Prevalence of musculoskeletal disorders among perioperative nurses: a systematic review and meta-analysis

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Abstract

Background

To evaluate the prevalence of work-related musculoskeletal disorders (WRMSDs) in perioperative nurses and to explore their association with personal characteristics.

Methods

Medline, Cumulative Index to Nursing and Allied Health Literature, Scopus, Web of Science, Cochrane Library and Joanna Briggs Institute Database were systematically searched. A meta-analysis calculating event rates, and relative 95% Confidence Intervals (CI) was performed for each musculoskeletal district. The contribution of perioperative nurses’ gender, age, and BMI was assessed through a meta-regression.

Results

Twenty-two studies, considering 3405 perioperative nurses, were included in the systematic review. The highest prevalence of WRMSDs was found for the lower-back (61%; 95% CI 0.52–0.70), followed by shoulder (45%; 95% CI 0.38–0.53), waist (45%; 95% CI 0.34–0.57), knee (45%; 95% CI 0.32–0.54), neck (39%; 95% CI 0.27–0.52), upper-back (34%; 95% CI 0.24–0.46), ankle-feet (33%; 95% CI 0.18–0.51), hand-wrist (29%; 95% CI 0.19–0.41), and elbow (18%; 95% CI 0.11–0.27). Meta-regression showed that gender, age, and BMI were not significant predictors of low-back disorders (p = 0.69; R² = 0).

Conclusions

WRMSDs represent a high prevalence issue among perioperative nurses. Perioperative nurses, in general, are steadily exposed to both physical and temporal risk factors. Several interventions may be adopted to reduce the burden of WRMSDs, including ergonomic education and physical rehabilitation. Our data could be used in future studies as a reference to assess the risk of WRMSDs in other health-care professionals’ population.

Background

Musculoskeletal disorders have been considered as an impactful occupational problem among most working categories [1, 2]. Work-related musculoskeletal disorders (WRMSDs) is an umbrella term for symptoms caused or worsened by work. These disorders are defined as discomfort, impairment, disability or persistent pain in the locomotor system [3].

Furthermore, WRMSDs are a social and economic issue due to their impact on mental and physical health [4]. In fact, they are reported to significantly influence the quality of life, resulting in different
degrees of disability, long-term diseases, work restrictions, high treatment costs, absenteeism or even transfers to other jobs [5].

Even if the general population also experience musculoskeletal disorders, some working groups are more encountered with those diseases. Recent studies have shown that physical factors, such as bending and twisting, manual handling, forceful movements are cardinal determinants of musculoskeletal disorders [2, 6]. From this perspective, no wonder that nurses, the largest professional group in health care system, have high incidence rates of musculoskeletal disorders. Nursing has been recognized as a physically demanding work and one of the jobs that continuously face high risks of WRMSDs.

Several studies have focused on the prevalence and risk factors of musculoskeletal disorders among nurses [7, 8]. On the other hand, few studies have been conducted internationally among perioperative nurses. In the operating room environment, the nurse's professional role involves care planning for patients in response to their needs. Working in the operating room carries its own risk of developing musculoskeletal disorders due to the exposure to additional risk factors such as prolonged standing and awkward posture during surgeries. To our knowledge, no literature review has previously been conducted to determine the occurrence of WRMSDs in this peculiar population.

Thus, the aim of this systematic review and meta-analysis is to evaluate the prevalence of work-related musculoskeletal disorders in perioperative nurses and to explore their association with personal characteristics.

**Methods**

Methods of the analysis and inclusion criteria were specified in advance and documented in a protocol, registered on Prospero (https://www.crd.york.ac.uk/PROSPERO; registration number: CRD42019121982). This systematic review was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [9]. No ethics approval was needed as all data were obtained from publicly available sources of information.

**Inclusion criteria**

- **Population:** perioperative nurses, including operating room nurses, scrub nurses, circulating and anesthesia nurses and perioperative technicians, without age and ethnic restrictions.
- **Exposure:** operating room environment
- **Outcomes:** identify the magnitude and characteristics of WRMSDs in perioperative nurses, define the personal characteristics related to musculoskeletal disorders and evaluate the relationships between the health effects/risk factors and working conditions.

