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# Associations between physical or psychosocial risk factors and work-related musculoskeletal disorders in construction workers based on literature in the last 20 years: A systematic review

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**Abstract**

The current systematic review aimed to summarize prevalence rates of work-related musculoskeletal disorders (WRMSDs) and quantify the associations between physical or psychosocial risk factors and WRMSDs in construction workers. Literature searches were conducted in Web of Science, PubMed, Medline, CINAHL, and EMBASE from 1st January 2000 to 30th September 2020. The methodological quality of the included studies was assessed by a validated risk of bias assessment tool used in population-based prevalence studies. Nineteen cross-sectional studies and one cohort study involving 194,863 participants were included. Eleven, five, and four included studies were classified as having high, moderate, and low quality, respectively. The 12-month prevalence rates of WRMSDs in construction workers were high (ranging from 25% to 96%). There was strong evidence to support the relationships between awkward postures (e.g., twisting, bending, or cramping positions) [odd ratio (OR)=2.4], manual material handling (MMH) (OR=2.2), prolonged works (OR=4.0), high job demands (OR 1.6) or mental stress (OR 1.8) and WRMSDs in construction workers. Additionally, there was moderate evidence for the associations between overhead works (OR=3.1), use of vibration (OR=3.2), or low job satisfaction (OR=1.5) and WRMSDs in construction workers. Furthermore, there was very limited evidence for the associations between repetitive works, low job control, or high job insecurity and WRMSDs in construction workers. Although many physical and psychosocial risk factors were associated with WRMSDs in construction workers, the causal relationships between these factors and the prevalence of WRMSDs remain unclear. Future prospective

studies should determine whether these factors can predict future WRMSDs and whether the modification of these factors can reduce the incidence and/or prevalence of WRMSDs in construction workers.

**Keywords:** Ergonomics; Occupational Health; Physical risk factors; Prevalence; Psychosocial risk factors; Work-related musculoskeletal disorders

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## 1. Introduction

Work-related musculoskeletal disorders (WRMSDs) refer to a wide range of degenerative and/or inflammatory conditions affecting joints, muscles, ligaments, cartilage, and blood vessels (Bulduk et al., 2017, Eatough et al., 2012, Kee and Karwowski, 2007). WRMSDs are the leading cause of disability among construction workers (Roja et al., 2017, Wang et al., 2017). The prevalence of WRMSDs is very high among construction workers worldwide (Kim et al., 2011, Punnett and Wegman, 2004). For example, the prevalence rates of WRMSDs in Hong Kong (3-month prevalence) (Yi and Chan, 2016), Ethiopia (12-month prevalence) (Lette et al., 2018), Taiwan (12-month prevalence) (Leung et al., 2012), and Malaysia (12-month prevalence) (Deros et al., 2014) were 41%, 36%, 68%, and 76%, respectively. A study found that approximately 77% of American construction workers reported at least one musculoskeletal symptom in the last 12 months (Goldsheyder et al., 2004).

In addition to physical agony, WRMSDs can lead to huge financial burdens and work absenteeism in the construction industry (Cheng et al., 2010). It has been estimated that more than US$400 million of workers' compensation is incurred annually due to WRMSDs in the US construction industry (Bhattacharya, 2014). Okenwa Emegwa (2014) found that approximately 85% of sick leave cases in the Swedish construction industry were related to WRMSDs. These findings highlight the huge negative impacts of WRMSDs on the economy and productivity in the construction industry.

Since construction workers are often exposed to multiple physical risk factors (such as awkward posture, vibration, kneeling, contact stress, environmental risk, static force, prolonged standing, sitting,

bending, twisting, as well as carrying and lifting heavy objects) (Antwi-Afari et al., 2017, Engholm and Holmström, 2005, Inyang et al., 2012, McGaha et al., 2014, Salas et al., 2016), physical exposures may be the leading cause of WRMSDs in construction workers. Low back, neck, and upper extremities are the most commonly affected body parts (Alghadir and Anwer, 2015, Holmström and Engholm, 2003, Umer et al., 2018, Villumsen et al., 2015, Widanarko et al., 2011). Non-neutral body postures during construction works may increase the risk of developing WRMSDs (Buchholz et al., 1996, Forde and Buchholz, 2004, Punnett and Wegman, 2004, Takala et al., 2010). Overhead work is also known to be a contributing factor for developing shoulder and neck pain among construction workers (Charles et al., 2018, Engholm and Holmström, 2005). Additionally, a prior narrative review suggested that vibration and awkward postures were related to shoulder and neck pain among workers in different industries (Charles et al., 2018). Therefore, reliable physical risk assessments are recommended to identify construction workers at risk of WRMSDs in different construction trades (Golabchi et al., 2017).

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have made recommendations for general ergonomic practices to reduce risk exposures associated with various WRMSDs, and to minimize the impact of occupational hazards on the development of WRMSDs in construction workers (Albers, 2007). Early evaluation/identification of potential physical risk factors for WRMSDs has been recommended at the construction planning stage (Golabchi et al., 2015), while some strategies (such as prevention through design) are suggested to minimize physical exposures that may lead to WRMSDs in construction workers (Golabchi et al., 2017).

However, since different construction trades may have different physical risks, it is necessary to identify trade-specific physical risk factors to develop tailored occupational guidelines.

Although a recent literature review has compared various assessment techniques in evaluating the risk of WRMSDs in the construction industry (Wang et al., 2015), it did not summarize the prevalence estimates of WRMSDs and the evidence regarding the associations between physical or psychosocial risk factors and WRMSDs in construction workers of different trades. To help refine the existing occupational guidelines for construction workers, the current systematic review aimed to summarize the prevalence rates of WRMSDs and to synthesize the levels of evidence regarding the associations between various physical or psychosocial risk factors and WRMSDs among construction workers in different trades.

## 2. Methods

### *2.1. Search strategies*

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) (Panic et al., 2013). This systematic review protocol has been registered in PROSPERO (CRD42019135027) and is available at http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019135027. Two independent reviewers (SA and AM) searched five electronic databases (i.e., Web of Science, PubMed, Medline, CINAHL, and EMBASE) for relevant studies published between 1st January 2000 and 30$^{th}$ September 2020. This period was chosen because many articles published in the last two decades focused on ergonomic analysis of construction workers. The major keywords (including ergonomics, occupational,

musculoskeletal disorders, and construction workers) and their similar derivatives were used for the search. The complete search strategies used in the current review is provided in **Table S1**. Backward and forward reference searching of the included studies were conducted to identify additional potential articles (Hu et al., 2011). The corresponding authors of the included studies were contacted to seek recently accepted relevant papers.

