REVIEW

Prevalence of musculoskeletal disorders among Canadian firefighters: A systematic review and meta-analysis

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ABSTRACT

Introduction: Firefighters are set to respond to a number of dynamic demands within their roles that extend well beyond fire suppression. These tasks (i.e., heavy lifting, awkward postures) and their unpredictable nature are likely contributing factors to musculoskeletal disorders (MSDs). Several individual studies have assessed the prevalence of MSDs among Canadian firefighters. Therefore, a systematic review and meta-analysis was conducted to critically appraise the quality of the body of available literature and to provide pooled point- and period-prevalence estimates of anatomical regions of MSDs among Canadian firefighters. **Methods:** The MEDLINE, Embase, PubMed and Web of Science databases were searched from inception to November 2018. Cross-sectional cohort studies with musculoskeletal prevalence estimates (point- and period-) of career/professional firefighters in Canada were identified and critically appraised. MSDs were defined as sprains/strains, fractures/dislocations and self-reported bodily pain (chronic or acute). Period- and point-prevalence estimates were calculated, and study-specific estimates were pooled using a random-effects model. **Results:** Five eligible cohort studies (3 prospective, 2 retrospective) were included, with a total of 4,143 firefighters. The participants had a mean age range of 34 (SD = 8.5) to 42.6 (SD = 9.7) years. The reported types of MSDs included sprain or strain, fractures, head, neck, shoulder, elbow, arm, hand, back, upper thigh, knee, and foot pain. The point-prevalence estimate of shoulder pain was 23.00% (3 studies, 312 of 1,491 firefighters, 95% CI, 15.00–33.00), back pain was 27.0% (3 studies, 367 of 1,491 firefighters, 95% CI, 18.00–38.00), and knee pain was 27.00% (2 studies, 180 of 684 firefighters, 95% CI, 11.00–48.00). The one-year period-prevalence estimate of all sprain/strain injuries (all body parts) was 10.0% (2 studies, 278 of 2,652 firefighters, 95% CI, 7.00–14.00). **Discussion:** High point-prevalence estimates (1 in 4 firefighters) of shoulder-, back-, and knee-related MSDs were identified among Canadian firefighters. This emphasizes the need for early assessment, intervention, and injury prevention strategies that reflect how units work together to maximize ergonomic efficiency and injury prevention.

Key words: acute pain, awkward postures, back pain, Canada, chronic pain, Embase, ergonomic efficiency, firefighters, fractures/dislocations, heavy lifting, injury prevention, knee pain, MEDLINE, multiple injury, musculoskeletal disorders (MSDs), PubMed and Web of Science databases, rehabilitation, self-reported bodily pain, shoulder pain, sprains/strains

RÉSUMÉ

Introduction : Dans le cadre de leur rôle, les pompiers sont appelés à répondre à plusieurs demandes dynamiques qui dépassent nettement l'extinction des incendies. Ces tâches (p. ex., soulèvement de lourdes charges, postures inconfortables) et leur nature imprévisible contribuent vraisemblablement à l'apparition de troubles musculosquelettiques. Plusieurs études distinctes ont évalué la prévalence des troubles musculosquelettiques chez les pompiers canadiens. Les chercheurs ont donc réalisé une analyse systématique et une méta-analyse pour procéder à l'évaluation critique de la qualité des publications scientifiques et ont estimé la prévalence ponctuelle et la prévalence sur une période donnée des régions anatomiques touchées par des troubles musculosquelettiques chez les pompiers canadiens. **Méthodologie :** Les chercheurs ont procédé à une recherche des bases de données MEDLINE, EMBASE, PubMed et Web of Science à compter de leur création jusqu'en novembre 2018. Ils ont extrait les études de cohorte transversales contenant des évaluations de la prévalence de troubles musculosquelettiques (ponctuelle et sur une période donnée) dont sont victimes les pompiers professionnels au Canada et en ont fait l'évaluation critique. Ils ont défini les troubles musculosquelettiques comme des entorses ou des foulures, des fractures ou des dislocations et des douleurs corporelles chroniques ou aiguës autodéclarées. Ils en ont évalué la prévalence ponctuelle et la prévalence sur une période donnée et ont regroupé

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les évaluations propres à chaque étude au moyen d'un modèle à effets aléatoires. **Résultats :** Les chercheurs ont inclus les cinq études de cohorte admissibles (trois études prospectives et deux rétrospectives), pour un total de 4 143 pompiers, d'un âge moyen de 34 ± 8,5 ans à 42,6 ± 9,7 ans. Les types déclarés de troubles musculosquelettiques incluaient les entorses et les foulures, les fractures ainsi que les douleurs à la tête, au cou, à l'épaule, au coude, au bras, à la main, au dos, à la partie supérieure de la cuisse, au genou et au pied. L'évaluation de la prévalence ponctuelle des douleurs à l'épaule s'élevait à 23,00 % (trois études, 312 pompiers sur 1 491, intervalle de confiance à 95 %, 15,00 à 33,00), des douleurs dorsales, à 27,0 % (trois études, 367 pompiers sur 1 491, intervalle de confiance à 95 %, 18,00 à 38,00) et douleur au genou, à 27,00 % (deux études, 180 pompiers sur 684, intervalle de confiance à 95 %, 11,00 à 48,00). La prévalence de l'ensemble des foulures et des entorses (toutes les parties du corps) sur une période d'un an était évaluée à 10,0 % (deux études, 278 des pompiers sur 2 652, intervalle de confiance à 95 %, 7,00 à 14,00). **Discussion :** Les chercheurs ont constaté des évaluations élevées de prévalence ponctuelle (un pompier sur quatre) des troubles musculosquelettiques de l'épaule, du dos et du genou chez les pompiers canadiens. Ces observations font ressortir la nécessité d'adopter des stratégies d'évaluation précoce, d'intervention et de prévention des blessures qui reflètent le travail d'équipe des unités, afin de maximiser l'efficacité ergonomique et la prévention des blessures de cette population.