**Exclusion criteria**
Articles related exclusively to musculoskeletal injuries and studies from non-peer reviewed journals will be excluded. Nurses working in home care were not be considered. No limit of publication date was affixed.

**Information sources**

Studies were identified by searching electronic databases, scanning reference lists of articles and through consultation with experts in the field. An expert librarian was involved in the search. A systematic search of Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus, Web of Science, Cochrane Library and Joanna Briggs Institute (JBI) Database was conducted from January 2019 to February 2019. A limited update literature search was performed on 31 June 2020. These comprehensive databases were selected because those are broad and extensive in the field of health and nursing sciences. The initial search was applied to Pubmed and then adapted to the other databases.

**Search strategy**

We used the following terms to search all database: perioperative nursing, musculoskeletal diseases, occupational diseases, musculoskeletal pain, cumulative trauma disorders. The complete list of the search strings for Pubmed in Online Resource 1.

**Study selection**

Following the search, all identified citations were gathered and uploaded on Mendeley Desktop (version 1.19.3; 2008–2018 Mendeley Ltd) and duplicates were removed. Two independent reviewers (MC, AG) screened titles and abstracts for assessment against the inclusion criteria. Afterwards, selected full texts were assessed in detail by two independent reviewers (MC, AG). Any disagreements arisen between the reviewers at any stage of the study selection process were solved through discussion, or with a third reviewer (GG).

**Data collection process and quality appraisal**

We developed a data extraction sheet (based on JBI Data Extraction Form for Review for Systematic Reviews and Research Syntheses [10], pilot-tested it on some randomly-selected included studies, and refined it accordingly. One review author (AG) extracted the following data (authors, year, country, setting/context, sample size, participants-characteristics/total number, results/findings divided by musculoskeletal districts, outcome assessed, appraisal, methods of analysis) from included studies and a second author (MC) checked the extracted data. Disagreements were resolved by discussion between the two review authors; if no agreement could be reached, a third author (GG) decided the data to be included. Five authors were contacted for further information. All answered, and one provided numerical data that were only presented graphically in the published paper.

Studies quality was appraised through the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies by the National Heart, Lung and Blood Institute. Two independent reviewers assessed the quality. Studies could be rated as good, fair or poor-quality basing on the reviewers assessment of risk of bias in the studies due to flaws in study design or implementation.
**Statistical analysis**

Period prevalence, quantified as event rates in 12 months, was the primary measure of WRMSDs occurrence. Proportion meta-analyses were performed by using the statistical software R version 3.6.3, using meta and metafore packages. All the studies presenting comparable outcomes were included. Event rates, and relative 95% Confidence Intervals (CI) were calculated. The Cochran Q and the $I^2$ were used to evaluate heterogeneity of studies. In order to tackle potential sources of heterogeneity between studies, the random effects model was used to combine studies if heterogeneity was shown (Cochran Q $p < 0.10$ and $I^2 > 50%$)(11). Moreover, to assess whether or not the publication bias was present, statistical analyses and graphs representing funnel plots were performed. Lastly, to examine the contribution of perioperative nurses’ personal characteristics (gender, age, and BMI) to the heterogeneity in study findings, a meta-regression was performed. P-values $< 0.05$ were considered statistically significant.

**Results**

The literature research yielded a total of 2328 citations. Twelve additional citations were added by checking the references of relevant papers and hand-searching for studies that have cited these papers. After adjusting for duplicates and screening by title, 354 articles remained. Of these, 271 studies were discarded after reviewing the abstracts. The full text of the remaining 83 citations was examined in detail. Then, 59 studies were excluded as described: 27 were not quantitative studies, 17 did not fulfill the inclusion criteria, and 15 had no pertinent data to extract. Finally, a total of 22 studies were identified for inclusion in the systematic review (Fig. 1) [12–33]

The studies were published from 2007 to 2019. They all used a cross-sectional design but Bakola et al. [29] that used a prospective design and Keriri et al. [20] that added a nested case control study to the cross-sectional design. The total sample of perioperative nurses included was 3405; most were female (77%), with a mean age of 37.8 years.

Mean seniority, calculated as years working as a perioperative nurse, was 11.32 years, working on average 7.7 hours/day. Most of the studies participants had a normal BMI (range: 22.8–26.9).

