20–24} Injury rates, especially traumatic knee injuries among young athletes in collision, contact and jumping/cutting/pivoting sports (eg, football (American, Australian rules), lacrosse, hockey, soccer, basketball), appear to have risen in recent years.\textsuperscript{25–27} These traumatic knee injuries, in turn, place athletes at profoundly increased risk for subsequent injury\textsuperscript{28} and early OA.\textsuperscript{29,30} Chronic injury can also impair function and limit daily activities, reducing overall health.\textsuperscript{31–33} Some sports prioritise high body weight (eg, American football), whereas other sports emphasise weight cycling (eg, wrestling, powerlifting) or restriction (eg, gymnastics, running)—all of which could hypothetically have harmful effects of on cardiometabolic and/or body composition metrics. The one published review to-date on cardiovascular and body composition measures in former athletes, however, evaluated male team-sport athletes only, focusing almost exclusively of former professional American football players and yielded inconsistent findings.\textsuperscript{9}

Despite mounting research on athletes, much remains unknown regarding the effects of previous high-level sport participation on long-term health. Recent review articles have evaluated pain,\textsuperscript{34} quality of life,\textsuperscript{35} OA,\textsuperscript{36} mortality\textsuperscript{3,5} and cardiovascular health\textsuperscript{9} among former athletes and the benefits of sport in adults 60 years of age and older.\textsuperscript{38} Prior studies have yet to systematically review data on physical function or to examine body composition and cardiometabolic health in male and female midlife former athletes across a broad range of sports. Midlife, approximately age 40–65 years, is a significant yet understudied population, as health in middle age strongly predicts health in older age.\textsuperscript{37–39} The purpose of this scoping review was threefold: (1) summarise the literature (methodologies and findings) pertaining to physical function, body composition and cardiometabolic health in midlife former competitive athletes compared with non-athlete controls, (2) identify areas for future study in long-term health in athletes and (3) determine outcomes pertaining to physical function, body composition and/or cardiometabolic measures among midlife former athletes compared with controls that could be evaluated in a future systematic review(s).

**METHODS**

This scoping review followed the process established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Review. A review protocol was not published or registered. A scoping review was more appropriate than a systematic review for several reasons,\textsuperscript{30} such that our aim was to identify gaps in the literature and areas of future study while also determining the feasibility of conducting a future systematic review(s). We included a heterogeneous population of former athletes, including all sports, nations and high levels of competition. We also included studies that examined physical function, body composition or any cardiometabolic indicators.

**Search strategy**

Searches were conducted in four electronic databases: PubMed, CINAHL, Web of Science and SPORTDiscus. Searches focused on studies that included former athletes and controls and evaluated physical function, body composition and/or cardiometabolic measures. For a complete list of the literature search strategies, see online supplemental appendix 1. The initial search was conducted on 19 August 2022, with an additional search for any updated content run on 4 January 2023. The reference lists of articles that were reviewed during full-text screening were also reviewed for additional relevant articles for screening (see the Study selection and figure 1).

**HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY**

- This scoping review surveyed the literature to summarise the implications of competitive athletics on long-term function, body composition, and cardiometabolic health and may inform how healthcare providers counsel or treat athletes for optimal long-term health.
- Our findings suggest that prior engagement in high levels of exercise, even at an elite level, does not provide lifelong protection for cardiometabolic health, function, or body composition. Continued activity is important in aging athletes, as former athletes who maintain higher physical activity levels are healthier than those who do not.
- Future research should include females and evaluate sex differences (when possible), control for prior sports-related injury, objectively quantify physical activity patterns, use more standardised outcome measures including performance-based functional assessments, and incorporate longitudinal study designs.
Inclusion/exclusion criteria

Studies published between 1 January 2000 and 31 December 2022 were eligible for inclusion to capture the most contemporary studies given that sports have changed dramatically in recent decades, including higher injury rates and greater training and competition expectations. Our search included former high-level athletes involved in competitive (i.e., ≥3×/week in organised sport training and matches), collegiate, professional and/or elite (i.e., national/international) sports. Studies were included if the mean or median age of the former athletes was between 40 and 65 years. Studies were required to have a comparison group of non-athlete controls (also between the ages of 40 and 65 years). Outcomes needed to focus on functional measures (e.g., aerobic capacity, strength and self-reported measures), body composition (e.g., anthropometrics, body fat, lean mass, bone density) and/or cardiometabolic indicators (e.g., blood pressure, blood lipids, inflammatory biomarkers). Articles where body mass index (BMI) was the sole outcome measure relevant to this review were not included due to the potential misclassification of overweight/obesity in athletes. We also did not include outcomes pertaining to cardiac arrhythmias (e.g., atrial fibrillation) or abnormalities (e.g., hypertrophic cardiomyopathy). Given that our focus was on former high-level athletes, articles were excluded if the participants were exclusively current master’s athletes (i.e., athletes over the age of 35 years who were presently active in sport competition). Articles were also excluded if the measurements focused exclusively on neurocognitive measures/traumatic brain injury or quality of life. While physical activity patterns were not an outcome of interest, we included studies that evaluated our outcomes of interest and considered physical activity as another outcome or grouping variable.