Mots-clés : blessures multiples, Canada, pompiers, réadaptation, réhabilitation, soulèvement de lourdes charges, postures inconfortables, troubles musculosquelettiques, banques de données MEDLINE, EMBASE, PubMed et Web of Science, entorses ou des foulures, des fractures ou des dislocations et des douleurs corporelles chroniques ou aiguës autodéclarées. des troubles musculosquelettiques de l'épaule, du dos et du genou, l'efficacité ergonomique, prévention

INTRODUCTION

Firefighters are at high risk of sustaining work-related injuries/trauma and this poses major threats to their health.[1–3] Firefighters are required to respond to a vast range of dynamic demands within their roles that extend well beyond fire suppression. Such tasks include ice water rescue, trench rescue, marine rescue, aircraft rescue, motor vehicle accidents, train derailments, automobile extrication, hazardous material, and confined space/high-angle rescue. Firefighting is a dangerous and high-risk profession with tremendous demands on the musculoskeletal system (MSK).[4–6] Such demands are largely due to high on-the-job death rates, unfavourable environment/working conditions, and extreme levels of physical exertion over long periods of time, all while carrying a heavy base load of personal protective equipment (PPE).[4–6] Despite the decline in total number of work-related musculoskeletal disorders (MSDs) injuries among firefighters reported by the National Fire Information Database since 2005, the frequency remains high at 1.5 injuries per firefighter, per reported fire response event in Ontario, Canada.[7]

MSDs (sprains, strains, pain) remain the leading type of injuries sustained during fireground operations (where firefighting operations are performed) among firefighters.[8] The tasks associated with firefighting (i.e., heavy lifting, awkward postures), along with its unpredictable nature and simultaneous exposure to hostile environments, are likely contributing factors.[4] Identifying the prevalence of MSDs among firefighters is crucial to assist the development of injury prevention strategies.

The prevalence of a condition pertains to the proportion of individuals in a population that have a specific condition.[9] Point- and period-prevalence are two distinct measures. Point-prevalence specifies prevalence measured at a particular point in time, whereas period-prevalence denotes prevalence assessed over an interval of time.[9] Such estimates are required for policymakers and health care professionals to enhance the development and delivery of services.[9]

Nearly 80% of Canadian firefighters in small rural communities are volunteers. The 20% of firefighters who perform the job full-time have a more sustained duration and rate of repetitive exposures to the high MSK demands through their role. Several individual studies have assessed the prevalence of MSDs among Canadian firefighters.[4,10–13] While individual studies provide valuable insights, they fail to (1) elucidate both the geographical and anatomical distribution of the condition, (2) compare subgroups, or (3) pool similar studies to provide an estimate from which inferences can be drawn.[9] Therefore, a systematic review and meta-analysis of prevalence studies was conducted in an attempt to:

1. Critically appraise the quality of the body of literature that reports the prevalence of MSDs among Canadian firefighters and;
2. Assess the point- and period-prevalence estimates of geographical and anatomical regions of MSDs among Canadian firefighters.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and the Joanna Briggs Institute [2014] Prevalence Critical Appraisal Checklist

was followed.[9,14] (Protocol registration number: PROSPERO CRD42018104235)

Eligibility criteria

Studies were included in the systematic review if the following criteria were met:

- **Design:** prospective or retrospective cross-sectional cohort studies
- **Participants:** career/professional Canadian firefighters
- **Outcomes:** point- and period-prevalence estimate of MSDs; and
- **Musculoskeletal disorders:** defined as sprains or strains, fractures, or dislocations and self-reported bodily pain (chronic or acute)

Studies that provided no information on the number of uninjured firefighters (required for prevalence calculation) were excluded from the systematic review. Conference abstracts and posters were also excluded.

Information sources

Systematic electronic searches were conducted to identify relevant prospective or retrospective cross-sectional cohort studies in MEDLINE, Embase, PubMed, and Web of Science, from inception until November 2018. Several different combinations of keywords were used, such as "firefighters", "prevalence", "proportion", "musculoskeletal injuries", "sprains", "strains", "joint injuries" and "head/neck/shoulder/arm/elbow/hand/hip/knee/ankle/back injuries/pain". In addition, a search in the clinical trial registers catalogues was conducted, including the World Health Organization (WHO) clinical trial registry and the National Institutes of Health (NIH) clinical trial registry, and a manual search of the references of all the included studies was performed.

Study selection

Two independent reviewers (GN and JM) performed systematic electronic searches in each database and clinical trial registers catalogue. Duplicate studies were identified and removed. Reviewers GN and JM then independently screened the titles and abstracts and retrieved, in full text, any article marked "include" or "uncertain". In the final stage of study selection, an independent full text review was conducted to determine final eligibility.

Data collection process

Two independent researchers (GN and JM) extracted the data from the eligible studies. Data extraction included the author, year, country, study population/setting/type, sample size, age, gender, point-/period-prevalence, types of MSDs, and ascertainment/case definition.[9] When insufficient data was presented, authors were contacted by email and further data was requested.