To evaluate the prevalence of WRMSDs, nine studies [12, 16, 18–20, 23, 27, 29, 31] used Research-Made Questionnaire (R-M Q), eight [13, 14, 17, 21, 25, 26, 28, 30] Nordic Musculoskeletal Questionnaire (NMQ), one [15] Musculoskeletal Symptoms Survey (MSS), one [22] American National Standards Institute Z-365 (ANSI Z-365), one [24] North American Spine Society-Questionnaire (NAAS-Q), one [28] Rapid Entire Body Assessment (REBA), one [33] Modify Oswestry Low Back Pain Disability Questionnaire (MOLBPDQ), one [32] Disabilities of the Arm, Shoulder and Hand (DASH). Moreover, two studies [25, 26] added a clinical examination to define the magnitude of WRMSDs.

A significant association between WRMSDs and perioperative nurses’ personal characteristics was reported in five studies for female gender [17, 20, 21, 28, 32] and age [16, 17, 19, 25, 28], in four studies for
BMI [17, 25, 27, 28], in two studies for seniority [25, 30] and number of working hours [21, 32].

All the studies had a fair quality rating. The complete critical appraisal is reported in Online Resource 2.

A detailed summary of the characteristics of the included studies is reported in Table 1.
| Author/Year                  | Country     | Study design                           | Sample size/gender/age | BMI | Data assessment | Critical appraisal |
|------------------------------|-------------|----------------------------------------|------------------------|-----|----------------|--------------------|
| Ruzafa-Martinez et al. (2003)| Spain       | cross-sectional                        | 24 PNs: 22 F; 2 M     | *   | R-M Q          | fair               |
| Bos et al. (2007)            | Netherlands | cross-sectional                        | 381 PNs: 324 F; 57 M. Age: 40 ± 10 | 24 ± 4 | NMQ           | fair               |
| Meijsen et al. (2007)        | Netherlands | cross-sectional                        | 463 PNs: 394 F; 69 M. Age: 36 ± 10,3 | *   | NMQ           | fair               |
| Sheikhzadeh et al. (2009)    | US          | cross-sectional                        | 32 PNs. Age: 43,9 ± 9,1 | *   | MSS           | fair               |
| Choobineh et al. (2010)      | Iran        | cross-sectional                        | 375 PNs: 249 F; 126 M. Age: 31,54 ± 8,46 | 22,83 ± 3,35 | NMQ     | fair               |
| Moscato et al. (2010)        | Italy       | cross-sectional                        | 185 PNs: 73 F; 112 M. Age: 36,08 ± 7,08 | M   | 22,60 ± 3,21 R-M Q | fair               |
|                             |             |                                        |                        | F   | 25,5 ± 3,75  |                    |
| Aljeesh et al. (2011)        | Palestine   | cross-sectional                        | 143 PNs: 33 F; 110 M. Age: 33,7 ± 9,59 | 26,6 ± 4,5  | R-M Q          | fair               |
| Simonsen et al. (2012)       | Sweden      | cross-sectional                        | 99 PNs                 | *   | R-M Q          | fair               |
| Hinmikaiye et al. (2012)     | Nigeria     | cross-sectional                        | 80 PNs: 56 F; 24 M.    | *   | R-M Q          | fair               |
| Keriri et al. (2013)         | Saudi Arabia| cross-sectional + nested case control  | 126 PNs: 99 F; 27 M. Age: 34,03 ± 8,02 | 24,93 ± 4,49 | R-M Q          | fair               |
| Arsalani et al. (2014)       | Iran        | cross-sectional                        | 117 PNs                | *   | NMQ           | fair               |
| Ryu et al. (2014)            | South Korea | cross-sectional                        | 35 PNs: 35 F           | *   | ANSI Z-365    | fair               |
| Nützi et al. (2015)          | Switzerland | cross-sectional                        | 116 PNs: 97 F; 19 M. Age: 39,9 ± 11,9 | *   | NAAS-Q         | fair               |
| Author/Year               | Country | Study design | Sample size/gender/age                | BMI | Data assessment | Critical appraisal |
|--------------------------|---------|--------------|---------------------------------------|-----|-----------------|---------------------|
| Uğurlu et al. (2015)     | Turkey  | cross-sectional | 74 PNs: 46 F; 28 M. Age: 29,3 ± 6,7 | *   | R-M Q           | fair                |
| Arvidsson et al. (2016)  | Sweden  | cross-sectional | 305 PNs: 305 F. Age: 47 ± 10         | 24 ± 4 | CE + NMQ      | fair                |
| Asadi et al. (2016)      | Iran    | cross-sectional | 45 PNs                              | *   | R-M Q           | fair                |
| El Ata et al. (2016)     | Egypt   | cross-sectional | 184 PNs: 155 F; 29 M. Age: 20–50 yrs | < 30 | CE + NMQ      | fair                |
| Bakola et al. (2017)     | Greece  | prospective   | 44 PNs: 35 F; 9 M. Age: 42,7 ± 5,5    | 24,7 ± 4,3 | R-M Q        | fair                |
| Mahmoudifar et al. (2017)| Iran    | cross-sectional | 50 PNs                              | *   | NMQ + REBA      | fair                |
| Nasiri-Ziba et al. (2017)| Iran    | cross-sectional | 133 PNs: 103 F; 30 M. Age: 29,13 ± 6,8 | 23,06 ± 2,7 | NMQ            | fair                |
| Jeyakumar et al. (2018)  | US      | cross-sectional | 250 PNs: 220 F; 30 M                 | 24,5 | MOLBPDAQ       | fair                |
| Clari et al. (2019)      | Italy   | cross-sectional | 148 PNs: 117 F; 31 M                | *   | DASH           | fair                |

