BMJ Open

Effects of cardiovascular health, musculoskeletal health and physical fitness on occupational performance of firefighters: protocol for a systematic review and meta-analysis

Jaron Ras ,[1] Andre Pascal Kengne,[2,3] Denise Smith,[4] Elpidoforos Soterakis Soteriades,[5,6] Lloyd Leach[7]

To cite: Ras J, Kengne AP, Smith D, *et al*. Effects of cardiovascular health, musculoskeletal health and physical fitness on occupational performance of firefighters: protocol for a systematic review and meta-analysis. *BMJ Open* 2022;**12**:e061435. doi:10.1136/bmjopen-2022-061435

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-061435).

Received 26 January 2022
Accepted 13 July 2022

For numbered affiliations see end of article.

Correspondence to
Mr Jaron Ras;
3405618@myuwc.ac.za

ABSTRACT

Introduction Firefighting is a hazardous occupation, where firefighters are involved in life-threatening situations, being placed under tremendous physical strain, while wearing heavy and insulated equipment to protect them from chemicals, fumes and high temperatures. This necessitates that firefighter stay in good physical condition and maintain adequate cardiovascular fitness to cope with these stressors and perform their duties with minimal health risks. The aim of this systematic review and meta-analysis is to determine the effect of cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters.

Methods and analysis All study types and designs will be included and appraised. The following electronic databases will be searched: PubMed/Medline, Scopus, Web of Science, Embase, EBSCOHost and CINAHL, with no restrictions on publication date. The literature search will be conducted comprehensively to enable the capturing of as many relevant articles as possible but will be limited to English-language papers only. A combination of the appropriate terms (search string) will be used to ensure the inclusion of the relevant components of the participants, exposure, comparison and outcome. A researcher-generated form with the key characteristics of each study will be used to retrieve all relevant details from the selected studies for initial eligibility screening. The Rayyan Intelligent Systematic Review tool will be used to screen and select studies for inclusion, and information from the included studies will be captured on the researcher-generated data extraction form. The The appraisal tool for cross-sectional studies (AXIS) checklist and the Critical Appraisal Skills Programme toolkit will be used to conduct the methodological assessment of each study. Data will be analysed using Review Manager V.5.3. Generated results will be presented using a combination of figures, graphs and tables. The synthesis of quantitative data (using a meta-analysis methodology) will involve the integration of quantitative findings from multiple studies to achieve coherence.

Ethics and dissemination This study obtained ethical clearance from the University of the Western Cape Biomedical Research Ethics Committee (BM21/10/9). We will disseminate the findings of in peer-reviewed journals and at national and international conferences. The protocol will form part of a chapter for a doctoral thesis.

PROSPERO registration number CRD42021258898.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A strength of this review is the use of reference methodologies to guide the study design, from study selection to synthesis.
⇒ A further strength of this review is the planned inclusion of studies that were conducted in various global regions and fire departments.
⇒ Additionally, all types of study designs and methodologies will be included in this review.
⇒ A limitation of this study is that considerable heterogeneity may be introduced through firefighters' age and gender.
⇒ A further limitation of this review is that only English-language articles will be included, which may lead to the exclusion of some relevant studies.

INTRODUCTION

Firefighting is a hazardous occupation, where firefighters are involved in life-threatening situations and routinely exposed to high temperatures, physical and psychological strain, hazardous chemicals, fumes and other health hazards.[1 2] These severe conditions necessitate that firefighters wear protective equipment, including breathing apparatus that is heavy and insulated, putting tremendous strain on their cardiovascular system.[3] Apart from extinguishing fires, firefighters also have additional strenuous work duties, such as rescuing people in dangerous situations and providing first aid and emergency medical services while working irregular hours.[1 4] These types of strenuous working conditions place significant strain on firefighters' musculoskeletal and cardiovascular

systems, predisposing them to higher risk of severe injuries and sudden cardiac events while on duty.[1 4–10]

Many firefighters have multiple cardiovascular disease (CVD) risk factors, primarily obesity, hypertension and dyslipidaemia, inadequate health-related physical fitness and numerous musculoskeletal health concerns affecting optimal functioning, such as previous injuries, moderate-to-severe musculoskeletal pain or discomfort, which significantly and negatively affects occupational performance.[11–19] Throughout firefighters' careers, they develop multiple CVD risk factors, negatively affecting their cardiovascular health, most notably physical inactivity, obesity, hypertension and dyslipidaemia,[11 20–25] which deteriorate as they age.[2 23–25] The literature in the USA indicated that among emergency services professionals, firefighters have the highest percentage of mortality (45%) due to sudden cardiac death, with the majority related to underlying CVD risk factors.[1 4 5] These sudden cardiac events are also due to inadequate health-related physical fitness that results in overexertion and increased cardiovascular strain.[26 27] Health-related physical fitness includes body composition, cardiorespiratory fitness, muscular strength, muscular endurance and flexibility.[28] Body composition, cardiorespiratory fitness, muscular strength and endurance have been reported to decrease throughout their careers and as they age, particularly those that are physically inactive.[29–34] Maintenance of good overall levels of health-related physical fitness is crucial for career longevity and overall well-being in firefighters.[2 35 36]