Assessment of quality of included studies

Two independent review authors (GN and JM) assessed the quality of included studies using the critical appraisal checklist from the Joanna Briggs Institute [2014] Reviewers' Manual.[9] This checklist used a domain-based approach. The evaluation criteria included (1) whether the sample was representative of the target population; (2) if study participants were recruited in an appropriate way (used a stratified random sampling with eligibility criteria to ensure that the sample was representative of the population that researchers were attempting to generalize to); (3) adequacy of sample size; (4) description of study subjects and setting in detail; (5) whether data analysis was conducted with sufficient coverage of the identified sample (was there a large number of dropouts or refusals among the eligible participants that may diminish a study's validity); (6) whether objective, standard criteria were used for measurement of the condition; (7) if the condition was measured reliably; (8) whether appropriate statistical analyses were performed and precision estimates reported; (9) if all important confounding factors/subgroups/differences were identified and accounted for; and (10) whether sub-populations were identified using objective criteria.[9]

Sub-group analysis and exploring heterogeneity

In the presence of heterogeneity, the authors planned to perform subgroup analyses (a priori) based on the duration of MSDs (chronic vs. acute) and gender (males vs. females). An I^2 estimate of at least 50% was interpreted as evidence of a substantial problem with hetero geneity.[15]

Synthesis of results

A total of 30 meta-analyses of studies reporting the prevalence of MSDs among Canadian firefighters were performed. Both period- and point-prevalence estimates were calculated, and study-specific estimates were pooled using a random-effects model. The proportion (random-effects), their weighted proportions, and 95% confidence intervals were summarized in forest plots. The software programs MedCalc bvba, version 16.2.1 (MedCalc Software Ltd., Ostend, BE) and StatsDirect,

version 3 (StatsDirect Ltd., Merseyside, UK) were used to facilitate all statistical analyses.

RESULTS

Study selection

The initial search yielded 256 publications. After removal of duplicates, 185 articles remained and were screened using their title and abstract, leaving 100 articles selected for full text review. A total of 95 studies were excluded due to ineligible population (35 studies), inappropriate study design (3 studies), or lack of MSK prevalence estimates (57 studies). Five studies were eligible to proceed to data extraction and analysis.[4,10–13] The flow of studies through the selection process is presented in Figure 1.

Study characteristics

The 5 eligible cohort studies (3 prospective, 2 retrospective) were conducted between 2015 and 2018 and included 4,143 firefighters.[4,10–13] Participants had a mean age range of 34 (SD = 8.5) to 42.6 (SD = 9.7) years. The reported types of MSDs included sprain or strain, fractures, head, neck, shoulder, elbow, arm, hand, back, upper thigh, knee, and foot pain. Study size ranged from 294 to 1,363 firefighters. Studies were conducted in various provinces across Canada. A summary description of all the included studies is displayed in Table 1.

Critical appraisal of the quality of individual studies

The authors assessed the quality of the included studies using the Joanna Briggs Institute [2014] Prevalence

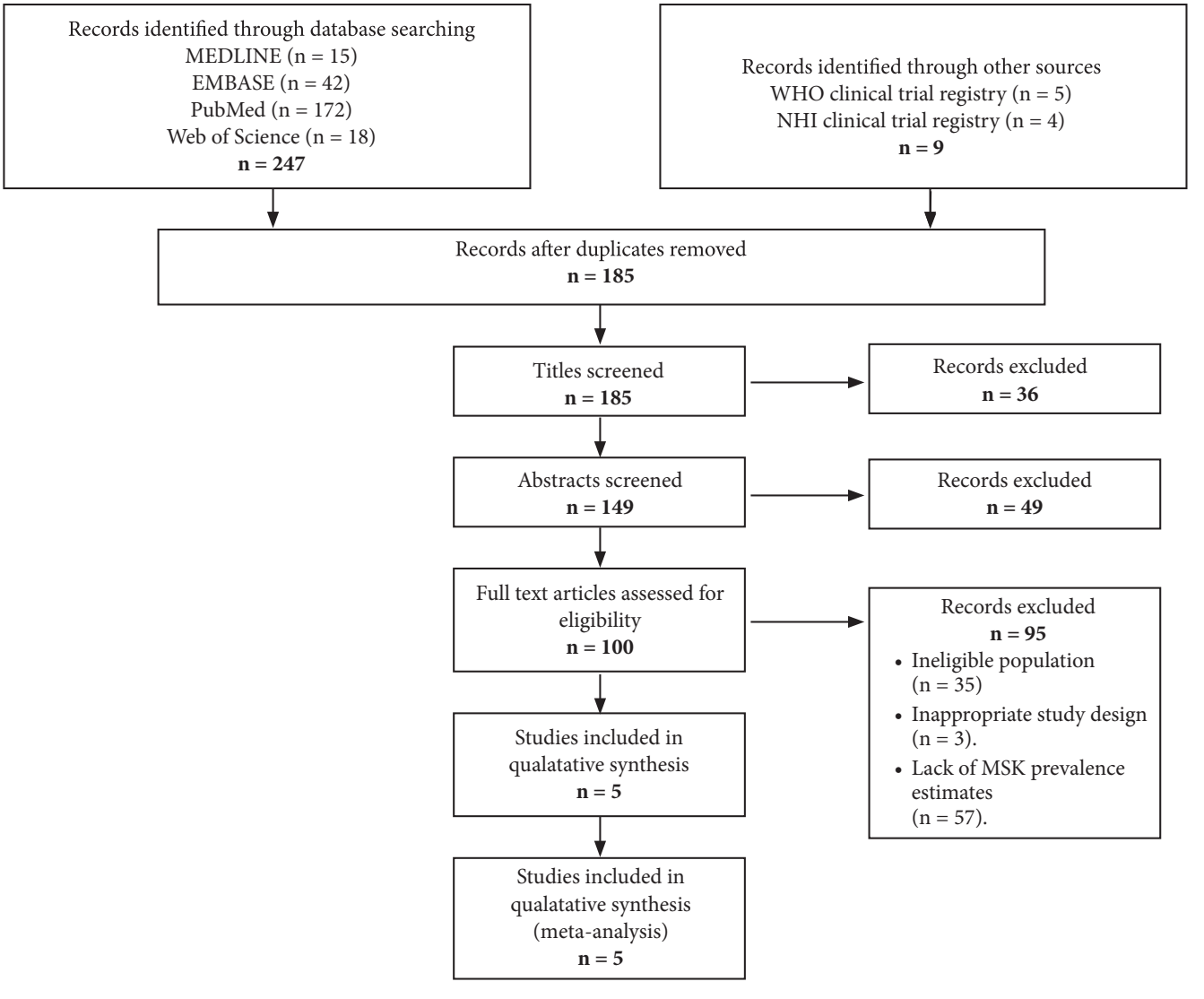

Figure 1. Selection of studies for inclusion in the systematic review

Table 1. Select characteristics of cross-sectional studies reporting on prevalence of musculoskeletal Injuries among firefighters