*Data not available.

BMI: Body Mass Index, M: Male, F: Female, PNs: perioperative nurses, R-M Q: Research-Made Questionnaire, NMQ: Nordic Musculoskeletal Questionnaire, MSS: Musculoskeletal symptom Survey, ANSI Z-365: American National Standards Institute Z-365, NAAS-Q: North American Spine Society-Questionnaire, CE: Clinical Examination, REBA: Rapid Entire Body Assessment, MOLBPDAQ: Modify Oswestry Low Back Pain Disability Questionnaire, DASH: Disabilities of the Arm, Shoulder and Hand.

**Meta-analysis**

Table 2 shows the 12 months prevalence of WRMSDs in the identified 9 musculoskeletal districts.

Lower back issues were the most present WRMSD with a 61% prevalence from 16 studies [13, 14, 26–30, 33, 15–17, 19, 20, 23–25]. Shoulder, waist, and knee had a 45% prevalence, followed by neck (39%), upper-back (34%), ankle-feet (33%), hand-wrist (29%), and elbow (18%). The forest plots illustrate the meta-analyses of the nine musculoskeletal districts’, grouped into upper-limbs (Fig. 2), back (Fig. 3), and lower-limbs (Fig. 4).
There was evidence of significant heterogeneity ($I^2 > 50\%$) in all the meta-analyses performed. The funnel plots for all the meta-analyses were scattered and asymmetrical, representing a possible presence of reporting bias.

Due to the limited number of studies considering perioperative nurses characteristics, it was possible to perform a meta-regression for low back district only. This meta-regression showed that gender, age, and BMI were not significant predictors of low back disorders ($p = 0.69; R^2 = 0$).

### Table 2
Twelve-month prevalence of WRMSDs in musculoskeletal districts

| Musculoskeletal districts | Studies (n) | Total sample | Event rate | 95% C.I. | Heterogeneity | Studies ID |
|--------------------------|------------|--------------|------------|----------|---------------|------------|
| Neck                     | 10         | 1756         | 0.39       | 0.27–0.52 | 95            | (13,15,17,24–26,28–30,32) |
| Shoulder                 | 9          | 1374         | 0.45       | 0.38–0.53 | 84            | (15,17,24–26,28–30,32) |
| Elbow                    | 7          | 958          | 0.18       | 0.11–0.27 | 88            | (15,17,25,28–30,32) |
| Hand-Wrist               | 9          | 1204         | 0.29       | 0.19–0.41 | 94            | (15,17,24–26,28–30,32) |
| Upper-Back               | 7          | 850          | 0.34       | 0.24–0.46 | 89            | (15,17,19,24,25,28,29) |
| Lower-Back               | 16         | 2811         | 0.61       | 0.52–0.70 | 95            | (13,14,26–30,33,15–17,19,20,23–25) |
| Waist                    | 6          | 876          | 0.45       | 0.34–0.57 | 90            | (15,17,24,25,29,30) |
| Knee                     | 7          | 926          | 0.45       | 0.32–0.54 | 92            | (15,17,24,25,28–30) |
| Ankle-Feet               | 8          | 1231         | 0.33       | 0.18–0.51 | 97            | (15,17,24–26,28–30) |