In addition, firefighters have been reported to have the highest incidence of musculoskeletal injuries among all emergency services personnel.[1] Firefighters performing fire suppression routinely exceed their maximum heart rates for prolonged periods of time, placing tremendous stress on their cardiovascular system. Coupled with the additional stressors, such as worsening cardiovascular health metrics, most frequently: physical inactivity, hypertension, dyslipidaemia and obesity, and poor health-related physical fitness, specifically cardiorespiratory fitness and muscular endurance, may lead to significant morbidity and mortality.[5 37–39] Lower physical fitness levels cause increased risk for musculoskeletal injuries in firefighters.[35 40–42] In addition, worsening cardiovascular health, increased cardiovascular risk profiles, deteriorating musculoskeletal health, especially moderate to severe pain and discomfort in the lower limbs, and poor health-related physical fitness, particularly cardiorespiratory fitness, significantly and negatively affects firefighters' occupational performance.[11–19]

Occupational performance in firefighters

Occupational performance is an important public and personal consideration, as substandard occupational fitness significantly increases the likelihood of cardiovascular and musculoskeletal adverse events while on duty.[3 43 44] Reduced occupational task performance is indicative of firefighters who are not fit for active duty and may be at increased risk of cardiovascular and musculoskeletal injuries. The simulated tasks in firefighting, such as the stair climb, hose drag and victim drag place significant strain on the cardiovascular and musculoskeletal systems that incorporate all aspects of physical fitness.[3 13 45–48] However, a review of the effects of cardiovascular health, musculoskeletal health and physical fitness on occupational performance has not been previously investigated. In the current review, as in previous literature, occupational performance will be quantified as firefighters passing or failing each individual occupational performance tasks and/or the overall ability test. In addition, the overall time taken, in seconds, to perform each simulated occupational task and the completion time of the overall occupational ability test will be assessed. These will include tasks such as the stair climb, hose drag and pull, equipment carry, forcible entry, equipment hoist, ladder raise and extension, and victim drag.[14 45 49–51]

Purpose and justification for this review

This study originated from the challenges firefighters face globally and, in particular, in South Africa. A concerning number of firefighters are at increased cardiovascular disease risk, with worsening musculoskeletal health and physical fitness negatively impacting their occupational performance.[16 52–55] These factors reduce the ability of firefighters to cope with the physical strain of firefighting, which many firefighters have described as being comparable with the physical demands of elite sportspersons.[56] There have been no previous systematic reviews investigating the effects of cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters, which motivated the need for the present study. The intention of this review includes, among others, informing policy makers in South Africa of the need for corrective action and developing strategies to improve and maintain the cardiovascular health, musculoskeletal health and physical fitness of firefighters.

Aims, objectives and research questions

Review aim

The aim of this systematic is to determine the effects of cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters.

Research question

What effects do cardiovascular health, musculoskeletal health and physical fitness have on the occupational performance of firefighters?

Review objectives

The objectives of the study are:

1. To investigate the effects of cardiovascular health on the occupational performance of firefighters.
2. To investigate the effects of musculoskeletal health on the occupational performance of firefighters.
3. To investigate the effects of physical fitness on the occupational performance of firefighters.

4. To investigate the relationship between cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters.

METHODS AND ANALYSIS

The guidelines for Meta-analysis of Observational Studies in Epidemiology studies and Quality of Reporting of Meta-analysis will guide the methods when conducting the review.[57 58] When considering studies for this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews will be followed, and the outcomes for each step will be described in a flow diagram.[59]

Study characteristics

We have chosen to address firefighters' occupational performance, which we describe as performance on simulated tasks or firefighter simulation protocols. This review will have a particular focus on the relationship between cardiovascular health, musculoskeletal health and health-related physical fitness on the occupational performance of firefighters. The study design of choice is a quantitative systematic review, assessing the relationship between the aforementioned variables on occupational performance in adult, full-time firefighters. All study types and designs will be included and appraised accordingly.

Participants

Full-time firefighters that are 18 years or older.

Exposures

Cardiovascular health, musculoskeletal health and health-related physical fitness in relation to the occupational performance of firefighters.

Outcomes

1. Cardiovascular health measures related to the occupational performance of firefighters.
2. Musculoskeletal health measures related to the occupational performance of firefighters.
3. Health-related physical fitness measures related to the occupational performance of firefighters.