Study	Population	Prevalence (point- or period-)	Study type	Types of MSDs	Ascertainment / case definition
Frost[11] – Metropolitan Calgary, Alberta	*n* = 1,289	Period-prevalence, 1-year	Retrospective cohort	Sprain or strain, (shoulder, ankle, back, knee sprains); fractures	Secondary analysis of data collected between January 1, 2012 and December 31, 2012 from the injury reports filed by Calgary Fire Department (CFD)
Frost[10] – Metropolitan Calgary, Alberta	*n* = 1,363; 1,336 males, 27 females; age 38 (SD = 9) years	Period-prevalence (2007–2011)	Retrospective cohort	Sprain or strain, (shoulder, ankle, back, knee sprains); fractures	Secondary analysis of data from the injury reports filed by Calgary Fire Department (CFD)
Negm[4] – Career; Hamilton, Ontario	*n* = 294 active-duty firefighters; 283 males, 8 females, 3 not reported; age 42.6 (SD = 9.7) years	Point-prevalence	Prospective cohort	Head, neck, shoulder, elbow, arm, hand, back, upper thigh, knee, and foot pain	Self-reported musculoskeletal disorder questionnaire – pain body diagram on the Iconic Pain Assessment Tool (IPAT); pain felt within the past week
Nazari[13] – Career; across Canada	*n* = 390 firefighters; 272 males, age 41 (SD = 9.5) years; 118 females, age 34 (SD = 8.5) years	Point-prevalence	Prospective cohort	Head, neck, shoulder, elbow, arm, hand, back, upper thigh, knee, and foot pain	Self-reported musculoskeletal disorder questionnaire; pain felt within the past week
Carleton[12] – Urban & rural; across Canada	807 firefighters	Point-prevalence	Prospective cohort	Neck, shoulder, arm and hand, foot, and back pain	Self-reported questionnaire – developed based on the work done International Association for the Study of Pain; pain lasting longer than 3 months

MSD = musculoskeletal disorder

Table 2. Critical appraisal results for included studies using Joanna Briggs Institute [2014] Prevalence Critical Appraisal Checklist

	Study	Frost[11]	Frost[10]	Nazari[13]	Carleton[12]	Negm[4]
Critical assessment components	Was the sample representative of the target population?	Yes	Yes	Yes	Yes	Yes
	Were study participants recruited in an appropriate way?	Yes	Yes	Yes	Yes	Yes
	Was the sample size adequate?	Yes	Yes	Yes	Yes	Yes
	Were the study subjects and setting described in detail?	Unclear	Yes	Yes	Yes	Yes
	Is the data analysis conducted with sufficient coverage of the identified sample?	No	No	Yes	Yes	Yes
	Was the condition measured reliably?	Unclear	Unclear	Yes	Yes	Yes
	Was there appropriate statistical analysis?	Yes	Yes	Yes	Yes	Yes
	Are all important confounding factors/ subgroups/ differences identified and accounted for?	Yes	Yes	Yes	Yes	Yes

Note. The domain "Were subpopulations identified using objective criteria?" was not applicable

Critical Appraisal Checklist (Table 2). The most common flaws noted were (1) not considering an objective, standard criteria for measurement of the condition; (2) lack of clarity on whether data analysis was conducted with sufficient coverage of the identified sample; and (3) how reliably the condition was measured.

Outcomes: MSDs

Overall, 5 cohort studies (3 prospective, 2 retrospective) were included in the review. Two of the included studies reported on the overall and anatomical regions period-prevalence of sprains/strains and fractures/dislocations.[10–11] In these two studies, MSDs were

examined retrospectively using the data extracted from Workers' Compensation forms and injury reports. The remaining three studies reported on the point-prevalence of anatomical bodily pain (head, neck, shoulder, elbow, arm, hand, back, upper thigh, knee, and foot).[4,12–13] In these studies, bodily pain was assessed prospectively through administering self-reported questionnaires.

Point-prevalence of anatomical regions of MSDs

HEAD

When focused on the pain in the head region, the point-prevalence estimate was 6.00% (3 studies, 100 of 1,491 firefighters, 95% CI, 3.00–10.00; I^2 = 87.00%; Table 3). When stratified by male gender and pain

Table 3. Meta-analyses of the point-prevalence of self-reported MSDs among Canadian firefighters