Study selection

Our search yielded 1095 articles after removing duplicates. Titles and abstracts from the initial search were uploaded into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia), a web-based collaboration software platform that streamlines study selection and data extraction. Two authors (JHS and ZPB) reviewed each title and abstract for inclusion and met to discuss and resolve disagreements; the senior author (JJC) served as the tiebreaker when consensus was not met. Sixty studies were reviewed in full text and 20 articles were included in the review (figure 1).

Data extraction and analysis

Data were pulled from the final articles using Covidence. Similar to study selection, two authors (JHS and ZPB) reviewed each article individually for extraction and met to discuss and resolve any disagreements; the senior author (JJC) served as the tiebreaker. Data extraction included study methodology (e.g., design, testing methods); participant characteristics (e.g., sex, sport, competition level, description of controls); functional performance (e.g., aerobic capacity, walk tests, strength, self-reported functional measures); body composition (e.g., anthropometrics, percent lean/fat mass, bone density) and cardiometabolic factors (e.g., blood pressure, hypertension, blood lipids, inflammatory biomarkers). Data were reported as they were presented in the primary studies: outcomes are typically presented as mean±SD for continuous variables percentages for categorical (e.g.
prevalence) outcomes; p values for statistical significance were extracted when possible. Subgroup analyses by sex, sport type and physical activity were also extracted and reported when available.

**Patient and public involvement**

Given that this study is a scoping review of prior literature, patients were not directly involved. All data are from previously published works.

**RESULTS**

**General study characteristics**

Our search yielded 20 articles. Most studies were cross-sectional, evaluated males only, and were conducted in Europe (table 1, online supplemental appendix 2). Nine studies included former athletes from multiple sports with a mix of endurance and team sports,33 42-49 while three studies included only American football40-52 and three studies included only soccer (ie, football).53-55 Most (12 of 20) studies involved athletes who had competed at national and international competitions, including seven studies on Olympic athletes. Five studies included former professional athletes,50-53 56 while only two studies involved former college (ie, National Collegiate Athletic Association (NCAA)) athletes.33 44

**Physical function**

Six studies evaluated functional performance using tests of aerobic capacity, strength and other outcomes (table 2), while five studies included self-reported functional measures (online supplemental appendix 3).

**Functional performance tests**

Aerobic capacity was evaluated using VO₂ max tests and walking tests. Three studies found that physically active former male athletes had a significantly higher VO₂ max than age-matched peers.54 55 57 One study found that former male endurance athletes who then led sedentary lives had a lower VO₂ max than physically active former athletes and controls,45 whereas another found that sedentary former male soccer athletes had a lower VO₂ max than physically active former athletes but higher than controls.54 Simon and Docherty33 found that former NCAA Division I College athletes took longer than recreationally active controls to complete a one-mi walk test,33 whereas Ravi et al45 found that female former competitive adolescent athletes walked faster and further on a 6min walk test compared with age-matched and sex-matched controls.57 One study reported that former college athletes performed fewer repetitions on a chair stand test than recreationally active controls.33

Two studies performed strength tests. Simon and Docherty33 found that former athletes completed fewer push-up repetitions but similar half sit-up repetitions than controls that were recreationally active during college.33 Ravi et al45 reported that female former athletes produced higher forces for handgrip and knee extension strength compared with physically active and sedentary controls.45