Inclusion criteria

1. Studies that recruit full-time adult firefighters, with no limitations to publication year.
2. Cross-sectional, observational and experimental (intervention) study designs.
3. Studies investigating the effects of cardiovascular health, musculoskeletal health and/or health-related physical fitness on the occupational performance of firefighters.
4. Studies available in full-text.

Exclusion criteria

1. Studies focusing on other outcome measures as the main exposures or outcomes.
2. Systematic reviews or other types of reviews.
3. Articles that are non-English.

Search strategy

A detailed literature search will be conducted to identify studies investigating the effects of cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters. Relevant studies, irrespective of publication date, will be searched, with guidance from a specialist librarian.

The team will be made up of three main contributors:

1. Reviewer I (JR) will be the primary investigator, who will take responsibility for all aspects of the review and independently extract the data, verify the data collected, analyse the results, grade the quality of the data and write up the first review draft.
2. Reviewer II (RN) will be responsible for independently extracting the data, verifying the data collected, analysing the results and grading the quality of the data.
3. Reviewer III (LL) will be the adjudicator and resolve any disagreements between the two independent reviewers.

Electronic literature search

The literature search for this systematic review will be conducted comprehensively to enable the capturing of as many relevant articles as possible but limited to English papers only. The following journal databases will be searched: PubMed/Medline, Scopus, Web of Science, Embase, EBSCOHost and CINAHL, with no limitation to publication year. Keywords and medical subject heading terms will be used in various arrangements depending on the specific database. A combination of the appropriate terms (search string) will be used to ensure the inclusion of the relevant components of the participants, exposure, comparison and outcome. The details of the search strategy in PubMed are given further. The search strategies for the other databases are presented in online supplemental appendix 1.

Search terms in PubMed

1. "firefighter" [MeSH] OR "fire and rescue personnel" [MeSH] OR "fire fighters" [MeSH] OR "fire fighter" [MeSH] OR "firefight" [MeSH]
2. "cardiovascular system"[MeSH] OR ("cardiovascular" [All Fields] AND "system" [All Fields]) OR "cardiovascular system" [All Fields] OR "cardiovascular" [All Fields] OR "cardiovasculars" [All Fields] OR "cardiovascular abnormalities" [MeSH] OR "HRV" [All Fields] OR "heart rate variability" [All Fields] OR "Heart Rate Interval" [All Fields] OR "RR variability" [All Fields] OR "cycle length variability" [All Fields] OR "heart period variability" [All Fields] OR "autonomic function" [All Fields] OR "vagal control" [All Fields] OR "lipid profile" [All Fields] OR "cholesterol" [MeSH] OR "dyslipidaemia" OR "hypercholesteremia" OR "diabetes" AND "mellitus" OR "blood glucose" OR "age" OR "obesity" OR "hypertension" OR "blood pressure" OR "metabolic syndrome" OR "hyperglycaemia"
3. "muscular injury" [MeSH] OR ("musculoskeletal" [All Fields] AND "system" [All Fields]) OR "muscular

pain" OR "chronic pain" [All Fields] OR "acute pain" [All Fields] "acute injury" [All Fields] OR "muscular health" [MeSH]
4. "physical fitness"[MeSH] OR "exercise" [All Fields] OR "physical exertion" [All Fields] OR "muscular strength" OR "muscular endurance" OR "aerobic fitness" OR "cardiorespiratory fitness" OR "cardiorespiratory capacity" OR "VO_2max OR "aerobic fitness" OR "power"
5. "work performance" [All Fields] OR "endurance" [All Fields] OR "fitness" [All Fields] OR "work performance" [MeSH Terms] AND "work classification" [All Fields] OR "occupational health" [MeSH] OR "employee health" [MeSH] OR "health, industrial" [MeSH] OR "industrial health" [MeSH] OR "occupational safety" [MeSH] OR "safety, occupational" [MeSH] OR "simulated work tasks" OR simulated "firefighting" OR "CPAT" OR "physical ability test"
6. #1 AND #2 OR #1 AND #3 OR #1 AND #4 OR #1 AND #5 OR #1 AND #2 AND #3 OR #1 AND #2 AND #4 OR #1 AND #3 AND #4 OR #1 AND #2 AND #3 AND #4 OR #2 AND #5 OR # 3 AND #5 OR #4 AND #5

Grey literature

The search strategy will be completed by searching the following databases for grey literature: Google, Google Scholar and Networked Digital Library of Theses and Dissertation. JR and RN will search the reference lists of identified articles to identify potential titles of articles possibly meeting the inclusion criteria.