*2.2. Selection criteria*

Potential articles were included based on the following criteria: (1) population: workers working in any construction trades; (2) publication years: between 2000 and 2020; (3) types of study: observational (cohort or case-control studies), or cross-sectional studies (these types of studies are important for evaluating the associations between physical risk factors and WRMSDs in construction workers); (4) published in English language; and (5) WRMSD related outcomes including musculoskeletal pain, repetitive motion injuries, repetitive strain injuries, regional musculoskeletal disorders, and soft tissue disorders. Included papers had to report associations between physical or psychosocial exposures and WRMSDs. Additionally, case reports, editorials, letters to the editor, and conference proceedings were excluded due to the potentially high risk of bias.

*2.3. Study selection and data extraction*

Two independent reviewers (SA and AM) screened the titles and abstracts for potential articles based on the selection criteria. Full texts of potential articles were then retrieved and reviewed. Any disagreements

were resolved by a third reviewer (AW). The agreement between reviewers at each stage of the review process was analyzed by Kappa statistics (Ben-David, 2008).

Data extracted from each study included: authors, year of publication, country, population, study design, sample size, ergonomic risk exposures, incidence and prevalence of WRMSDs, as well as strengths of associations between exposure to physical or psychosocial risk factors and WRMSDs [e.g., odd ratios (ORs)] among construction workers.

*2.4. Quality assessments*

The two independent reviewers evaluated the methodological quality of each included study using a risk of bias tool, which was developed by Hoy et al. (2012) for evaluating the risk of bias in epidemiological studies. This tool has been used in multiple systematic reviews of epidemiological studies (Fayaz et al., 2016, Thomas et al., 2015). The tool comprises 10 items in two sub-categories including the assessments of four external validity items and six internal validity items. (**Table S2**) (Hoy et al., 2012). The tool has demonstrated an excellent inter-rater reliability with a Kappa statistic of 0.83 (95% CI, 0.78–0.88) for the 10 individual items, a good inter-rater reliability with a weighted Kappa statistic of 0.48 (95% CI, 0.31–0.64) for the evaluation of overall methodological quality (Hoy et al., 2012). The included studies were rated as high (++, low risk of bias), moderate (+, moderate risk of bias), or low quality (-, high risk of bias) (Hoy et al., 2012). A study was considered to have a high risk of bias if it met $\leq$4 criteria in the risk of bias tool, moderate risk of bias if it met 5 or 6 criteria, and low risk of bias if it met $\geq$ 7 criteria (Fayaz et al., 2016, Thomas et al., 2015).

142 *2.5. Levels of evidence for each risk factor*

143 The levels of evidence for physical or psychosocial risk factors for WRMSDs in construction workers
144 were examined based on four criteria modified from Bongers et al. (2002): (1) consistency of findings
145 across relevant included studies; (2) strength of the associations; (3) the quality of those studies; and (4)
146 the study design. In particular, more weight was given to longitudinal and observational studies, quality
147 score of 60% or higher, and at least 75% of the included studies had to report associations between physical
148 or psychosocial risk factors and WRMSDs to qualify the consistency of findings. Additionally, in the
149 current review, the updated method guidelines for systematic reviews in the Cochrane collaboration back
150 review group method to determine levels of evidence for each risk factor was used (Jun et al., 2017, Van
151 Tulder et al., 2003). This method classifies the levels of evidence as: (1) strong evidence: consistent
152 narrative findings in multiple high-quality studies; (2) moderate evidence: consistent findings from multiple
153 studies with at least one high-quality study; (3) limited evidence: consistent findings from multiple
154 moderate- or low-quality studies; (4) very limited evidence: results obtained from one moderate- or low-
155 quality study; and (5) Conflicting evidence: inconsistent findings (Jun et al., 2017, Van Tulder et al., 2003).

156 **3. Results**

157 *3.1. Study selection and characteristics*

158 After removing duplicates from 777 identified studies, 486 titles and abstracts were screened (**Figure**
159 **S1**). Of 96 potential full-text articles, 20 studies involving approximately 194,863 participants were
160 included in this review. There were high agreements between the two independent reviewers in the title,

abstract, and full-text screening (all kappa coefficients, ≥0.83). Characteristics of the included studies are presented in **Table 1**. The included studies were conducted in 11 countries/regions including Denmark, India, Japan, Lithuania, the Netherland, Nigeria, Sweden, Taiwan, Thailand, Trinidad, and the USA. While 13 included studies were cross-sectional, six and one included studies were an observational and a longitudinal survey, respectively. Participants' ages ranged from 16 years to 66 years. Most of the included studies only recruited male participants (female participants, <1%). Response rates of surveys in the included studies ranged between 55% and 100%.

*3.2. Risk of bias of the included studies*

The risks of bias scores of the included studies are presented in **Table 2**. The two independent reviewers showed high agreements in their risk of bias assessments (kappa coefficient = 0.86). Eleven studies were considered to have a low risk of bias, five had a moderate risk, and four had a high risk. More than 50% of the included studies failed to meet most of the external validity criteria.

*3.3. Subjective assessments of incidence/prevalence of WRMSDs*

Seven included studies used the Nordic musculoskeletal disorder questionnaire to determine the prevalence of WRMSDs in construction workers (Ekpenyong and Inyang, 2014, Elders and Burdorf, 2004, Jensen and Kofoed, 2002, Kaminskas and Antanaitis, 2010, Lee et al., 2005, Merlino et al., 2003, Neeraja and Swarochish, 2014). Three included studies used self-designed questionnaires (Engholm and Holmström, 2005, Hanklang et al., 2014, Kaneda et al., 2001), two used the modified Iowa construction questionnaire (Goldsheyder et al., 2002, Goldsheyder et al., 2004), and one study (Egwuonwu et al., 2016)

used the short version Dutch musculoskeletal questionnaire to evaluate the prevalence of WRMSDs in construction workers (Table S5). The Nordic musculoskeletal disorder questionnaire is a reliable and valid self-reported tool to assess the prevalence of WRMSDs in many industries, including construction. The reported kappa coefficients between test and retest scores of this questionnaire ranged from 0.63 to 1.00, indicating a moderate to almost perfect agreement (Fang et al., 2013, Kuorinka et al., 1987, Mesquita et al., 2010). Two included studies reported fair to substantial test-retest reliability of the modified Iowa construction questionnaire (Kappa coefficients between test and retest scores = 0.36 to 0.81)(Goldsheyder et al., 2002, Goldsheyder et al., 2004). The short version Dutch musculoskeletal questionnaire showed good test-retest reliability (Kappa coefficients between test and retest scores = 0.83) in examining signs and symptoms of WRMSDs over the past 12 months (Egwuonwu et al., 2016).