### Discussion

This systematic review and meta-analysis evaluated the prevalence of WRMSDs in perioperative nurses and their association with personal characteristics. Musculoskeletal disorders are one of the highest contributors to global disability. [34] Recently, the World Health Organization estimated that between 20–33% of general population live with a painful musculoskeletal condition [35]. In particular, WRMSDs remain the most common work-related health problem in the European Union and workers in all sectors and occupations can be affected. Of all workers in the European Union with a work-related health problem, 60% identify musculoskeletal disorders as their most serious issue [6].
Specifically, health-care professionals might be at high risk of incurring in musculoskeletal disorders (36). Our results are in line with literature for other health-care professionals. According to a recent systematic review, nearly three out of four nurses employed in a hospital, suffered from pain or discomfort in at least one of any of musculoskeletal district during the past 12 months of work (5). In this review, the three musculoskeletal districts mostly affected where: lower back (65.3%), knees (56.2%) and neck (49.8%) (5). Also, results from a cross-sectional study conducted on nursing aides working in nursing homes showed that 87.4% of the study population experienced musculoskeletal disorders in the previous year (lower back 41.4%, shoulders 53%, knees 37.5%) [37]. Furthermore, a high prevalence of WRMSD has been also observed in X-ray technologists with an overall 12-months prevalence of low back pain of 75.1% and a 64.2% of the neck-shoulder segment [13]. In particular, the operating room setting appears to be at high risk of developing WRMSDs. Epstein et al. reported, among a large sample of surgeons and interventionalists, an overall 12-month prevalence of neck pain of 60%, of shoulder pain of 52%, of back pain of 49% and of upper extremities of 35% [38].

The highest prevalence of musculoskeletal disorders in the working population is attributable to disorders at the back district. Consistently, the general population shows a low back pain life-time prevalence between 51–90% [39]. Just for the low back district, it has been estimated that approximately $50 billion per year is spent in the United States [40]. Nursing has been identified amongst the top professions at risk of low back pain [41]. Our results showed that more than 60% of perioperative nurses suffered from work-related low back pain and this is particularly relevant if we consider that perioperative nurses, in general, could be highly exposed to both physical and temporal risk factors, such as low temperature, highly repetitive tasks at high force, often using vibrating instruments. Furthermore, perioperative health-care professionals have to maintain static postures during surgical procedures for an extended time [42]. The impossibility of switching body positions is a relevant contributor to fatigue and health problems related to the low back district [43].

Several personal characteristics could be related to WRMSDs. Among these characteristics, the female gender seems to be associated with a greater risk of lower-back problems both in nurses [44, 45] and in the population of operating room nurses [17, 20, 21, 24, 28, 32]. Despite this, in our review female gender was not a significant predictor of low back disorders. Traditionally, gender has not been considered a predictor of WRMSDs, but a confounding or modifying factor due to the mixed exposure to work and extra-work activities. However, according to some recent studies, employed women seem to have an increased risk of WRMSDs, in particular in the upper-body musculoskeletal district. The most likely explanation of the increased risk of WRMSDs in female workers might be the differences in somatic, hormonal, and psychological aspects. Furthermore, women are more prone to WRMSDs in cold working environments [46] and there can be differences in repetitive procedures used between male and female gender [47]. Moreover, women are usually more in charge of the domestic work, and this further burden could increase musculoskeletal issues [48]. The combined work-home exposure to musculoskeletal demands could also reduce the opportunity for recovery time, and for strengthening body muscles with a higher risks of overweight consequences [49].
Percentages of overweight and obesity are high among employed adults with rising rates over the past few decades (50, 51). Several studies have linked a high BMI with musculoskeletal disorders and the repetitive work (52, 53). This statement could have been true especially for our population, particularly exposed to prolonged repetitive tasks in awkward postures. Surprisingly, although some studies [17, 25, 27, 28] considered in our meta-analysis reported an association between an increased BMI and WRMDs, the meta-regression results did not confirm this assumption. This might be due to a younger age of perioperative nurses compared to other nursing roles [54], and that the BMI alone could not represent a reliable predictor.