Study selection

All studies, as full-text articles, that meet the inclusion criteria will be selected for screening. Every attempt will be made to contact the authors for full-text articles or missing data. Thereafter, the full-text articles will be assessed independently by two reviewers using the Rayyan Intelligent Systematic Review tool.[60] When screening the studies, three categories will be used, namely, included, excluded and unsure. Any uncertainties regarding study inclusion will be discussed between the two reviewers. In the event of disagreement, a discussion will be held with the third reviewer and resolved by the latter.

The first step in conducting this review includes performing the literature search, which involves: (1) searching all preselected databases to identify and screen the titles and abstracts of potential studies for eligibility; (2) compiling the search outputs into a reference software, namely, Mendeley Desktop V.1.19.8; (3) removing any duplicates; (4) screening of full-text articles against the inclusion criteria and determining the final studies for inclusion in the review; (5) extracting the data from the included studies using a predesigned data extraction form; and (6) performing a meta-analysis using Review Manager V.5.3[61] for the analyses, interpretation and reporting the results of the review.

Data extraction and management

A researcher-generated data extraction form (online supplemental appendix 2), for extracting the key characteristics of each study, will be used by the two reviewers. Thereafter, information of included studies will be captured on the researcher-generated data extraction form (online supplemental appendix 3). The information extracted will be, first, the general study details, such as authors, date of study publication, study title, study design and country of study, the exposure assessed and the outcome measures. Second, the study characteristics will be collected, such as sampling method and sample size, and details of the participants (number of participants, age, gender, years of experience, marital status and core job description). Lastly, the details of exposure and the outcome variables will be extracted, that is, the study must report on at least one of the exposure variables in relation to firefighter occupational performance.

Critical appraisal of included studies

The appraisal tool for cross-sectional studies (AXIS) checklist[62] and the Critical Appraisal Skills Programme (CASP) toolkit (Middle Way, Oxford, UK) (https://casp-uk.net/casp-tools-checklists/) will be used to conduct the methodological assessment of each study included. The CASP toolkit (Middle Way, Oxford, UK) has been previously used in systematic reviews on firefighters and tactical personnel to assess study methodologies and allows for fair and equitable assessment of a variety of study types. The AXIS toolkit was shown to be a reliable and valid tool for assessing the quality of cross-sectional studies.[62 63] Both questionnaires assess for overall methodological quality and validity of the studies.[62–64] For questions that are answered dichotomously, an article will be awarded a point of '1' for each question that is answered 'yes', and scored a '0' if 'no' or 'can't tell'. Where the CASP checklist requires written grading, the question will be adapted to a dichotomous rating and, if a rating is not possible, then the question will be excluded from the checklist. The Rayan systematic review manager will be used to record the decisions of the two reviewers. Again, a third reviewer will be used to resolve any disagreements between reviewers.

Publication bias

To assess publication bias, the Begg's funnel chart will be used to perform a visual inspection and evaluation of publication bias on the selected data.

Data synthesis and analysis

The aim of the data analysis and synthesis is to describe, analyse and draw conclusions about the research evidence and to assess the effects of cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters. The synthesis of quantitative data (using a meta-analysis) involves the integration of quantitative findings from multiple studies to achieve coherence.[65 66] Achieving coherence allows a more

profound understanding of the exposure being investigated and the outcome thereof, in this case, firefighter occupational performance.[65] In addition, a systematic review and meta-analysis allows for determining the generalisability and applicability of the results of the review to a certain context or population.[65 66] An inherent limitation of using observational studies, which will make up the majority of the studies in the present review, is that there is usually high heterogeneity between studies and will require more careful consideration when synthesising data, as compared with randomised controlled trials.[57 66]

Once the systematic search of literature is complete and all relevant documents are identified, the process of analysing and synthesising the data will begin. For this review, a systematic synthesis of the results obtained from the literature will be used. The use of a systematic review synthesis allows the researcher to identify, evaluate and summarise similar study findings of all relevant individual studies.[65–67] For dichotomous data, the risk ratio and OR will be generated, whereas for continuous data, the standardised mean difference of estimation will be used to estimate the relationship between the cardiovascular health, musculoskeletal health and physical fitness measures on the occupational performance of firefighters.[68]

Measures of exposure effect

Data will be imported into Review Manager V.5.3 and then analysed.[61] The outcome measure (occupational performance) will be considered as categorical or continuous variables, where applicable. The meta-analyses will be performed on each of the subgroups and is explained in the subsequent section on subgroup analysis. The random-effects model will be used, where significant heterogeneity is found. The effectiveness of the interventions will be calculated as standard mean difference and 95% CI.