### *3.4. Subjective assessments of physical and psychosocial risk factors for WRMSDs*

Seven included studies used self-designed questionnaires to identify both physical and psychosocial risk factors for WRMSDs among construction workers (Egwuonwu et al., 2016, Ekpenyong and Inyang, 2014, Elders and Burdorf, 2004, Engholm and Holmström, 2005, Hanklang et al., 2014, Kaneda et al., 2001, Neeraja and Swarochish, 2014), while four and one included studies used self-designed questionnaire to investigate either physical (Goldsheyder et al., 2002, Goldsheyder et al., 2004, Kaminskas and Antanaitis, 2010, Merlino et al., 2003) or psychosocial (Lee et al., 2005) risk factors for WRMSDs. One study used semi-structured interviews to identified various factors (such as working methods, use of new tools, work planning and organization, physical work strain, psychological work strain, and mental stress) that were

associated with WRMSDs (Goldsheyder et al., 2002, Goldsheyder et al., 2004, Jensen and Kofoed, 2002). The contents of various self-designed questionnaires are presented in Table S3.

Five included studies reported the test-retest reliability of their self-designed questionnaires that investigated physical (Goldsheyder et al., 2002, Merlino et al., 2003), psychological (Lee et al., 2005), or both physical and psychosocial risk factors (Egwuonwu et al., 2016, Ekpenyong and Inyang, 2014) for WRMSDs in construction workers (Kappa coefficients between test and retest scores = 0.36 to 0.87) (Table S3). One included study reported the interrater reliability correlation coefficient (intraclass correlation coefficient=0.95) of their self-designed questionnaire for evaluating both physical and psychosocial risk factors for WRMSDs (Hanklang et al., 2014) (Table S3). However, six included studies did not report the reliability of their self-designed questionnaires (Elders and Burdorf, 2004, Engholm and Holmström, 2005, Goldsheyder et al., 2004, Kaminskas and Antanaitis, 2010, Kaneda et al., 2001, Neeraja and Swarochish, 2014).

### *3.5. Observation-based assessments of physical risk factors for WRMSDs*

Three observation-based assessment tools were used in the included studies to evaluate physical risk factors for WRMSDs. Six included studies used an observation-based method (e.g., postural assessment) to assess physical risk factors for WRMSDs in construction workers (Table S4)(Chatterjee and Sahu, 2018, Das, 2014, Das, 2015, Gilkey et al., 2007, Mungroo and Choi, 2018, Sain and Meena, 2018). Five included studies (Chatterjee and Sahu, 2018, Das, 2014, Das, 2015, Sain and Meena, 2018, Mungroo and Choi, 2018) used the rapid entire body assessment (REBA) to systematically assess whole body working postures, force

exertion, repetitions, types of movement, and coupling during job tasks. Two included studies (Mungroo and Choi, 2018, Sain and Meena, 2018) used the rapid upper limb assessment (RULA) to evaluate the ergonomic exposure of upper limb, neck, and trunk in terms of range of motion and force/load at work. Another two included studies (Chatterjee and Sahu, 2018, Gilkey et al., 2007) used the Ovako working analysis system (OWAS) to examine physical exposures (i.e., posture, and external load) of back, arms, and legs during work in construction workers. These methods used a freeze-frame video to record the most frequent postures adopted by the workers to draw stick diagrams. Each posture was then analyzed to identify physical risk factors for WRMSDs during a given construction task (Das, 2014). Likewise, the OWAS work assessment tool was used to analyze ergonomic posture-related risk factors for WRMSDs at work (Karhu et al., 1981, Kivi and Mattila, 1991, Li, 2000, Mattila et al., 1993).

Five included studies reported high to very high physical risk (REBA scores, 8 – 14; RULA scores, 5 – 7) during various tasks in different construction workers (Chatterjee and Sahu, 2018, Das, 2014, Das, 2015, Mungroo and Choi, 2018, Sain and Meena, 2018). Two other studies also found that many construction workers spent the majority of their working hours in postures that can cause some strain to harmful strain leading to WRMSDs (Chatterjee and Sahu, 2018, Gilkey et al., 2007).

### *3.6. Prevalence rates of WRMSDs among construction workers*

Three studies reported point prevalence of WRMSDs in construction workers (Goldsheyder et al., 2002, Goldsheyder et al., 2004, Kaneda et al., 2001), whereas 13 included studies reported 12-month prevalence of WRMSDs (Egwuonwu et al., 2016, Ekpenyong and Inyang, 2014, Elders and Burdorf, 2004, Engholm

and Holmström, 2005, Goldsheyder et al., 2002, Goldsheyder et al., 2004, Hanklang et al., 2014, Jensen and Kofoed, 2002, Kaminskas and Antanaitis, 2010, Lee et al., 2005, Merlino et al., 2003, Neeraja and Swarochish, 2014, Wang et al., 2017)(Table S5). Low back pain was the most common WRMSDs (Gilkey et al., 2007, Goldsheyder et al., 2004) followed by shoulder (Hanklang et al., 2014), neck (Goldsheyder et al., 2004), and knee (Engholm and Holmström, 2005) in construction workers. The point prevalence rates of lumbar, shoulder, neck, knee, wrist, and hand pain ranged between 14% and 54% (Gilkey et al., 2007, Goldsheyder et al., 2002), between 21% and 30% (Goldsheyder et al., 2002), between 22% and 36% (Engholm and Holmström, 2005, Goldsheyder et al., 2004), between 18% and 22% (Elders and Burdorf, 2004, Goldsheyder et al., 2002), and between 17% and 21% (Goldsheyder et al., 2002, Goldsheyder et al., 2004) in construction workers, respectively. Similarly, the 12-month prevalence rates of low back pain (LBP), shoulder pain, neck pain, knee pain, wrist and hand pain were from 38 to 66% (Gilkey et al., 2007, Goldsheyder et al., 2004), 30% to 47% (Goldsheyder et al., 2004, Merlino et al., 2003), 24% to 44% (Engholm and Holmström, 2005, Goldsheyder et al., 2004), 30% to 41% (Goldsheyder et al., 2002, Hanklang et al., 2014), and 14% and 44% (Engholm and Holmström, 2005, Hanklang et al., 2014) among construction workers, respectively.