Two studies45 46 analysed jump height. Ravi et al45 found that former female athletes from several different sports jumped higher than controls who were either physically active or did not exercise,45 whereas Räty et al46 compared former soccer, weightlifting, running and marksmen athletes, with former weightlifters performing the best.46 Unt et al47 concluded that physically active former athletes produced higher power during a Modified Balke test compared with sedentary former athletes and controls.55 Simon and Docherty45 found no differences between former athletes and controls on two flexibility tests (ie, back scratch and sit and reach).33 Räty et al46 found that the former soccer, weightlifting, running and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Meta-data of the 20 included studies</th>
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<tbody>
<tr>
<td><strong>Total sample size</strong></td>
<td>Former athletes n=6535 Controls n=12524</td>
</tr>
<tr>
<td><strong>Study design</strong></td>
<td>Cross-sectional study n=16 (80%) Retrospective study n=2 (10%) Cohort study n=1 (5%) Other n=1 (5%)</td>
</tr>
<tr>
<td><strong>Method of testing</strong></td>
<td>In-person testing n=17 (85%) Internet/email n=2 (10%) Mail n=1 (5%)</td>
</tr>
<tr>
<td><strong>Country of origin</strong></td>
<td>Europe n=11 (55%) Finland n=4 (20%) Estonia n=2 (10%) Portugal n=2 (10%) Germany n=1 (5%) Poland n=1 (5%) Sweden n=1 (5%) USA n=5 (25%) Brazil n=1 (5%) India n=1 (5%) Iran n=1 (5%) International (multiple countries) n=1 (5%)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td>Male only n=12 (60%) Female only n=4 (20%) Both male and female n=4 (20%)</td>
</tr>
<tr>
<td><strong>Former athlete sport</strong></td>
<td>Multisport n=9 (45%) Endurance sports n=4 (20%) American football n=3 (15%) Soccer (football) n=3 (15%) Javelin/high jump n=1 (5%)</td>
</tr>
<tr>
<td><strong>Former athlete level of competition</strong></td>
<td>International/national (60%) Olympics n=7 (35%) Professional n=5 (25%) National Football League n=3 (15%) Collegiate n=2 (10%) NCAA division 1 n=1 (5%) NCAA division 3 n=1 (5%) Youth n=1 (5%)</td>
</tr>
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Values are presented as number (n) and percent (%). NCAA, National Collegiate Athletic Association.
### Table 2  Functional performance tests

<table>
<thead>
<tr>
<th>Study</th>
<th>Aerobic capacity (mean±SD)</th>
<th>Strength (mean±SD)</th>
<th>Other (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babaei 2014</td>
<td>VO$_{2\text{max}}$ test: FA aerobic group=45±5.8 mL/kg/min, FA anaerobic group=43±4.4 mL/kg/min, controls aerobic group=32±4.5 mL/kg/min, controls anaerobic group=33±4.8 mL/kg/min, aerobic groups p&lt;0.01, anaerobic groups p&lt;0.02</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Dey 2002</td>
<td>VO$_{2\text{max}}$ test: PAFA=44.9±1.48 mL/kg/min, SFA=40.0±2.19 mL/kg/min, controls=36.8±1.65 mL/kg/min, p&lt;0.01</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Räty 2002</td>
<td>–</td>
<td>–</td>
<td>Jumping height: soccer FA=26±3 cm, Weightlifting FA=27±4 cm, running FA=23±2 cm, marksmen FA=24±2 cm, p=0.012</td>
</tr>
</tbody>
</table>

Balance Test Completion Time: soccer FA=38±2.4 s, weightlifting FA=38±2.5 s, running FA=42±2.4 s, marksmen FA=37±2.4 s, 47-year-old controls=48±1.0 s, 57-year-old controls=54±1.2 s, p=0.38 between FA, p<0.01 between FA and controls ||

Balance test times loss of balance: soccer FA=4.8±0.8, weightlifting FA=4.9±0.8, running FA=5.0±0.8, marksmen FA=3.5±0.8, 47-year-old controls=5.0±0.3, 57-year-old controls=7.1±0.4, p=0.49 between FA ||

Ravi 2020     | 6 min Walk Test: competitive FA=696.7 m (684.8–708.5), regular physical activity controls=667.5 m (662.3–672.7), no exercise controls=660.7 m (651.1–670.2), p<0.001 walking speed: competitive FA=2.9 m/s, regular physical activity controls=2.6 m/s, no exercise controls=2.6 m/s, p<0.001 | Handgrip force: competitive FA=333.5 n (322.6–344.4), regular physical activity controls=313.5 N (308.7–318.4), no exercise controls=305.5 N (296.7–318.4), p=0.001 Knee extension force: competitive FA=509.1 N (488.4–529.8), regular physical activity controls=460.4 N (452.7–468.4), no exercise controls=442.3 N (425.6–458.9), p<0.001 | Jumping height: competitive FA=21.3 cm, regular physical activity controls=19.0 cm, no exercise controls=18.7 cm, p<0.001 |