Assessment of heterogeneity

Heterogeneity will be evaluated using the χ^2 test and I^2 test.[58] Heterogeneity will be identified through visual inspection of the forest plots to judge the extent of CI overlap, including the I^2 statistic, which calculates heterogeneity across studies. This will measure the impact of heterogeneity of the meta-analysis.[61] The following will be used to explain I^2 statistics:

1. 0%–30%: may not be important.
2. 31%–60%: may indicate moderate heterogeneity.
3. 61%–80%: may indicate substantial heterogeneity.
4. 81%–100%: considerable heterogeneity.

In the case of identified heterogeneity, possible reasons will be determined by assessing individual studies and subgroup characteristics. A meta-analysis will be favoured by a low degree of heterogeneity.[58] However, if there is significant heterogeneity of the included studies, then a descriptive interpretation of the results will be presented. If homogeneity is found in the studies, then a pooled effect will be determined and a fixed-effects model will be used.[58] However, if studies have several intervention effects, then a random-effects model will be preferred.

Subgroup analysis and investigation of heterogeneity

The authors anticipate the following characteristics to introduce clinical heterogeneity, that is, firefighters' age, gender, marital status, years of experience and core job description, and plan to implement subgroup analysis, where possible. Although all exposures will be measured during firefighters' work or simulated performance, the methods used could be different, which will require comparing and converting certain measurements to produce similar findings for comparison. The authors will use Review Manager for the subgroup analysis if there are adequate numbers of included studies.[65 68 69]

Presenting and reporting of results

Generated results will be presented using a combination of figures, graphs and tables. This will include the methods and steps of how studies were sourced and selected using the PRISMA guidelines. Excluded studies and the reasons for exclusion will be tabulated and further explained in the methodology section of the systematic review. In addition, summary tables will be created, if the use of forest plots is not possible or appropriate.

Patient and public involvement

It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

ETHICS AND DISSEMINATION

This study has been granted ethical clearance by the University of the Western Cape (BM21/10/9) and has been registered onto PROSPERO (CRD42021258898). There will be no direct engagement with human subjects. Accessible and published data will be used in the study; thus, no confidentiality or ethical procedures need to be considered for this review.[70]

The results of this review will be obtainable via the University of the Western Cape's repository (https://kikapu.uwc.ac.za/). We will disseminate the findings of in peer-reviewed journals and at national and international conferences. The protocol will form part of a chapter for a doctoral thesis. The information gathered will also be presented in webinars and to local firefighting organisations.

Study status

The study is expected to commence in July 2022 and be completed by December 2022.

DISCUSSION

To the best of the authors' knowledge, no conclusive evidence exists on the relationship between cardiovascular health, musculoskeletal health and physical fitness on the occupational performance of firefighters. As a

consequence, all reviews performed on this subject are at risk of different types of heterogeneity due to various research designs, study settings, as well as of unavoidable bias due to the complicated nature of sampling firefighters, such as the variability in the age, sex and job description of firefighters. The inclusion of only English-language articles may result in the exclusion of relevant studies.

The results of this systematic review can help clarify the relationship between cardiovascular health metrics, musculoskeletal health and physical fitness on occupational performance, either individually or as a collective impact. This review is expected to make a significant contribution to the international scientific literature and will assist policy makers in developing intervention strategies to promote health, wellness and career longevity of firefighters in South Africa, and globally. In addition, the proposed review will assist researchers who wish to design novel primary or secondary studies concerning this issue and, potentially, aid in identifying research gaps for further studies. Reference methodologies will be used to guide the study design from study selection to the synthesis of results, significantly improving the overall reliability and reducibility of the study results. The broad inclusiveness of the current systematic review, such as not having a publication date limit and including studies from multiple global regions, increases the potential applicability and generalisability of the results. In addition, the inclusion of all types of study designs and methodologies allows for a broader scope of applicable articles for selection and screening.

Author affiliations
[1]Department of Sport, Recreation and Exercise Science, University of the Western Cape, Cape Town, Western Cape, South Africa
[2]Non-Communicable Diseases Research Unit, South African Medical Research Council, Cape Town, Western Cape, South Africa
[3]Department of Medicine, University of Cape Town, Cape Town, South Africa
[4]Department of Health and Human Physiological Sciences, Skidmore College, Saratoga Springs, New York, USA
[5]School of Economics and Management, Healthcare Management Program, Open University of Cyprus, Nicosia, Cyprus
[6]Department of Environmental Health, Environmental and Occupational Medicine and Epidemiology (EOME), Harvard T.H. Chan School of Public Health, Boston, Massachusetts, USA
[7]Department of Sport, Recreation and Exercise Science, University of the Western Cape, Bellville, South Africa

Contributors JR will be the primary investigator who will take responsibility for all aspects of the project and independently extract the data, verify the data collected, analyse the results, grade the quality of the data and write up the review; LL is the principal supervisor of the study and will be the adjudicator and resolve any disagreements between the two independent reviewers and be responsible for the final proof-reading of the review. APK is a cosupervisor who will be responsible for oversight of analyses and general guidance in conducting the review and proof-reading the review. DS is a cosupervisor and will provide guidance in completing and proof-reading the review; ESS is a cosupervisor and will provide guidance in completing and proof-reading the review.