It is also known that musculoskeletal disorders related to work are a major cause of disability in older workers [55]. In this regard, more than one third of the nursing workforce in the United States is between the ages of 50 and 64 [56]. In our sample, mean age was lower with an average age of 36.7 years. This could be explained in part by the fact that perioperative nurses begin their career usually right after the graduation. And that through the years they usually change their position from the operation room to outpatients’ settings, usually with minor physical burden. This assumption could explain the absence of association in the meta-regression. Only a few studies [16, 17, 19, 27, 28] have shown a correlation between age and WRMSDs.

In the operating room setting several interventions may be adopted to reduce WRMSDs with a multidisciplinary approach. In this regard, environmental and ergonomic factors should be taken into great consideration. Particular attention should be given to the evaluation of repetitive motions and prolonged restricted posture, handling heavy weight, forceful gripping, low temperatures, the use of vibrating instruments and to the frequency, intensity, and duration of each task performed at work. Possible ergonomic interventions to minimize risks and reduce the incidence of work-related low back disorders should include: propping alternating feet on foot stools, using anti-fatigue mats, using sit/stand stools, and limiting standing times, wearing appropriate footwear, implementing postural exercises such as regular contraction and relaxation of muscles during the surgical procedures [57]. Moreover, perioperative nurses could benefit from ergonomic education and physical rehabilitation, if needed. Also, organizational strategies can be adopted to allow a more effective management of human resources, especially when assigning workers to specific jobs or tasks such as job mechanization, job rotation, job enlargement, and the design of a safe work environment [58].

This review has some potential limitations. Data from the articles included in the meta-analysis may not represent the general population heterogeneously, in fact about a quarter of the studies were conducted in Iran, limiting the generalizability due to contextual factors. The high heterogeneity in the meta-analyses could be related to the different clinical settings where the studies were conducted. It was not possible to stratify by surgical specialties due to the lack of data. Also, within the same surgical specialty the surgical procedures could differ between countries or for the adoption of specific surgical technique. Furthermore, the role of perioperative nurses could differ between countries. Moreover, prevalence of WRMSDs was assessed through self-reported measures, further studies using clinical examination could increase the reliability of findings. Lastly, the lack of data from included studies could have limited the
results of the meta-regression. Despite these limitations, this is the first systematic review conducted on this topic providing a meta-analysis.

**Conclusions**

WRMSDs represent a high prevalence issue among perioperative nurses. The musculoskeletal districts mostly affected were lower back, shoulder, waist, and knee. Age, gender and BMI seem not to be related to WRMSDs prevalence. Ergonomic, organizational, and preventive measures need to be implemented to reduce the WRMSDs burden in perioperative nurses. Our data could be used in future studies as a reference to assess the risk of WRMSDs in other health-care professionals’ population.

**Abbreviations**

Work-related musculoskeletal disorders (WRMSDs), Confidence Intervals (CI), Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), Cumulative Index to Nursing and Allied Health Literature (CINAHL), BMI: Body Mass Index, PNs: perioperative nurses, R-M Q: Research-Made Questionnaire, NMQ: Nordic Musculoskeletal Questionnaire, MSS: Musculoskeletal symptom Survey, ANSI Z-365: American National Standards Institute Z-365, NAAS-Q: North American Spine Society-Questionnaire, CE: Clinical Examination, REBA: Rapid Entire Body Assessment, MOLBPDQ: Modify Oswestry Low Back Pain Disability Questionnaire, DASH: Disabilities of the Arm, Shoulder and Hand.

**Declarations**

**Ethics approval and consent to participate**

not applicable

**Consent for publication**

not applicable

**Availability of data and materials**

The majority of data generated or analysed during this study are included in this published article [and its supplementary information files]. Further datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

All authors declare that they have no conflict of interest.

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This study did not received any funding.
Authors' contributions

MC, AG and GG designed the work and made substantial contribution to its conception and development. GV, GM and MRG performed the statistical analyses. MC, AG and GV drafted the paper. AG, CC and VD critically revised the manuscript and helped to realize the final draft.