Study	No. of Injuries	No. of Firefighters	Weight (%)	Proportion (%)	95% CI
Body part: Head					
Nazari[13]	15	390	26.00	4.00	2.00–6.00
Negm[4]	12	294	20.00	4.00	2.00–7.00
Carleton[12]	73	807	54.00	9.00	7.00–11.00
Total	100	1,491	100%		
Random-effects model; heterogeneity I^2 = 87.0%, $p < 0.001$				**6.00**	**3.00–10.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	8	272	49.00	2.90	1.30–5.70
Negm[4]	11	283	51.00	3.90	2.00–6.80
Total	19	555	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.55$				**3.60**	**2.20–5.30**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	7	118	93.00	6.00	2.40–11.80
Negm[4]	1	8	7.00	12.50	0.30–52.60
Total	8	126	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.34$				**6.80**	**3.20–11.70**
Body part: Neck					
Nazari[13]	74	390	26.00	19.00	15.00–23.00
Negm[4]	58	294	20.00	20.00	15.00–25.00
Carleton[12]	99	807	54.00	12.00	10.00–15.00
Total	231	1,491	100%		
Random-effects model; heterogeneity I^2 = 86.0%, $p < 0.001$				**17.00**	**12.00–22.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	46	272	49.00	17.00	12.70–21.90
Negm[4]	57	283	51.00	20.00	15.60–25.30
Total	103	555	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.33$				**18.60**	**15.50–22.00**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	28	118	93.00	24.00	16.40–32.40
Negm[4]	1	8	7.00	12.50	0.30–52.70
Total	29	126	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.58$				**23.40**	**16.50–31.00**

MSD = musculoskeletal disorder

duration (past 1 week), the pooled results displayed point estimates of 3.6% (2 studies, 19 of 555 firefighters, 95% CI, 2.20–5.30; I^2 = 0.0%; Table 3). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 6.80% (2 studies, 8 of 126 firefighters, 95% CI, 3.20–11.70; I^2 = 0.0%; Table 3).

NECK

In terms of neck pain, the point-prevalence estimate was 17.00% (3 studies, 231 of 1,491 firefighters, 95% CI, 12.00–22.00; I^2 = 86.00%; Table 3). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 18.60% (2 studies, 103 of 555 firefighters, 95% CI, 15.50–22.00; I^2 = 0.0%; Table 3). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 23.40% (2 studies, 29 of 126 firefighters, 95% CI, 16.50–31.00; I^2 = 0.0%; Table 3).

SHOULDER

For shoulder pain, the point-prevalence estimate was 23.00% (3 studies, 312 of 1,491 firefighters, 95% CI, 15.00–33.00; I^2 = 94.00%; Table 4). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 28.60% (2 studies, 159 of 555 firefighters, 95% CI, 22.00–35.80; I^2 = 71.00%; Table 4). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 23.70% (2 studies, 27 of 126 firefighters, 95% CI, 12.10–37.70; I^2 = 26.50%; Table 4).

ELBOW, ARM, AND HAND

Regarding elbow, arm, and hand regions, the point-prevalence estimate of pain was 17.00% (3 studies, 235 of 1,491 firefighters, 95% CI, 8.00–27.00; I^2 = 96.00%; Table 4). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 18.50% (2 studies, 107 of 555 firefighters, 95% CI, 5.20–37.50; I^2 = 96.0%; Table 4). When stratified by female gender and pain duration (past one week), the pooled results indicated point estimates of 29.20% (2 studies, 14 of 126 firefighters, 95% CI, 0.07–85.00; I^2 = 92.00%; Table 4).

BACK

In terms of back pain, the point-prevalence estimate was 27.0% (3 studies, 367 of 1,491 firefighters, 95% CI, 18.00–38.00; I^2 = 95.00%; Table 5). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 31.60% (2 studies, 175 of 555 firefighters, 95% CI, 27.80–35.50; I^2 = 0.0%; Table 5). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 42.60% (2 studies, 44 of 126 firefighters, 95% CI, 18.70–68.50; I^2 = 63.00%; Table 5).

UPPER THIGH

When focused on the pain in the upper thigh region, the point-prevalence estimate was 6.0% (2 studies, 41 of 684 firefighters, 95% CI, 3.00–11.00; I^2 = 82.00%; Table 5). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 5.80% (2 studies, 33 of 555 firefighters, 95% CI, 2.30–11.00; I^2 = 79.00%; Table 5). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 12.00% (2 studies, 8 of 126 firefighters, 95% CI, 0.30–37.10; I^2 = 70.00%; Table 5).

KNEE

For knee pain, the point-prevalence estimate was 27.00% (2 studies, 180 of 684 firefighters, 95% CI, 11.00–48.00; I^2 = 97.00%; Table 6). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 29.00% (2 studies, 163 of 555 firefighters, 95% CI, 13.80–46.80; I^2 = 95.00%; Table 6). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 21.00% (2 studies, 17 of 126 firefighters, 95% CI, 3.00–48.80; I^2 = 70.00%; Table 6).

FOOT

Regarding the foot region, the point-prevalence estimate of pain was 7.00% (3 studies, 105 of 1,491 firefighters, 95% CI, 6.00–8.00; I^2 = 0.0%; Table 6). When stratified by male gender and pain duration (past 1 week), the pooled results displayed point estimates of 6.80% (2 studies, 37 of 555 firefighters, 95% CI, 4.90–9.10; I^2 = 0.0%; Table 6). When stratified by female gender and pain duration (past 1 week), the pooled results indicated point estimates of 6.30% (2 studies, 7 of 126 firefighters, 95% CI, 2.20–12.50; I^2 = 7.40%; Table 6).