Simon 2017    | 1 Mile Walk Test: FA=16.03±1.54 min, controls=13.61±1.24 min, p=0.03 | Sit to Stand Test: FA=17.97±5.79 reps, controls=22.29±6.14 reps, p=0.01 Push Up Test: FA=21.87±9.39 reps, controls=30.78±9.82 reps, p=0.01 Half Sit-Up Test: FA=49.59±6.26 reps, controls=49.96±7.18 reps, p value not stated | Back Scratch Test: FA=−3.68±1.33 cm, controls=−3.97±1.25 cm, p value not stated Sit and Reach Test: FA=25.79±8.51 cm, Controls=26.13±9.85 cm, p value not stated |

Continued
marksment athletes performed better on a balance test than similarly aged controls.46

Self-reported functional measures
Arliani et al53 found that male former soccer athletes scored worse than controls on the Knee Injury and Osteoarthritis Outcome Score pain, symptom and knee-related quality of life subscales.53 Former athletes, most notably those previously in endurance sports, had a lower prevalence of self-reported hip disability and pain than age-matched military controls.47 In contrast, knee disability and pain were higher in former team sport athletes than in controls.47

Body composition and cardiometabolic measures
All 20 studies included at least one body composition or cardiometabolic measurement (online supplemental appendix 4; 5).

Body weight and anthropometrics
Several studies found that former athletes had a lower BMI than controls.42 49 53–55 57 58 Physically active former athletes had significantly lower BMI than their sedentary counterparts.47 58 Additionally, former female athletes had lower BMI values than their male athlete peers.43 Chang et al’s study51 was the only study that found higher BMI values in former athletes, all of whom were American football players.51

Three studies found a significantly lower body weight in former athletes compared with age-matched and sex-matched controls.49 54 58 while two studies found that former American football players had a higher body weight than controls.51 52 Physically active former athletes had a lower body weight compared with sedentary former athletes in three studies.54 57 58

One study found that former female athletes had smaller waist circumferences compared with female controls.42 Former male athletes who were currently more physically active had lower waist-to-hip ratios compared with sedentary athletes and controls.54 58 Dey et al54 also found that active former athletes had lower waist-to-thigh ratios than sedentary athletes or sedentary controls.54

Body composition
Several studies evaluated body composition (figure 2). Simon and Docherty33 found higher percent body fat in former collegiate athletes compared with recreationally active controls. In contrast, three studies found that former athletes had a lower percent body fat.45 49 59 Physically active former athletes had a lower body fat percentage compared with sedentary former athletes.54 57 58 Former athletes had greater total lean mass,45 49 59 lean mass index,45 appendicular lean mass45 and body surface area.52

Bone density
Ravi et al45 and Kettunen et al48 found that former female and male athletes of various sports had higher femoral neck bone mineral density, while Kettunen et al48 also found the same result in trochanter bone mineral density for male athletes.48 Andreoli et al59 determined that former female runners and swimmers also had higher total spine and leg bone mineral density than age-matched and sex-matched sedentary controls. Swimmers only had greater upper extremity bone mineral density than controls.59

Blood pressure/hypertension
Two studies found that former athletes had a lower prevalence of hypertension.43 44 while another found that former National Football League (NFL) athletes had a higher prevalence of hypertension than controls.50 Several studies found lower systolic blood pressure in former athletes.42 51 58 with physically active54 58 and female former athletes having lower values compared with sedentary and male former athletes, respectively. In contrast, Hurst et al52 found higher systolic blood pressure in former NFL athletes.52 Regarding diastolic

### Table 2 Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Aerobic capacity (mean±SD)</th>
<th>Strength (mean±SD)</th>
<th>Other (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unt 200857</td>
<td>VO_{2\text{max}} test: PAFA=4.0±0.5 L/min, SFA=3.42±0.56 L/min, controls=3.44±0.53 L/min, p&lt;0.001 PAFA compared with SFA and controls</td>
<td>–</td>
<td>Modified Balke Test: PAFA=4.4±0.7 W/kg, SFA=3.5±0.7 W/kg, Controls=3.6±0.9 W/kg, p&lt;0.001 PAFA compared with SFA and controls</td>
</tr>
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FA, former athletes; PAFA, physically active former athletes; SFA, sedentary former athletes.
blood pressure, former NFL athletes had lower values,\textsuperscript{51} and physically active former male soccer and endurance athletes had lower values compared with their non-athletic peers.\textsuperscript{54,58} Hagmar et al.\textsuperscript{49} found that former female athletes had lower resting heart rates compared with age-matched controls.\textsuperscript{49}