Funding The Ryoichi Sasakawa Young Leaders Fellowship Fund (Sylff) Program (Grant number: N/A) and the National ResearchFoundation (Grant number: 141282).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iD
Jaron Ras http://orcid.org/0000-0002-7915-4883

REFERENCES

1 Shin J-H, Lee J-Y, Yang S-H, *et al*. Factors related to heart rate variability among firefighters. *Ann Occup Environ Med* 2016;28:1–9.
2 Smith DL, Barr DA, Kales SN. Extreme sacrifice: sudden cardiac death in the US fire service. *Extrem Physiol Med* 2013;2:1–9.
3 Smith DL, DeBlois JP, Kales SN, *et al*. Cardiovascular strain of firefighting and the risk of sudden cardiac events. *Exerc Sport Sci Rev* 2016;44:90–7.
4 Feairheller DL. Blood pressure and heart rate responses in volunteer firefighters while wearing personal protective equipment. *Blood Press Monit* 2015;20:194–8.
5 Al-Zaiti SS, Carey MG. The prevalence of clinical and electrocardiographic risk factors of cardiovascular death among on-duty professional firefighters. *J Cardiovasc Nurs* 2015;30:440–6.
6 Liao L-M, Al-Zaiti SS, Carey MG. Depression and heart rate variability in firefighters. *SAGE Open Med* 2014;2:2050312114545530:2050312 11454553.
7 Carey MG, Al-Zaiti SS, Dean GE, *et al*. Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. *J Occup Environ Med* 2011;53:928–33.
8 Hom MA, Stanley IH, Rogers ML, *et al*. The association between sleep disturbances and depression among firefighters: emotion dysregulation as an explanatory factor. *J Clin Sleep Med* 2016;12:235–45.
9 Rodrigues S, Paiva JS, Dias D, *et al*. Stress among on-duty firefighters: an ambulatory assessment study. *PeerJ* 2018;6:e5967.
10 Gulliver SB, Zimering RT, Knight J, *et al*. A prospective study of firefighters' PTSD and depression symptoms: the first 3 years of service. *Psychol Trauma* 2021;13:44–55.
11 Ras J, Leach L. Prevalence of coronary artery disease risk factors in firefighters in the city of Cape Town fire and rescue service - A descriptive study. *J Public Health Res* 2021;10:2000.
12 Hunter AL, Chb MB, ShahASv. Fire simulation and cardiovascular health 2017:1284–95.
13 Siddall AG, Stevenson RDM, Turner PJF, *et al*. Physical and physiological performance determinants of a Firefighting simulation test. *J Occup Environ Med* 2018;60:637–43 https://journals.lww.com/joem/Fulltext/2018/07000/Physical_and_Physiological_Performance.10.aspx
14 Skinner TL, Kelly VG, Boytar AN, *et al*. Aviation rescue firefighters physical fitness and predictors of task performance. *J Sci Med Sport* 2020;23:1228–33.
15 Findley BW, Brown LE, Whitehurst M. Age-Group performance and physical fitness in male firefighters. *The Journal of Strength & Conditioning Research* 1995;9 https://journals.lww.com/nsca-jscr/Fulltext/1995/11000/Age_Group_Performance_and_Physical_Fitness_in_Male.12.aspx
16 Nazari G, MacDermid JC, Sinden KE, *et al*. The relationship between physical fitness and simulated Firefighting task performance. *Rehabil Res Pract* 2018;2018:1–7.
17 MacDermid JC, Tang K, Sinden KE, *et al*. Work functioning among firefighters: a comparison between self-reported limitations and functional task performance. *J Occup Rehabil* 2019;29:194–204.