Period-prevalence of sprain/strain injuries

In terms of all sprain/strain injuries (all body parts), the 1-year period-prevalence estimate was 10.0% (2

Table 4. Meta-analyses of the point-prevalence of self-reported MSDs among Canadian firefighters

Study	No. of injuries	No. of firefighters	Weight (%)	Proportion (%)	95% CI
Body part: Shoulder					
Nazari[13]	92	390	26.00	24.00	19.00–28.00
Negm[4]	94	294	20.00	32.00	27.00–38.00
Carleton[12]	126	807	54.00	16.00	13.00–18.00
Total	312	1,491	100%		
Random-effects model; heterogeneity I^2 = 94.0%, $p < 0.001$				**23.00**	**15.00–33.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	68	272	50.00	25.00	20.00–30.60
Negm[4]	91	283	50.00	32.20	26.70–38.00
Total	159	555	100%		
Random-effects model; heterogeneity I^2 = 71.0%, $p = 0.06$				**28.60**	**22.00–35.80**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	24	118	82.00	20.30	13.50–28.70
Negm[4]	3	8	18.00	37.50	8.50–75.50
Total	27	126	100%		
Random-effects model; heterogeneity I^2 = 26.50%, $p = 0.24$				**23.70**	**12.10–37.70**
Body part: Arm, elbow, and hand					
Nazari[13]	38	390	26.00	10.00	7.00–13.00
Negm[4]	85	294	20.00	29.00	24.00–34.00
Carleton[12]	112	807	54.00	14.00	12.00–16.00
Total	235	1,491	100%		
Random-effects model; heterogeneity I^2 = 96.0%, $p < 0.001$				**17.00**	**8.00–27.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	29	272	50.00	10.70	7.30–15.00
Negm[4]	78	283	50.00	27.50	22.40–33.00
Total	107	555	100%		
Random-effects model; heterogeneity I^2 = 96.0%, $p < 0.001$				**18.50**	**5.20–37.50**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	9	118	53.00	7.70	3.50–14.00
Negm[4]	5	8	47.00	62.50	24.50–91.50
Total	14	126	100%		
Random-effects model; heterogeneity I^2 = 92.0%, $p < 0.001$				**29.20**	**0.07–85.00**

MSD = musculoskeletal disorder

studies, 278 of 2,652 firefighters, 95% CI, 7.00–14.00; I^2 = 89.00%; Table 7). Further anatomical region analyses indicated 1-year period-prevalence estimates of 1.30% (shoulder; 2 studies, 35 of 2,652 firefighters, 95% CI, 0.60–2.30; I^2 = 76.00%; Table 7), 2.00% (knee; 2 studies, 51 of 2,652 firefighters, 95% CI, 0.60–4.00; I^2 = 90.00%; Table 7), 3.00% (back; 2 studies, 89 of 2,652 firefighters, 95% CI, 2.00–5.00; I^2 = 64.00%; Table 7), and 2.00% (ankle; 2 studies, 41 of 2,652 firefighters, 95% CI, 1.00–2.00; I^2 = 64.00%; Table 7).

Period-prevalence of fractures/dislocation injuries

When focused on fractures/dislocations (all body parts), the 1-year period-prevalence estimate was 1.00% (2 studies, 26 of 2,652 firefighters, 95% CI, 0.70–1.40; I^2 = 4.50%; Table 8).

DISCUSSION

This systematic review and meta-analysis of MSDs found high point-prevalence estimates of neck, shoulder, arm/elbow/hand, back, and knee pain among both male and female Canadian firefighters. In addition, high period-prevalence (1 year) estimates of sprain/strain injuries (1 in 10 firefighters) were found. These findings represent a unique synthesis of the evidence and put an emphasis on the importance of developing firefighter-specific rehabilitation and injury prevention programs.

The conduct of reliable and valid epidemiologic studies is required to describe and compare the prevalence of MSDs among various populations. Such studies can then be used for identification of risk factors and development of injury prevention and rehabilitation programs. In this review, the point-prevalence estimates of pain in regions of neck (17.00%), shoulder (23.00%), arm/elbow/hand (17.00%), back (27.00%), knee (27.00%), and foot (7.00%) were nearly 1 to 4 times higher than that of the general population in

Table 5. Meta-analyses of the point-prevalence of self-reported MSDs among Canadian firefighters

Study	No. of injuries	No. of firefighters	Weight (%)	Proportion (%)	95% CI
Body part: Back					
Nazari[13]	123	390	26.00	32.00	27.00–36.00
Negm[4]	96	294	20.00	33.00	27.00–38.00
Carleton[12]	148	807	54.00	18.00	16.00–21.00
Total	367	1,491	100%		
Random-effects model; heterogeneity I^2 = 95.0%, $p < 0.001$				**27.00**	**18.00–38.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	84	272	49.00	31.00	25.40–36.70
Negm[4]	91	283	51.00	32.20	26.70–38.00
Total	175	555	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.75$				**31.60**	**27.80–35.50**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	39	118	66.00	33.00	24.70–42.30
Negm[4]	5	8	34.00	62.50	24.50–91.50
Total	44	126	100%		
Random-effects model; heterogeneity I^2 = 63.0%, $p = 0.10$				**42.60**	**18.70–68.50**
Body part: Upper thigh					
Nazari[13]	16	390	57.00	4.00	2.00–7.00
Negm[4]	25	294	43.00	9.00	6.00–12.00
Total	41	684	100%		
Random-effects model; heterogeneity I^2 = 82.0%, $p = 0.02$				**6.0**	**3.00–11.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	10	272	50.00	3.70	1.80–6.65
Negm[4]	23	283	50.00	8.10	5.20–12.00
Total	33	555	100%		
Random-effects model; heterogeneity I^2 = 79.00%, $p = 0.03$				**5.80**	**2.30–11.00**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	6	118	63.00	5.10	1.90–10.70
Negm[4]	2	8	37.00	25.00	3.20–65.10
Total	8	126	100%		
Random-effects model; heterogeneity I^2 = 70.0%, $p = 0.07$				**12.00**	**0.30–37.10**

MSD = musculoskeletal disorder

Canada (neck pain 5.40%; shoulder pain 6.10%; arm/elbow/hand pain 7.40%; back pain 22.30%; knee pain 9.50%; foot pain 3.40%).[16] Although these proportions cannot, statistically, be directly compared to the general population estimates in 2007–2008, they do appear higher.[16] Similarly, the 10% period-prevalence (1-year) estimates of sprain/strain injuries among firefighters were much higher than that of the general population estimates of approximately 5.5% in Canada in 2009–2010.[17]