Blood lipids

Half (n=10, 50\%) of the studies included blood lipid measurements (figure 3A–D). Former athletes consistently had lower total cholesterol\textsuperscript{43,44,49,58} and lower triglyceride levels\textsuperscript{54,57,58} than controls. Compared with sedentary former athletes, physically active former athletes had lower total cholesterol in three studies,\textsuperscript{54,57,58} lower triglycerides in three studies,\textsuperscript{54,57,58} higher high-density lipoprotein (HDL) cholesterol in two studies\textsuperscript{54,58} and lower low-density lipoprotein (LDL) cholesterol in one study.\textsuperscript{58} Dey et al.\textsuperscript{54} found that sedentary former male soccer athletes had higher total cholesterol, higher triglycerides and lower HDL cholesterol than sedentary controls.\textsuperscript{54}

Other blood biomarkers and cardiometabolic indicators

Several other blood biomarkers and cardiometabolic measures were evaluated. Former athletes had lower glucose levels than controls.\textsuperscript{42,43,51,52} Former athletes also had a lower prevalence of diabetes,\textsuperscript{56} hyperglycemia\textsuperscript{45} and metabolic syndrome.\textsuperscript{42} One study found that former NFL football players had lower high-sensitivity C reactive protein compared with controls.\textsuperscript{51} Measures of oxidative stress differed between physically active and sedentary former athletes but not to controls.\textsuperscript{57,58}

DISCUSSION

The purpose of our scoping review was to summarise the literature published since 2000 on long-term function, body composition and cardiometabolic health in former athletes and to make recommendations for future research areas. We identified 20 published articles that met our criteria. In summary, our findings suggest that prior engagement in elite sport does not necessarily position individuals for optimal long-term health and function. The available data suggest that former national and international class endurance athletes may have higher aerobic capacity (ie, higher VO\textsubscript{2} max), better cardiometabolic indicators and leaner body compositions than non-athlete controls. Data from a few studies\textsuperscript{54,57,58} suggest former athletes who maintain higher activity patterns (ie, self-reported exercise frequency of at least 3×/week) in midlife are healthier than former athletes who lead more sedentary lives and controls.

Though limited by quantity of studies and samples, our findings suggest that former team sport athletes—who also have a much higher prevalence of former time-loss injury\textsuperscript{69}—have poorer physical function and cardiometabolic health than individuals who were recreationally active during young adulthood.
Our findings that few studies included females or evaluated sex differences are well supported by prior literature demonstrating inequalities in research conducted on female versus male athletes. While some sports (e.g., American football) are not widely practiced among both sexes, including both males and females in studies and evaluating sex differences when possible is essential and may have substantial clinical implications. Female sports participation has seen drastic increases since the passage of Title IX, furthering the need for sports medicine research to actively include female athletes in research studies to enable appropriate investigation of sex-based differences. Most of the former athletes in the included studies evaluated European males at a previous professional/elite level of competition, thus the findings may not generalise to females or athletes at lower competition levels. Four studies included only female participants, though two had sample sizes totalling less than 50 participants, including controls. Future studies should include female and male athletes to evaluate long-term health in both sexes and evaluate

Figure 3  Mean blood lipid values in former athletes (dark) and controls (light): (A) total cholesterol, (B) HDL cholesterol, (C) LDL cholesterol and (D) triglyceride Levels. Batista and Soares only reported HDL cholesterol and triglyceride values and only separated sex comparisons for HDL levels, as the triglyceride values include both males and females. Chang et al have two values for FA and controls due to two different cohorts. FA, former athletes; HDL, high-density lipoprotein; LDL, low-density lipoprotein; PAFA, physically active former athletes; SFA, sedentary former athletes.
sex differences in long-term health among athletes in similar sports.