### *3.7. Associations between physical risk factors and WRMSDs*

Although the current review initially intended to summarize the evidence regarding trade-specific risk factors for WRMSDs, it was not possible to be conducted such a summary because the included studies mixed up workers in multiple trades together. Therefore, this review only reported the risk factors for

WRMSDs in construction workers as a whole. Overall, different physical exposures may differentially increase the risk of WRMSDs at different body parts (details are given in Table S5). Physical risk factors can be classified into eight categories: (a) awkward body postures such as twisting, bending, or cramping positions; (b) strenuous arm movements such as reaching or arms over shoulders level or arms away from body; (c) repetitive, forced, or prolonged works; (d) frequent or heavy lifting; (e) squatting or kneeling; (f) pushing, pulling, and carrying objects; (g) manual material handling (MMH); and (h) use of vibrating machines.

Greater physical exposures are associated with higher risks of LBP development among construction workers (details are given in Table S5). For instance, prolonged works (defined as working in the same position for long periods) (OR: 2.90; 95%CI: 2.23 to 3.76) (Merlino et al., 2003), overhead work with elevated arms above the shoulder level (OR: 1.93; 95%CI: 0.84 to 4.45) (Elders and Burdorf, 2004), lifting heavy objects frequently as compared to rarely (OR: 1.90; 95%CI: 1.72 to 2.11) (Engholm and Holmström, 2005), working in an awkward posture such as bent and twisted back (ORs, ranging from 1.47 to 3.66) (Elders and Burdorf, 2004, Goldsheyder et al., 2004, Kaneda et al., 2001, Merlino et al., 2003), frequent bending activities for long periods (half bending or deep forward bending) (OR, ranging from 1.37 to 1.80) (Kaneda et al., 2001), squatting for long periods (OR: 1.14; 95%CI: 0.99 to 1.32) (Kaneda et al., 2001), and MMH (OR: 1.05; 95%CI: 0.49 to 2.27) (Elders and Burdorf, 2004) increased the risk of developing LBP among construction workers.

Three physical risk factors were specific to shoulder pain in construction workers Specifically, these factors included frequent overhead work (OR: 3.66; 95%CI: 3.32 to 4.04) (Engholm and Holmström, 2005), MMH (OR: 2.96; 95%CI: 1.81 to 4.85) (Neeraja and Swarochish, 2014), and repetitive work with hands (e.g., repetitive movements ≥ 1000 times per day) (OR: 2.01; 95%CI: 1.25 to 3.24) (Neeraja and Swarochish, 2014).

Common physical risk factors for neck pain were prolonged working hours (> 8 hours per day) (OR: 7.63; 95%CI: 2.06 to 28.31) (Hanklang et al., 2014), MMH (OR: 2.96; 95%CI: 1.81 to 4.85) (Neeraja and Swarochish, 2014), overhead work (OR: 2.93; 95%CI: 2.65 to 3.24) (Engholm and Holmström, 2005), and repetitive works (e.g., repetitive movements ≥ 1000 times per day) (OR: 2.01; 95%CI: 1.25 to 3.24) (Neeraja and Swarochish, 2014).

Kneeling (OR: 3.94; 95%CI: 3.55 to 4.37) (Engholm and Holmström, 2005), working in the same position for long periods (OR: 2.90; 95%CI: 2.20 to 3.78) (Merlino et al., 2003), and working in an awkward posture such as cramped (restricted) position (OR: 1.31; 95%CI: 0.93 to 1.84) (Merlino et al., 2003) were the major risk factors contributing to knee pain in construction workers.

Similarly, repetitive tasks (OR: 4.53; 95%CI: 3.24 to 6.34) (Merlino et al., 2003), working in the same position (OR: 2.71; 95%CI: 2.09 to 3.52) (Merlino et al., 2003), using a vibrating machinery (OR: 2.21; 95%CI: 2.00 to 2.44) (Engholm and Holmström, 2005), and often lifting heavy objects (OR: 1.60; 95%CI: 1.40 to 1.84) (Engholm and Holmström, 2005) were significantly associated with wrist/hand pain among construction workers.

293 *3.8. Associations between psychosocial risk factors and WRMSDs*

294 Psychosocial risk factors for WRMSDs in construction workers are presented in Table S5. The most
295 common psychosocial factors that were associated with a higher 12-month prevalence of WMRSDs were
296 high job demands (ORs ranging from 1.16 to 2.50) (Ekpenyong and Inyang, 2014, Elders and Burdorf,
297 2004, Engholm and Holmström, 2005, Hanklang et al., 2014, Jensen and Kofoed, 2002, Neeraja and
298 Swarochish, 2014), mental stress (ORs ranging from 1.34 to 1.80) (Engholm and Holmström, 2005, Jensen
299 and Kofoed, 2002, Kaneda et al., 2001), low job control (ORs ranging from 1.16 to 2.16) (Ekpenyong and
300 Inyang, 2014, Elders and Burdorf, 2004, Engholm and Holmström, 2005, Neeraja and Swarochish, 2014),
301 low job satisfaction (ORs ranging from 1.10 to 1.83) (Engholm and Holmström, 2005, Neeraja and
302 Swarochish, 2014), and high job insecurity (ORs ranging from 1.35 to 1.42) (Egwuonwu et al., 2016,
303 Ekpenyong and Inyang, 2014). These factors were usually associated with higher 12-month prevalence
304 rates of WMRSDs at low back, upper back, shoulder, neck, elbow, wrist or hand, and knee.

305 *3.9. Levels of the evidence for associations between physical or psychosocial risk factors and WRMSDs*

306 Table 3 shows strong evidence to support relationships between awkward postures (e.g., twisting,
307 bending, or cramping positions) (OR: 2.43), MMH (OR: 2.21), or prolonged works (OR: 4.02) and
308 WRMSDs in construction workers. Additionally, there was moderate evidence for the associations between
309 overhead works (OR: 3.12) or use of vibration (OR: 3.17) and WRMSDs in construction workers. Evidence
310 for the relationship between the use of vibration and WRMSDs was downgraded from strong to moderate

311 effect because of a large confidence interval. Furthermore, there was very limited evidence to substantiate
312 the association between repetitive works and WRMSDs in construction workers.

313 Table 4 indicates strong evidence to support relationships between high job demands (OR: 1.63) or
314 mental stress (OR: 1.79) and WRMSDs in construction workers. Additionally, there was moderate evidence
315 for the associations between low job satisfaction (OR: 1.47) and WRMSDs in construction workers. Further,
316 there was very limited evidence that low job control or high job insecurity was associated with WRMSDs
317 in construction workers. Evidence for the relationship between low job satisfaction and WRMSDs was
318 downgraded from strong to moderate due to the large confidence interval. Likewise, the association
319 between low job control or high job insecurity and WRMSDs was degraded from limited to very limited
320 effects because of the large confidence interval.