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Figures
Figure 1

Literature review flow-diagram

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed.1000097
Figure 2a: Neck

| Study name       | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|------------------|------------|----------|------------------------|------|--------|
| Sheikzadeh 2009  | 0.715      | [0.545, 0.844] | 32 | 8.88% |
| Choubineh 2010   | 0.440      | [0.361, 0.541] | 375 | 10.80% |
| Nüzi 2015        | 0.054      | [0.025, 0.112] | 112 | 8.64% |
| Arvidsson 2015   | 0.380      | [0.328, 0.439] | 305 | 10.64% |
| El Ata 2016      | 0.572      | [0.469, 0.642] | 180 | 10.60% |
| Bahro 2017       | 0.477      | [0.398, 0.551] | 44  | 9.37% |
| Mahmoudifar 2017 | 0.440      | [0.312, 0.577] | 50  | 9.61% |
| Naasri-Ziba 2017 | 0.414      | [0.333, 0.499] | 133 | 10.90% |
| Clari 2019       | 0.056      | [0.028, 0.106] | 144 | 9.14% |

Random effects model: 0.389 [0.275; 0.516] 100.00%
Heterogeneity: $I^2 = 55\%$, $t^2 = 0.8240, p < 0.001$

Figure 2b: Shoulder

| Study name       | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|------------------|------------|----------|------------------------|------|--------|
| Sheikzadeh 2009  | 0.750      | [0.579, 0.897] | 32 | 7.01% |
| Choubineh 2010   | 0.517      | [0.457, 0.577] | 375 | 13.48% |
| Nüzi 2015        | 0.384      | [0.296, 0.475] | 112 | 11.52% |
| Arvidsson 2015   | 0.441      | [0.386, 0.497] | 304 | 13.27% |
| El Ata 2016      | 0.611      | [0.538, 0.675] | 180 | 12.54% |
| Bahro 2017       | 0.455      | [0.317, 0.569] | 44  | 9.11% |
| Mahmoudifar 2017 | 0.300      | [0.191, 0.438] | 50  | 8.60% |
| Naasri-Ziba 2017 | 0.346      | [0.270, 0.430] | 133 | 11.89% |
| Clari 2019       | 0.361      | [0.297, 0.442] | 144 | 12.00% |

Random effects model: 0.415 [0.383; 0.529] 100.00%
Heterogeneity: $I^2 = 84\%$, $t^2 = 0.5185, p < 0.001$

Figure 2c: Elbow

| Study name       | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|------------------|------------|----------|------------------------|------|--------|
| Sheikzadeh 2009  | 0.531      | [0.364, 0.691] | 32 | 13.72% |
| Choubineh 2010   | 0.229      | [0.150, 0.275] | 375 | 17.04% |
| El Ata 2016      | 0.239      | [0.162, 0.309] | 180 | 15.48% |
| Bahro 2017       | 0.227      | [0.128, 0.327] | 44  | 13.03% |
| Mahmoudifar 2017 | 0.080      | [0.032, 0.158] | 50  | 10.51% |
| Naasri-Ziba 2017 | 0.113      | [0.070, 0.178] | 133 | 15.09% |
| Clari 2019       | 0.040      | [0.024, 0.067] | 144 | 13.15% |

Random effects model: 0.180 [0.113; 0.273] 100.00%
Heterogeneity: $I^2 = 86\%$, $t^2 = 0.4418, p < 0.001$

Figure 2d: Hand-Wrist

| Study name       | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|------------------|------------|----------|------------------------|------|--------|
| Sheikzadeh 2009  | 0.625      | [0.453, 0.771] | 32 | 10.19% |
| Choubineh 2010   | 0.472      | [0.422, 0.523] | 375 | 12.25% |
| Nüzi 2015        | 0.098      | [0.056, 0.197] | 112 | 10.95% |
| Arvidsson 2016   | 0.404      | [0.356, 0.451] | 304 | 12.11% |
| El Ata 2016      | 0.522      | [0.450, 0.594] | 180 | 12.02% |
| Bahro 2017       | 0.318      | [0.200, 0.456] | 44  | 10.90% |
| Mahmoudifar 2017 | 0.100      | [0.043, 0.214] | 50  | 9.08% |
| Naasri-Ziba 2017 | 0.353      | [0.277, 0.438] | 133 | 11.82% |
| Clari 2019       | 0.125      | [0.061, 0.186] | 144 | 11.27% |