Current physical activity patterns in former athletes may be a key consideration for later health outcomes. Three studies compared male former athletes who led a more active lifestyle in midlife with former athletes who were sedentary in midlife, consistently finding that greater exercise in midlife was correlated with better functional performance, higher VO₂ max, and better body composition. While these athletes were male endurance athletes and male soccer players, limiting generalisability, substantial literature supports male endurance athletes and male soccer players, leading to improved cardiovascular health in midlife and older age. Despite noted limitations, the importance of current health practices (ie, physical activity) on current health is clear, highlighting a reality for former athletes: prior engagement in high levels of exercise through elite sport does not provide athletes with lifelong protection for function, body composition and cardiometabolic health. Prior research on long-term cardiovascular health in former athletes has focused heavily on American football players. McCrory et al performed a systematic review and meta-analysis on cardiovascular health in male team-sport athletes (ie, American football (12 studies) and soccer (1 study)), finding that some factors (eg, fasting glucose, triglycerides) were better in former athletes whereas others (eg, systolic blood pressure, LDL cholesterol) were better in controls. While former NFL players who have higher BMI at time of professional sport participation have significantly greater cardiovascular disease risk, current behaviours including physical activity, exercise, diet and sleep, likely influence not only cardiovascular disease risk but also function, body composition, and other health outcomes. Future research should explore biopsychosocial factors for why some former athletes engage in healthy behaviours and others do not.

While it is well known that athletes sustain musculoskeletal injuries at much higher rates than non-athletes, one notable finding of our scoping review was that the included studies did not rigorously control for prior injury. Given the well-established link between traumatic joint injury, particularly intra-articular knee injury and subsequent risk for early OA, future research must compare former athletes with and without prior injury/surgery. To illustrate this point, Simon and Docherty found poorer functional performance and higher body fat percentage in former NCAA college athletes compared with controls, but 78/100 of the former athletes sustained a time-loss injury compared with just 20/100 controls. In short, prior injury likely influences long-term health in athletes and should be evaluated thoroughly in future research.

One of the best datasets on long-term athlete health evaluated Finnish former athletes who competed in national/international competitions from 1920 to 1965. Collectively, these studies suggest former athletes may be fitter, healthier and stronger well into midlife and older age, despite high rates of radiographic OA. It is possible that former athletes benefit from persistently greater quadriceps muscle strength, which could help preserve better function, and/or high cardiorespiratory fitness, which could partially counteract deleterious consequences of higher OA prevalence. Future studies could investigate the effect of prior sports participation on cardiorespiratory fitness and function in midlife and older adults who have OA. In recent decades, however, sports have changed dramatically, including higher injury rates, differences in training and competition times and expectations, and artificial playing field surfaces. These factors limit the applicability of studies on athletes from many years ago to today’s athletes.

**Limitations**

A scoping review was pursued instead of a systematic review for several reasons, so our conclusions are limited primarily to summarising general findings, discussing gaps in the literature and identifying areas of future research. While we synthesised outcomes when possible, we did not perform meta-analyses or quality assessments of included studies in line with scoping review guidelines. Most studies evaluated male participants only and athletes who competed at the professional/elite competition levels, thus the findings may not generalise to females or athletes at lower competition levels. Most studies also used a cross-sectional study design, limiting the ability to determine cause and effect. Prior injury, the type and level of sport, subsequent and current physical activity patterns, and outcome measures likely influence the findings and generalisability. Finally, we did not consider atrial fibrillation or other cardiac arrhythmias or abnormalities, though there has already been considerable research including a systematic review and meta-analysis on atrial fibrillation in athletes. Further research is needed in many areas (eg, standardised functional performance tests, inclusion of females, study of sex differences) before a systematic review(s) would be feasible, although systematically evaluating BMI, body composition and blood lipids—at least in male former athletes—may be possible.

**CONCLUSION**

Our scoping review findings suggest that prior engagement in high levels of exercise, even at an elite level,
does not provide lifelong protection for cardiometabolic health, function or body composition. While many former endurance athletes have leaner body compositions, higher aerobic capacity and better cardiometabolic indicators than controls, other former athletes do not and may have similar or worse outcomes. Former team sport athletes, who have higher injury prevalence, may have poorer physical function than recreationally active controls. Continued activity is important in ageing athletes, as former athletes who maintain higher physical activity patterns are healthier than those who do not. Future research should include females and evaluate sex differences, control for prior sports-related injury(ies), objectively measure current physical activity patterns, use standardised outcome measures including performance-based functional assessments, incorporate longitudinal designs and determine why some former athletes engage in positive health behaviours whereas others do not.

Findings from these proposed studies may facilitate our understanding of high-level sports competition on long-term health and ultimately inform how sports medicine providers counsel and intervene for optimal long-term health.

Twitter Jacob John Capin @JacobCapin

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ORCID iD Jacob John Capin http://orcid.org/0000-0001-9381-3700

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