321 **4. Discussion**

322 This systematic review aimed to summarize the prevalence of WRMSDs in construction workers and
323 to synthesize evidence regarding various physical or psychosocial risk factors for WRMSDs in construction
324 workers. Low back pain is the most common WRMSDs followed by shoulder, neck, and knee pain in
325 construction workers (Elders and Burdorf, 2004, Engholm and Holmström, 2005, Gilkey et al., 2007,
326 Goldsheyder et al., 2002, Goldsheyder et al., 2004, Merlino et al., 2003, Widanarko et al., 2011). Wrist and
327 hand pain among construction workers was also commonly reported in many studies (Engholm and
328 Holmström, 2005, Goldsheyder et al., 2002, Goldsheyder et al., 2004, Hanklang et al., 2014). While there
329 was strong evidence that certain physical (e.g., awkward postures, MMH and prolonged works) or

330 psychosocial (high job demands, and mental stress) factors were significantly related to WRMSDs,
331 moderate evidence also supports the relationships between other physical (e.g., overhead work and use of
332 vibrating machinery) or psychosocial (e.g., low job satisfaction) factors and WRMSDs in construction
333 workers. Additionally, there was a very limited evidence to substantiate the associations between repetitive
334 works, low job control, or high job insecurity and WRMSDs in construction workers.

335 Our prevalence findings concurred with a recent systematic review that studied the 12-month
336 prevalence estimates of musculoskeletal symptoms among construction workers (Umer et al., 2018). Umer
337 et al. (2018) found that LBP was the most common WRMSDs among construction workers (51%), while
338 other commonly affected body parts were knee (37%), shoulder (32%), and wrist (30%). The slight
339 discrepancy in the prevalence of shoulder pain in the current review might be attributed to different
340 participant samples and search strategies. Since most of the included studies used the cross-sectional design
341 and only one study reported the 12-month incidence of LBP and chronic LBP in scaffolders (Elders and
342 Burdorf, 2004). Future studies are warranted to quantify the incidence of WRMSDs in different
343 construction trades.

344 Although LBP is the most common WRMSDs among construction workers, the relation between
345 physical exposures and the risk of LBP remains unclear. Of various potential physical risk factors for LBP,
346 lifting activity is the only factor that has consistently been reported as a risk factor for WRMSDs among
347 workers in construction (Das, 2015, Engholm and Holmström, 2005), and other industries (e.g., agriculture,
348 maritime, petroleum, paper products, transportation, automobile, aircraft, steel, and machine manufacturing)

(Bernard and Putz-Anderson, 1997, Vieira and Kumar, 2006, Wai et al., 2010). One systematic review reported a moderate evidence for the relationship between lifting (e.g., > 25 kg loads or >35 kg loads) and prevalence of LBP in people from various occupations (such as construction, firefighter, nurses, forestry, postal workers, podiatrists, etc.) (Wai et al., 2010). While three physical risk factors (e.g., bending, twisting, or cramped postures activity) may theoretically increase intradiscal pressure and lead to LBP (Lis et al., 2007, Yip et al., 2004), findings from epidemiological studies showed inconsistent results (Roffey et al., 2010, Wai et al., 2010). Future large-scale longitudinal field studies should use objective measurements (e.g., wearable sensors, or validated ergonomic assessment tools) to quantify the impacts of these risk factors (e.g., bending, twisting) on the development or maintenance of LBP in construction workers.

While the current review identified some common physical risk factors for WRMSDs at different body parts (e.g., shoulder or knee) of construction workers, these risk factors differed from those reported in other industries. For instance, the current review found that overhead work, and repetitive tasks with hands increased the risk of shoulder pain. However, previous systematic reviews reported that awkward postures, repetition works, high force (e.g., exposed to higher loads), vibration, MMH, bending and twisting, and extreme temperature) were related to shoulder pain in people working in agriculture, forestry, fishery, or machine manufacturing (Bernard and Putz-Anderson, 1997, Charles et al., 2018). The disparity highlights that risk factors may be task specific. As such, findings from construction workers in one trade (e.g., painters) may not be generalized to workers in other construction trades (e.g., rebar workers). Unfortunately, since many included studies investigated physical risk factors for WRMSDs based on a cohort of workers

368 from different construction trades, it was difficult to identify the trade-specific risk factors for WRMSDs.
369 Future studies should address this issue by investigating task- or trade-specific risk factors for WRMSDs.

370 Likewise, although previous systematic reviews have reported causal relations between certain
371 physical risk factors (such as awkward postures and repetitive work) and neck, knee, or wrist/hand pain
372 among workers in various industries (such as construction, agriculture, maritime, petroleum, etc.) (Bernard
373 and Putz-Anderson, 1997, da Costa and Vieira, 2010), their findings cannot be generalized to construction
374 workers (Bernard and Putz-Anderson, 1997, da Costa and Vieira, 2010). Future prospective field studies
375 should determine the causal relationships between different physical risk factors and WRMSDs in
376 construction workers of various trades.

377 Psychosocial risk factors (e.g., high job demands, low job satisfaction, and stress) were shown to be
378 related to WRMSDs in construction workers. Our findings concurred with those of a previous literature
379 review that reported a consistent association between high job stress and WRMSDs in various occupational
380 settings including construction (Bongers et al., 2002). Similarly, a systematic review found strong evidence
381 for the association between high job stress or low job satisfaction and WRMSDs, and moderate evidence
382 for the relationship between low job control or high job demands and WRMSDs in construction workers
383 (Sobeih et al., 2006). Other studies also reported significant associations between high job demands, low
384 job control, or low job satisfaction and WRMSDs at the neck (Ariëns et al., 2001), shoulder (Van Der
385 Windt et al., 2000), or lower back regions (Hoogendoorn et al., 2000). Although various psychosocial
386 factors are associated with WRMSDs, the mechanisms underlying causal effects between these factors and

387 WRMSDs remain elusive. One mechanism hypothesizes that psychological stress may reduce an
388 individual's pain tolerance, which increases the perception of WRMSD-related pain (Lundberg, 2002,
389 Theorell and Karasek, 1996). Another mechanism propounds that high psychological stress may cause
390 individuals to perform their tasks differently (e.g., using extra efforts for a certain task), resulting in higher
391 biomechanical loading (Eatough et al., 2012). A third mechanism proposes that suboptimal psychological
392 wellbeing may result in greater perceived pain or disability via different cognitive and behavioral responses
393 (Eatough et al., 2012).