The quality of the included studies was assessed using the Joanna Briggs Institute [2014] Prevalence Critical Appraisal Checklist (Table 2). Use of the Joanna Briggs Institute domain-based tool revealed that the most common limitation was not considering an objective, standard criteria for measurement of the condition, found in two retrospective cohort studies of the five studies included. The Frost 2015 and 2016 studies both involved secondary analyses of data collected from the injury reports filed within the Calgary Fire

Table 6. Meta-analyses of the point-prevalence of self-reported MSDs among Canadian firefighters

Study	No. of injuries	No. of firefighters	Weight (%)	Proportion (%)	95% CI
Body part: Knee					
Nazari[13]	70	390	57.0	18.0	14.0–22.0
Negm[4]	110	294	43.0	37.0	32.0–43.0
Total	180	684	100%		
Random-effects model; heterogeneity I^2 = 97.0%, $p < 0.001$				**27.0**	**11.00–48.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	56	272	50.00	20.50	16.00–26.00
Negm[4]	107	283	50.00	38.00	32.10–43.70
Total	163	555	100%		
Random-effects model; heterogeneity I^2 = 95.0%, $p < 0.001$				**29.00**	**13.80–46.80**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	14	118	63.00	12.00	6.60–19.10
Negm[4]	3	8	37.00	37.50	8.50–75.50
Total	17	126	100%		
Random-effects model; heterogeneity I^2 = 70.0%, $p = 0.06$				**21.00**	**3.00–48.80**
Body part: Foot					
Nazari[13]	23	390	26.0	6.0	4.0–9.0
Negm[4]	21	294	20.0	7.0	4.0–11.0
Carleton[12]	61	807	54.0	8.0	6.0–10.0
Total	105	1,491	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.58$				**7.00**	**6.00–8.00**
Subgroup analysis stratified by gender (male) and duration of self-reported MSD (past 1 week)					
Nazari[13]	17	272	49.00	6.30	3.70–9.80
Negm[4]	20	283	51.00	7.10	4.40–10.70
Total	37	555	100%		
Random-effects model; heterogeneity I^2 = 0.0%, $p = 0.70$				**6.80**	**4.90–9.10**
Subgroup analysis stratified by gender (female) and duration of self-reported MSD (past 1 week)					
Nazari[13]	6	118	90.00	5.10	1.90–10.70
Negm[4]	1	8	10.00	12.50	0.30–52.70
Total	7	126	100%		
Random-effects model; heterogeneity I^2 = 7.40%, $p = 0.30$				**6.30**	**2.20–12.50**

MSD = musculoskeletal disorder

Department. However, it was unable to be determined if the measurement tools used were validated instruments, limiting the ability to speak to outcome assessment validity.

Despite the decline in the total number of firefighter injuries reported by the National Fire Protection Association in the United States, firefighter injuries remain high. A total of 62,085 injuries were reported in the United States in 2016.[18] Furthermore, the major types of injuries received during fireground operations were strain, sprain and muscular pain 45.7%.[8] This U.S. data was comparable with the results found by the authors. Similarities exist between individuals in the firefighting profession, the military, and

Table 7. Meta-analyses of the period-prevalence (1 year) sprains/strains among Canadian firefighters

Study	No. of injuries	No. of firefighters	Weight (%)	Proportion (%)	95% CI
All body parts					
Frost[11]	159	1,289	49.00	12.00	11.00–14.00
Frost[10]	119	1,363	51.00	9.00	7.00–10.00
Total	278	2,652	100%		
Random-effects model; heterogeneity I^2 = 89.00%, $p < 0.001$				**10.00**	**7.00–14.00**
Body part: Shoulder					
Frost[11]	23	1,289	49.00	2.00	1.10–2.60
Frost[10]	12	1,363	51.00	0.80	0.40–1.50
Total	35	2,652	100%		
Random-effects model; heterogeneity I^2 = 76.0%, $p = 0.04$				**1.30**	**0.60–2.30**
Body part: Knee					
Frost[11]	36	1,289	49.00	3.00	2.00–4.00
Frost[10]	15	1,363	51.00	1.00	0.60–2.00
Total	51	2,652	100%		
Random-effects model; heterogeneity I^2 = 90.00%, $p < 0.001$				**2.00**	**0.60–4.00**
Body part: Back					
Frost[11]	51	1,289	49.00	4.00	3.00–5.00
Frost[10]	38	1,363	51.00	3.00	2.00–4.00
Total	89	2,652	100%		
Random-effects model; heterogeneity I^2 = 64.0%, $p = 0.10$				**3.00**	**2.00–5.00**
Body part: Ankle					
Frost[11]	17	1,289	49.00	1.00	0.80–2.10
Frost[10]	24	1,363	51.00	2.00	1.00–3.00
Total	41	2,652	100%		
Random-effects model; heterogeneity I^2 = 64.0%, $p = 0.10$				**2.00**	**1.00–2.00**

MSD = musculoskeletal disorder

Table 8. Meta-analyses of the period-prevalence (1 year) fractures among Canadian firefighters

All body parts					
Study	No. of injuries	No. of firefighters	Weight (%)	Proportion (%)	95% CI
Frost[11]	10	1,289	49.00	0.70	0.40–1.40
Frost[10]	16	1,363	51.00	1.10	0.60–2.00
Total	26	2,652	100%		
Random-effects model; heterogeneity I^2 = 4.50%, $p = 0.30$				**1.00**	**0.70–1.40**

professional sports, in that all involve extended periods of training, conduct of heavy and repetitive tasks, and extreme physical exertions; however, athletes are not exposed to occupational loads. Soldiering, or a career in the military, is extremely challenging, considering its high operational tempo and wide spectrum of mission requirements.[19] In addition, members of the armed forces must attain and maintain high levels of physical readiness to be able to carry out their operational tasks.[19]