18 NLAM A, Masuri MG. Work-related musculoskeletal disorder (WMSDs) and functional status of firefighters in Klang Valley. Healthscope: The Official Research Book of Faculty of Health Sciences, *UiTM*, 2019. Available: http://healthscopefsk.com/index.php/research/article/view/74 [Accessed 07 Aug 2021].
19 Kodom-Wiredu JK. The relationship between firefighters' work demand and work-related musculoskeletal disorders: the moderating role of task characteristics. *Saf Health Work* 2019;10:61–6.
20 Savall A, Charles R, Bertholon A, *et al*. Volunteer and career French firefighters: cardiovascular risk factors and cardiovascular risk assessment. *Eur J Prev Cardiol* 2020;27:107–9.
21 Nogueira EC, Porto LGG, Nogueira RM, *et al*. Body composition is strongly associated with cardiorespiratory fitness in a large Brazilian military Firefighter cohort: the Brazilian firefighters study. *J Strength Cond Res* 2016;30:33–8 https://journals.lww.com/nsca-jscr/Fulltext/2016/01000/Body_Composition_is_Strongly_Associated_With.5.aspx
22 Martin ZT, Schlaff RA, Hemenway JK, *et al*. Cardiovascular disease risk factors and physical fitness in volunteer firefighters. *Int J Exerc Sci* 2019;12:764–76 http://www.ncbi.nlm.nih.gov/pubmed/31156744%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=
23 Gendron P, Lajoie C, Laurencelle L, *et al*. Cardiovascular disease risk factors in Québec male firefighters. *J Occup Environ Med* 2018;60:e300–6.
24 Soares EMKVK, Smith D, Grossi Porto LG. Worldwide prevalence of obesity among firefighters: a systematic review protocol. *BMJ Open* 2020;10:1–5.
25 Smith DL, Graham E, Stewart D, *et al*. Cardiovascular disease risk factor changes over 5 years among male and female us firefighters. *J Occup Environ Med* 2020;62:398–402 https://journals.lww.com/joem/Fulltext/2020/06000/Cardiovascular_Disease_Risk_Factor_Changes_Over_5.2.aspx
26 Smith DL, Haller JM, Korre M, *et al*. The relation of emergency duties to cardiac death among US firefighters. *Am J Cardiol* 2019;123:736–41.
27 Farioli A, Yang J, Teehan D, *et al*. Duty-related risk of sudden cardiac death among young us firefighters. *Occup Med* 2014;64:428–35.
28 Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep* 1985;100:126–31 https://pubmed.ncbi.nlm.nih.gov/3920711
29 Yu CCW, Au CT, Lee FYF, *et al*. Association between leisure time physical activity, cardiopulmonary fitness, cardiovascular risk factors, and cardiovascular workload at work in firefighters. *Saf Health Work* 2015;6:192–9.
30 Donovan R, Nelson T, Peel J, *et al*. Cardiorespiratory fitness and the metabolic syndrome in firefighters. *Occup Med* 2009;59:487–92.
31 Mehrdad R, Movasatian F, Momenzadeh AS. Fitness for work evaluation of firefighters in Tehran. *Acta Med Iran* 2013;51:265–9.
32 Houck JM, Mermier CM, Beltz NM, *et al*. Physical fitness evaluation of career urban and Wildland firefighters. *J Occup Environ Med* 2020;62:e302–7.
33 Kirlin LK, Nichols JF, Rusk K, *et al*. The effect of age on fitness among female firefighters. *Occup Med* 2017;67:528–33.
34 Noh K, Lee K, Jamrasi P, *et al*. Physical fitness levels of South Korean national male and female firefighters. *J Exerc Sci Fit* 2020;18:109–14.
35 Smith DL. Firefighter fitness: improving performance and preventing injuries and fatalities, 2011. Current sports medicine reports10. Available: https://journals.lww.com/acsm-csmr/Fulltext/2011/05000/Firefighter_Fitness__Improving_Performance_and.13.aspx
36 Soteriades ES, Smith DL, Tsismenakis AJ, *et al*. Cardiovascular disease in US firefighters: a systematic review. *Cardiol Rev* 2011;19:202–15.
37 Al-Zaiti S, Rittenberger JC, Reis SE, *et al*. Electrocardiographic responses during fire suppression and recovery among experienced firefighters. *J Occup Environ Med* 2015;57:938–42.
38 Schmit M, DeBeliso M. The Relationship between Firefighters' Physical Performance Aspects and Simulated Firefighting Demands. *Turkish Journal of Kinesiology* 2019;5:63–75.
39 Smith DL, Haller JM, Benedict R, *et al*. Firefighter incident rehabilitation: interpreting heart rate responses. *Prehosp Emerg Care* 2016;20:28–36.
40 Gordon H, Larivière M. Physical and psychological determinants of injury in Ontario forest firefighters. *Occup Med* 2014;64:583–8.
41 Kleinberg CR, Ryan ED, Tweedell AJ, *et al*. Influence of lower extremity muscle size and quality on Stair-Climb performance in career firefighters. *J Strength Cond Res* 2016;30:1613–8.