394 **5. Study implications**

395 Since WRMSDs are common among construction workers, the prevention of WRMSDs in these
396 workers is crucial. The current review revealed different levels of evidence in supporting significant
397 associations between various physical or psychosocial factors and WRMSDs in construction workers. To
398 effectively allocate resources to prevent WRMSDs in construction workers, several important steps should
399 be undertaken. First, future studies are warranted to develop proactive preventive measures such as real-
400 time measurements of physical or mental stress, or physical workloads to minimize the modifiable physical
401 or psychosocial risk factors, thereby reducing the incidence/prevalence of WRMSDs in construction
402 workers. Second, instead of using diverse self-developed questionnaires for risk factor assessments, future
403 ergonomic studies should use validated questionnaires, and/or observational risk assessment tools (e.g.,
404 OWAS, WERA, and REBA) to minimize the bias in reporting and assessing risk factors for WRMSDs in
405 construction workers. The REBA and RULA methods are the most widely used ergonomic assessment

tools for assessing posture during construction tasks such as MMH (Hignett and McAtamney, 2000, Kulkarni and Devalkar, 2019, Ryu et al., 2018, Shanahan et al., 2013). These methods are inexpensive and easy to analyze postures. However, trained observers are needed to minimize the inter-observer variability (Sain and Meena, 2018). Third, wearable sensors (e.g., pressure insole, motion sensors, video capture with machine learning) can be used to quantify physical risk factors for WRMSDs (Antwi-Afari et al., 2018a, Nath et al., 2017, Valero et al., 2017, Yan et al., 2017). Although prior laboratory studies have used wearable sensors to identify physical risk factors for WRMSDs during simulated construction tasks (Antwi-Afari et al., 2018a, Antwi-Afari et al., 2018b, Antwi-Afari et al., 2020b, Antwi-Afari et al., 2020a, Antwi-Afari et al., 2020c, Umer et al., 2017, Yang et al., 2019), these findings should be validated in field studies before being generalized to construction workers. Fourth, future longitudinal studies should be conducted to establish the causal relationships between various prognostic or risk factors and subsequent development of WRMSDs in construction workers. In short, a better understanding of the role of these factors in the etiology of WRMSDs can help design proper preventive measures for construction workers. Stakeholders (e.g., construction site managers, and construction workers) will also find it difficult to select the most cost-effective approaches [e.g., lower extremity exoskeleton devices (Wehner et al., 2009) or robots (Bernold et al., 2001), or adopting specific work rest schedule (Geurts and Sonnentag, 2006, Goldenhar et al., 2003)] to prevent WRMSDs in construction workers.

## 6. Study limitations

Although the current review was conducted and reported according to the PRISMA guideline, the included studies had some limitations that prevented the direct application of our findings to prevent WRMSDs in construction workers. First, the cross-sectional study designs of most of the included studies prevented the determination of causal relationships between physical or psychosocial risk factors and WRMSDs in construction workers. Second, 11 out of 20 included studies used self-reported questionnaires and five of them only used self-developed questionnaires without reporting reliability and validity. These questionnaires might be subject to recall bias, missing data, and misinterpretation of questions by the respondents (Wai et al., 2010). Future studies should use validated questionnaires to assess risk factors. Third, many included studies (38%) did not provide clear definitions nor quantifiable specifications of physical risk factors, which prevented comparisons of findings across studies. Many included studies (n = 5) used poorly defined physical risk factors (e.g., awkward posture or MMH) in their OR calculations. For example, there was no measurement of flexion/rotation angles of neck or trunk for a specific duration during ergonomic risk assessments. Similarly, the definitions and durations of repetitive works, overhead work, the frequency of machine vibration, or the loading and duration of MMH activities were not reported. Although six included studies used observation-based postural assessment methods (such as OWAS, REBA, and RULA methods) to estimate physical exposures, they did not report relevant statistics (e.g., ORs) to quantify the associations between physical exposures and the prevalence of WRMSDs (Chatterjee and Sahu, 2018, Das, 2014, Das, 2015, Gilkey et al., 2007,

Mungroo and Choi, 2018, Sain and Meena, 2018). Therefore, these studies were excluded from the current review.

In addition to the limitations of primary studies, the current review had some other limitations. First, the current review only included English articles. Relevant articles in other languages might have been missed. Second, given the heterogeneity of the included studies and cross-sectional nature of most studies, a meta-analysis was not conducted. That said, our review highlights the needs for further investigation of several physical or psychosocial risk factors.

## 7. Conclusions

This systematic review updated the prevalence rates of WRMSDs and summarized new evidence regarding the associations between physical or psychosocial risk factors and WRMSDs in construction workers. Our results reveal that WRMSDs are ubiquitous in construction workers. There was strong evidence that many physical (e.g., awkward postures, MMH, and prolonged works) and psychosocial (e.g., high job demands and stress) risk factors were associated with WRMSDs in construction workers. Additionally, there was moderate evidence for the relationships between other risk factors (e.g., overhead works, use of vibration, or low job satisfaction) and WRMSDs in construction workers. However, causal relationships between these factors and the prevalence of WRMSDs remain unclear due to the cross-sectional nature of the included studies. Future longitudinal studies are warranted to explore the causal effects between these factors and WRMSDs in construction workers.

## 8. Relevance to the industry

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This review highlights that most previous studies did not investigate trade-specific risk factors. Since different construction trades have different physical or psychosocial demands/risks, it is necessary to identify trade-specific physical or psychosocial risk factors so as to design tailored prevention strategies. Therefore, future studies should examine trade-specific risk factors. Additionally, although the current review has summarized many physical or psychosocial risk factors for WRMSDs in construction workers, future prospective studies should evaluate whether the modification of these risk factors can lower the prevalence of WRMSDs in construction workers.

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747 **Table 1: Study characteristics**