Likewise, professional athletes train and practice constantly and are expected to be in top physical condition. The results from this review were comparable across both military and athletic populations, when considering different point- and period-prevalence studies. When considering point-prevalence, the bodily pain point estimates (shoulder 23.0%; neck 17.0%) identified in our review were comparable to the 2009 Lew study of 340 U.S. Veterans, with point-prevalence estimates of shoulder 21.0% and neck 19.0%.[20] However, a higher point-prevalence estimate of back pain (58.0%) was reported relative to this study (27.0%).[20] In terms of period-prevalence estimates and comparison with military and athletic populations, estimates of sprain/strain injuries (10.0%) in this review were also similar to the period-prevalence estimates reported in the literature. Jacobsson et al.[21] noted that the period-prevalence (1 year) estimate of sprain/strain injuries among 276 Swedish elite track and field athletes was 8.5%. Lovalekar et al.[22] reported that the period-prevalence (1 year) estimate of sprain/strain injuries among 210 Naval Special Warfare Sea, Air, and Land (SEAL) operators was 9.5% (20 of 210 SEALs)[22] and 10.6% (48 of 451 soldiers) for sprain/strain injuries among the 451 soldiers from the Army 101st Airborne (Air Assault) Division.[23] Abt[24] noted that the period-prevalence (1 year) estimate of sprain/strain injuries among 106 U.S. Army Special Operations Command (USASOC) special forces soldiers was 8.5% (9 of 106 soldiers).[24] It is important to note that the period-prevalence estimate of sprain/strain injuries in this review (10.0%; 278/2,652 firefighters, substantial heterogeneity I^2 = 89%), based on two retrospective cohort studies, was consistent with similar high-demand occupational (military) estimates.

Firefighter-related studies tend to exclude women from statistical analyses due to inadequate sample size (underpowered), which ultimately leads to a lack of data concerning female firefighters. Furthermore, it is important to distinguish the prevalence of MSDs by anatomical regions between male and female firefighters. Therefore, in this review, the authors planned a priori to conduct subgroup analysis by sex (male and female) to address these issues. It was identified that the point-prevalence of shoulder- and knee-related MSDs were higher in male firefighters, by 5% and 8%, respectively. Conversely, head-, neck-, arm/elbow/hand-, back- and upper thigh-related MSDs were more prevalent in female firefighters by 3%, 5%, 10.7%, 11% and 6%, respectively. These findings highlight the high prevalence of MSDs among firefighters who are already at an elevated risk of sustaining MSDs, compared to the general Canadian population.

Identifying prevalence estimates and distribution of MSDs is necessary to assist the development of data-driven rehabilitation programs.[25–26] In this review, nearly 1 out of 4 Canadian firefighters reported having suffered from shoulder, back or knee pain in the past three months. Therefore, physical therapists and other health care providers, and personnel with a keen understanding of the occupational knowledge and specific biomechanical requirements of the MSK system, are indicated in the design and implementation of rehabilitation programs that take into account firefighters' demands and occupational requirements. The standard of physical performance to which they need to return after injury must be front of mind in effective service delivery for firefighters.

When interpreting the results of this review, it is important to note that heterogeneity was high in the analyses. High heterogeneity was explained/reduced by sex (male or female) and duration of MSDs (acute or chronic) in the subgroup analyses. However, subgroup analyses are inherently underpowered, and caution must be used when interpreting prevalence estimates.

Firefighting tasks, such as hose dragging or stair climbing with a high-rise pack, have been reported to be physiologically demanding, necessitating firefighters to work at near maximal heart rates.[5–6] Sex is believed to have an impact on fitness levels. Fitness profiles of female firefighters consistently differ in comparison to their male counterparts, in terms of cardiovascular levels, muscle strength and endurance.[27] Furthermore,

there are biomechanical strategies that are distinct among male and female firefighters. For example, in needing to pull up to a window, a male firefighter might use his upper body to achieve the task, whereas a female firefighter might rely on core and leg strength. In addition, female firefighters also employ compensatory strategies, such as bodily momentum, to achieve task completion.[27] This review highlights the need for early assessment and intervention; assessing how firefighters carry out tasks; injury prevention strategies that reflect gender differences in biomechanics; and re-evaluating how units work together to maximize ergonomic efficiency and injury prevention. Furthermore, "women firefighters are not just 'size small' men"[28] and PPE needs to be both functional, as well as safe, in order to ensure firefighter health. The implications are very real in the potential for non-gender-sensitive PPE to enhance risk.

CONCLUSION

This systematic review provides evidence of the prevalence of MSDs among Canadian firefighters. Overall, high point-prevalence estimates (one in four firefighters) of shoulder-, back- and knee-related MSDs were found among Canadian firefighters. The point-prevalence of shoulder- and knee-related MSDs were higher in male firefighters, whereas head-, neck-, arm/elbow/hand-, back-, and upper thigh-related MSDs were more prevalent in female firefighters. Furthermore, the period-prevalence of sprain/strain injuries were also noticeably high (1 in 10 firefighters).

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COMPETING INTERESTS

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CONTRIBUTORS

Goris Nazari conceived and designed the study and acquired and analyzed data. Joy MacDermid was

partially involved in study design, data analysis and revised the article for important intellectual content and approved the final version submitted for publication. Heidi Cramm was heavily involved in interpretation of the data; she also provided important intellectual content and approved the final version submitted for publication.

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