Random effects model: 0.289 [0.193; 0.410] 100.00%
Heterogeneity: $I^2 = 94\%$, $t^2 = 0.5933, p < 0.001$

**Figure 2**

Meta-analysis of the prevalence of upper-limbs work-related musculoskeletal disorders for the neck (2a), shoulder (2b), elbow (2c), and hand-wrist (2d) musculoskeletal districts
Figure 3a: **Upper-Back**

| Study name          | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|---------------------|------------|----------|-----------------------|------|--------|
| Sheikzadeh 2009     | 0.438      | [0.282; 0.607] |                        | 32   | 12.66% |
| Choobineh 2010      | 0.547      | [0.496; 0.596] |                        | 375  | 16.47% |
| Hinmikaiye 2012     | 0.351      | [0.240; 0.481] |                        | 57   | 14.06% |
| Nützli 2015         | 0.205      | [0.141; 0.289] |                        | 112  | 14.79% |
| El Ata 2016         | 0.372      | [0.305; 0.445] |                        | 180  | 15.94% |
| Bakola 2017         | 0.250      | [0.146; 0.394] |                        | 44   | 12.81% |
| Mahmoudifar 2017    | 0.260      | [0.159; 0.396] |                        | 50   | 13.27% |

**Random effects model** 0.343 [0.241; 0.461]  
Heterogeneity: $I^2 = 89\%$, $\tau^2 = 0.3756$, $p < 0.001$


Figure 3b: **Lower-Back**

| Study name          | Event rate | 95% CI   | Event rate and 95% CI | Size | Weight |
|---------------------|------------|----------|-----------------------|------|--------|
| Bos 2007            | 0.766      | [0.721; 0.806] |                        | 381  | 6.69%  |
| Meijsen 2007        | 0.581      | [0.536; 0.625] |                        | 463  | 6.76%  |
| Sheikzadeh 2009     | 0.844      | [0.682; 0.931] |                        | 32   | 4.81%  |
| Choobineh 2010      | 0.605      | [0.555; 0.653] |                        | 375  | 6.73%  |
| Moscato 2010        | 0.173      | [0.125; 0.234] |                        | 185  | 6.43%  |
| Hinmikaiye 2012     | 0.772      | [0.648; 0.862] |                        | 57   | 5.82%  |
| Keriri 2013         | 0.516      | [0.429; 0.601] |                        | 126  | 6.49%  |
| Nützli 2015         | 0.527      | [0.435; 0.617] |                        | 112  | 6.45%  |
| Ugurlu 2015         | 0.622      | [0.508; 0.724] |                        | 74   | 6.22%  |
| Arvidsson 2016      | 0.401      | [0.348; 0.457] |                        | 304  | 6.70%  |
| Asadi 2016          | 0.667      | [0.521; 0.786] |                        | 45   | 5.82%  |
| El Ata 2016         | 0.761      | [0.694; 0.818] |                        | 180  | 6.51%  |
| Bakola 2017         | 0.773      | [0.630; 0.872] |                        | 44   | 5.57%  |
| Mahmoudifar 2017    | 0.500      | [0.366; 0.634] |                        | 50   | 6.00%  |
| Nasiri-Ziba 2017    | 0.421      | [0.341; 0.506] |                        | 133  | 6.50%  |
| Jeyakumar 2018      | 0.840      | [0.789; 0.880] |                        | 250  | 6.51%  |

**Random effects model** 0.615 [0.521; 0.701]  
Heterogeneity: $I^2 = 95\%$, $\tau^2 = 0.5562$, $p < 0.001$

**Figure 3**

Meta-analysis of the prevalence of upper-limbs work-related musculoskeletal disorders for the neck (2a), shoulder (2b), elbow (2c), and hand-wrist (2d) musculoskeletal districts
Figure 4

Meta-analysis of the prevalence of lower-limbs work-related musculoskeletal disorders for the waist (4a), knee (4b), and ankle-feet (4c) musculoskeletal districts

Supplementary Files
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