| **Citations** | **Country of study** | **Study design** | **Participants (Construction trades), All male workers except otherwise reported** | **Task duration (Hrs./day)** | **Age, years (range)** | **Response rate** |
|---|---|---|---|---|---|---|
| Kaneda et al. 2001 | Japan | Cross-sectional survey | All trades (n=19,948). | 8.2 ± 1.3 | 42.0 ± 12.3 | 59.5% |
| Goldsheyder et al. 2002 | USA | Cross-sectional survey | Mason tenders (n=300); Laborers (n=135) | Not reported | 39.1 ± 9.5 | 70.2% |
| Merlino et al. 2003 | USA | Cross-sectional survey | Apprentice construction workers (n = 996) | 6.4±1.2 | 27.7 ± 6.2 | 84.8% |
| Elders et al. 2004 | Netherland | Longitudinal survey with three-year follow-up | Scaffolders (n = 288) | Not reported | 30 to 50 | 85% |
| Goldsheyder et al. 2004 | USA | Cross-sectional survey | Cement and concrete workers (n = 200) | Not reported | 38.9±10.4 | 55% |
| Engholm et al. 2005 | Sweden | Cross-sectional survey | Construction workers (n = 85,191) | Not reported | (25 – 60) | 94.4% |
| Gilkey et al. 2007 | USA | Observational study using OWAS and ErgoMaster™ 2D software | Residential carpenters (n = 94) | Not reported | 37 | 100% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Kaminskas et al. 2010 | Lithuania | Cross-sectional survey | Construction workers (n = 276); Female (n=36) | Not reported | 38.8 ± 12.6 | 62.7% |
| Das et al. 2014 | India | Observational study using REBA method | Brick Field Workers (n = 216); Female (n=112) | 7- 8 | 30.3 ± 10.7 (21 – 52) | 100% |
| Ekpenyong et al. 2014 | Nigeria | Cross-sectional survey | Ironworkers (n=143); Administrative workers (n=47); Security workers (n=93); Carpenters (n=152); Mechanical workers (n=161); Bricklaying workers (n=183); Electrical workers (n=131); Transportation workers (n=82); Storekeeper (n=67); Earth-movement unit workers (n=141) | Not reported | 26.4 ± 0.4 (18 – 55) | 100% |
| Hanklang et al. 2014 | Thailand | Cross-sectional survey | Female Rebar workers (n = 272) | > 8 | 48.2 ± 9.7 | 100% |
| Neeraja et al. 2014 | India | Cross-sectional survey | Construction workers (n = 220), Female (n=68) | 6.3±1.2 | 31.5 ± 8.2 | 100% |
| Das 2015 | India | Observational study using REBA method | Brick field workers (n=148) | 7- 8 | (21 – 52) | 100% |
| Egwuonwu et al. 2016 | Nigeria | Cross-sectional descriptive survey | Road construction workers (n=100) | 7.9 ± 1.2 | 35.9 ± 8.5 (23 – 60) | 100% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wang et al. 2017 | USA | Cross-sectional survey | Multiple trades (n=82,630) | Not reported | >16 | Not reported |
| Mungroo et al. 2018 | Trinidad | Observational study using REBA and RULA methods | Construction roofers (n=61) | 8 | 34 ± 8.5 | 100% |
| Chatterjee and Sahu, 2018 | India | Observational study using REBA and OWAS methods | Construction laborer (n = 164) | 8.18 ± 0.99 | 34.6 ± 2.7 (28 – 36)<br>43.1 ± 3.0 (40 – 48) | 100% |
| Jensen and Kofoed 2002 | Denmark | Cross-sectional survey | Floor layers (n = 102) and apprentice floor layers (n = 180) | Not reported | 37 years (17–66), and 22 years (16–54) | 88%<br>95% |
| Lee et al. 2005 | Taiwan | Cross-sectional survey | Construction workers (n = 1,814) | Not reported | 25 – 65 | 85% |
| Sain and Meena, 2018 | India | Observational study using REBA and RULA methods | Brick kiln workers (n = 328); Female (n = 111) | Not reported | 17 – 53 | 100% |

REBA: Rapid Entire Body Assessment; RULA: Rapid Upper Limb Assessment; OWAS: Ovako Working Analysis System

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749 **Table 2: Risk of Bias Scores for included studies (Quality Assessment)**

| **Citations** | **External validity criteria** | | | | **Internal validity criteria** | | | | | | **Total score** | **%** | ***Overall quality** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | | | |
| Goldsheyder et al. 2002 | N | N | N | N | Y | N | Y | Y | Y | Y | 5/10 | 50 | High risk |
| Goldsheyder et al. 2004 | N | N | N | N | Y | N | N | Y | Y | Y | 4/10 | 40 | High risk |
| Wang et al. 2017 | N | Y | N | Y | N | Y | N | N | N | Y | 4/10 | 40 | High risk |
| Mungroo et al. 2018 | N | N | N | N | Y | N | N | Y | Y | Y | 4/10 | 40 | High risk |
| Kaneda et al. 2001 | Y | Y | N | N | Y | N | N | Y | Y | Y | 6/10 | 60 | Moderate risk |
| Engholm et al. 2005 | Y | N | N | Y | Y | N | N | Y | Y | Y | 6/10 | 60 | Moderate risk |
| Kaminskas et al. 2010 | N | N | Y | N | Y | N | Y | Y | Y | Y | 6/10 | 60 | Moderate risk |
| Neeraja et al. 2014 | N | N | N | Y | Y | N | Y | Y | Y | Y | 6/10 | 60 | Moderate risk |
| Egwuonwu et al. 2016 | N | N | N | Y | Y | N | Y | Y | Y | Y | 6/10 | 60 | Moderate risk |
| Merlino et al. 2003 | N | Y | N | Y | Y | N | Y | Y | Y | Y | 7/10 | 70 | Low risk |
| Elders et al. 2004 | N | N | N | Y | Y | Y | Y | Y | Y | Y | 7/10 | 70 | Low risk |
| Gilkey et al. 2007 | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | 9/10 | 90 | Low risk |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Das et al. 2014 | N | N | Y | Y | Y | Y | Y | Y | Y | Y | 8/10 | 80 | Low risk |
| Ekpenyong et al. 2014 | N | N | N | Y | Y | Y | Y | Y | Y | Y | 7/10 | 70 | Low risk |
| Hanklang et al. 2014 | N | N | Y | Y | Y | Y | N | Y | Y | Y | 7/10 | 70 | Low risk |
| Das 2015 | N | N | Y | Y | Y | N | Y | Y | Y | Y | 7/10 | 70 | Low risk |
| Chatterjee and Sahu, 2018 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | 10/10 | 100 | Low risk |
| Jensen and Kofoed 2002 | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | 9/10 | 90 | Low risk |
| Lee et al. 2005 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | 10/10 | 100 | Low risk |
| Sain and Meena, 2018 | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | 9/10 | 90 | Low risk |

*Overall Quality criteria: Low risk: ≥7 criteria met; Moderate risk: 5 or 6 criteria met; High risk: ≤4 criteria met (Hoy et al., 2012)