42 Nowak A, Molik B, Wójcik A, *et al*. Physical activity and injuries relating to physical fitness of professional firefighters. *Advances in Rehabilitation* 2018;32:13–22.
43 Hong O, Chin DL, Phelps S, *et al*. Occupational injuries, duty status, and factors associated with injuries among firefighters. *Workplace Health Saf* 2012;60:517–23.
44 Frost DM, Beach TAC, Crosby I, *et al*. Firefighter injuries are not just a fireground problem. *Work* 2015;52:835–42.
45 Williams-Bell FM, Villar R, Sharratt MT, *et al*. Physiological demands of the firefighter candidate physical ability test. *Med Sci Sports Exerc* 2009;41:653–62.
46 Sheaff AK, Bennett A, Hanson ED, *et al*. Physiological determinants of the candidate physical ability test in firefighters. *J Strength Cond Res* 2010;24:3112–22.
47 Taylor NAS, Lewis MC, Notley SR, *et al*. A fractionation of the physiological burden of the personal protective equipment worn by firefighters. *Eur J Appl Physiol* 2012;112:2913–21.
48 Nazari G, Lu S, MacDermid JC. Quantifying physiological responses during simulated tasks among Canadian firefighters: a systematic review and meta-analysis. *J Mil Veteran Fam Health* 2021;7:55–75.
49 Mamen A, Oseland H, Medbø JI. A comparison of two physical ability tests for firefighters. *Ergonomics* 2013;56:1558–68.
50 Michaelides MA, Parpa KM, Thompson J, *et al*. Predicting performance on a firefighter's ability test from fitness parameters. *Res Q Exerc Sport* 2008;79:468–75.
51 Chizewski A, Box A, Kesler R, *et al*. Fitness fights fires: exploring the relationship between physical fitness and firefighter ability. *Int J Environ Res Public Health* 2021;18. doi:10.3390/ijerph182211733. [Epub ahead of print: 09 11 2021].
52 Phelps SM, Drew-Nord DC, Neitzel RL, *et al*. Characteristics and predictors of occupational injury among career firefighters. *Workplace Health Saf* 2018;66:291–301.
53 Wynn P, Hawdon P. Cardiorespiratory fitness selection standard and occupational outcomes in trainee firefighters. *Occup Med* 2012;62:123–8.
54 McDonough SL, Phillips JS, Twilbeck TJ. Determining best practices to reduce occupational health risks in firefighters. *J Strength Cond Res* 2015;29:2041–4 https://journals.lww.com/nsca-jscr/Fulltext/2015/07000/Determining_Best_Practices_to_Reduce_Occupational.34.aspx
55 Nazari G, Osifeso TA, MacDermid JC. And comorbidities, and determinants of work limitations among firefighters. *Rehabilitation Research and Practice* 2020;2020:1942513.
56 Bucala M, Sweet E. Obesity in the fire service: an inside look at the perceptions of firefighters towards obesity and other health issues. *Research Square Published Online First* 2019.
57 Stroup DF, Berlin JA, Morton SC. Meta-Analysis of observational studies in EpidemiologyA proposal for reporting. *JAMA* 2000;283:2008–12.
58 Brand RA. Editorial: standards of reporting: the CONSORT, quorum, and STROBE guidelines. *Clinical Orthopaedics and Related Research®* 2009;467:1393–4.
59 Moher D, Liberati A, Tetzlaff J, *et al*. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6:e1000097.
60 Ouzzani M, Hammady H, Fedorowicz Z, *et al*. Rayyan—a web and mobile APP for systematic reviews. *Syst Rev* 2016;5:1–10.
61 Collaboration C. *Review manager (RevMan) version 5.3*. Copenhagen: The Nordic Cochrane Centre, 2014.
62 Downes MJ, Brennan ML, Williams HC, *et al*. Development of a critical appraisal tool to assess the quality of cross-sectional studies (axis). *BMJ Open* 2016;6:e011458.
63 Sanderson S, Tatt ID, Higgins JPT. Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: a systematic review and annotated bibliography. *Int J Epidemiol* 2007;36:666–76.
64 Long HA, French DP, Brooks JM. Optimising the value of the critical appraisal skills programme (CASP) tool for quality appraisal in qualitative evidence synthesis. *Res Methods Med Health Sci* 2020;1:31–42.
65 Gurevitch J, Koricheva J, Nakagawa S, *et al*. Meta-Analysis and the science of research synthesis. *Nature* 2018;555:175–82.
66 Metelli S, Chaimani A. Challenges in meta-analyses with observational studies. *Evid Based Ment Health* 2020;23:83–7.
67 Harris JD, Quatman CE, Manring MM. The American Journal of sports medicine P. *P How to Write a Systematic Review* 2013.
68 Haidich AB. Meta-Analysis in medical research. *Hippokratia* 2010;14:29–37 https://pubmed.ncbi.nlm.nih.gov/21487488
69 Lin L. Comparison of four heterogeneity measures for meta-analysis. *J Eval Clin Pract* 2020;26:376–84.
70 Vergnes J-N, Marchal-Sixou C, Nabet C, *et al*. Ethics in systematic reviews. *J Med Ethics* 2010;36:771–4.