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753 **Table 3.** Strength of the evidence for the relationship between physical risk factors and work-related musculoskeletal disorders

| **Physical risks** | **Citations** | **Consistency of positive findings** | **Strength of the association (Odd ratios, OR)** | **Effects** | *** Levels of evidence of a given risk factor** |
|---|---|---|---|---|---|
| 1. Awkward postures<br>All studies<br>QS > 60%<br>QS < 60% | Egwuonwu et al. 2016; Ekpenyong et al. 2014; Elders et al. 2004; Engholm et al. 2005; Goldsheyder et al. 2002; Goldsheyder et al. 2004; Hanklang et al. 2014; Kaminskas et al. 2010; Kaneda et al. 2001; Merlino et al. 2003 | <br>8/10 = 80%<br>7/8 = 88%<br>1/2 = 50% | OR = 2.43 (95% CI, 1.5 to 3.4) | Risk factor | Strong effect |
| 2. Repetitive works<br>All studies<br>QS > 60%<br>QS < 60% | Egwuonwu et al. 2016; Goldsheyder et al. 2002; Hanklang et al. 2014; Merlino et al. 2003; Neeraja et al. 2014 | <br>2/5 = 40%<br>2/4 = 50%<br>0/1 = 0% | OR = 3.27 (95% CI, -12.7 to 19.3) | Risk factor | Very limited effect** |

| | | | | | |
|---|---|---|---|---|---|
| 3. Overhead work<br>All studies<br>QS > 60%<br>QS < 60% | Elders et al. 2004; Engholm et al. 2005; Goldsheyder et al. 2002; Goldsheyder et al. 2004; Merlino et al. 2003; Neeraja et al. 2014 | <br>4/6 = 67%<br>2/4 = 50%<br>2/2 = 100% | OR = 3.12 (95% CI, 1.7 to 4.5) | Risk factor | Moderate effect |
| 4. Vibration<br>All studies<br>QS > 60%<br>QS < 60% | Egwuonwu et al. 2016; Ekpenyong et al. 2014; Engholm et al. 2005; Wang et al. 2017 | <br>4/4 = 100%<br>3/3 = 100%<br>0/1 = 0% | ORs = 3.17 (95% CI, -9.2 to 15.6) | Risk factor | Moderate effect** |
| 5. Manual material handling<br>All studies<br>QS > 60%<br>QS < 60% | Ekpenyong et al. 2014; Elders et al. 2004; Goldsheyder et al. 2002; Goldsheyder et al. 2004; Neeraja et al. 2014 | <br>5/5 = 100%<br>3/3 = 100%<br>2/2 = 100% | ORs = 2.21 (95% CI, 1.3 to 3.2) | Risk factor | Strong effect |
| 6. Prolonged works<br>All studies<br>QS > 60% | Goldsheyder et al. 2004; Hanklang et al. 2014; Merlino et al. 2003; | <br>3/3 = 100% | ORs = 4.02 (95% CI, 0.2 to 7.8) | Risk factor | Strong effect |

| | |
|---|---|
| QS < 60% | 2/2 = 100% |
| | 1/1 = 100% |

Note: QS = Quality score; CI = Confidence Interval; * [**Strong evidence:** consistent narrative findings in multiple high-quality studies; **Moderate evidence:** consistent findings from multiple studies with at least one high quality study; **Limited evidence:** consistent findings from multiple moderate or low-quality studies; **Very limited evidence:** results obtained from one moderate or low-quality study; **Conflicting evidence:** inconsistent findings (Jun et al., 2017; van Tulder et al., 2003)]; **Evidence downgraded from limited to very limited or strong to moderate due to large CI.

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**Table 4.** Strength of the evidence for the relationship between psychosocial risk factors and work-related musculoskeletal disorders

| **Physical risks** | **Citations** | **Consistency of positive findings** | **Strength of the association (Odd ratios, OR)** | **Effects** | *** Levels of evidence of a given risk factor** |
|---|---|---|---|---|---|
| 1. Mental stress | Engholm et al. 2005; Jensen and Kofoed 2002; Kaneda et al. 2001 | | OR = 1.79 (95% CI, 0.1 to 3.5) | Risk factor | Strong effect |
| All studies | | 3/3 = 100% | | | |
| QS > 60% | | 3/3 = 100% | | | |
| QS < 60% | | | | | |
| 2. High job demand | Ekpenyong et al. 2014; Elders et al. 2004; Engholm et al. 2005; Hanklang et al. 2014; Jensen and Kofoed 2002; Neeraja et al. 2014; | | OR = 1.63 (95% CI, 1.2 to 2.0) | Risk factor | Strong effect |
| All studies | | 6/6 = 100% | | | |
| QS > 60% | | 6/6 = 100% | | | |
| QS < 60% | | | | | |
| 3. Low job satisfaction | Engholm et al. 2005; Neeraja et al. 2014 | | ORs = 1.47 (95% CI, -3.2 to 6.1) | Risk factor | Moderate effect** |
| All studies | | 2/2 = 100% | | | |
| QS > 60% | | 2/2 = 100% | | | |
| QS < 60% | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 4. Low job control<br>All studies<br>QS > 60%<br>QS < 60% | Ekpenyong et al. 2014; Elders et al. 2004; Engholm et al. 2005; Neeraja et al. 2014 | <br>2/4 = 50%<br>2/2 = 100%<br>0/2 = 0% | ORs = 1.43 (95% CI, 0.6 to 2.2.) | Risk factor | Very limited effect** |
| 5. High job insecurity<br>All studies<br>QS > 60%<br>QS < 60% | Egwuonwu et al. 2016; Ekpenyong et al. 2014 | <br>1/2 = 50%<br>1/2 = 50% | ORs = 1.96 (95% CI, -0.5 to 4.5) | Risk factor | Very limited effect** |

Note: QS = Quality score; CI = Confidence interval; * [Strong evidence: consistent narrative findings in multiple high-quality studies; Moderate evidence: consistent findings from multiple studies with at least one high quality study; Limited evidence: consistent findings from multiple moderate or low-quality studies; Very limited evidence: results obtained from one moderate or low-quality study; Conflicting evidence: inconsistent findings (Jun et al., 2017; van Tulder et al., 2003)]; **Evidence downgraded from strong to moderate or limited to very limited due to large CI.

Anwer S, Li H, Antwi-Afari MF, Wong AYL. Associations between physical or psychosocial risk factors and work-related musculoskeletal disorders in construction workers based on literature in the last 20 years: A systematic review. International Journal of Industrial Ergonomics (Accepted)

**Table S1.** Search strategy

| **Keywords (30-09-2020)** | **Web of Science** | **PubMed** | **Medline** | **CINAHL Complete** | **EMBASE** |
|---|---|---|---|---|---|
| Ergonomics OR Work environment OR Workplace OR Construction Ergonomics OR Occupational Safety OR Construction Safety OR Ergonomic exposures OR Ergonomic performance OR Manual Material Handling tasks | 309,361 | 226591 | 25,398 | 74,543 | 646858 |
| Musculoskeletal dis* OR Musculoskeletal injury OR Musculoskeletal Symptom OR Musculoskeletal complaint | 37,396 | 26118 | 6,706 | 14,511 | 38931 |
| Construction workers OR Construction industry OR Construction trade OR Construction sector OR Industrial Construction OR Construction | 514,811 | 90105 | 28,132 | 37,939 | 98460 |
| Risk factor OR Occupational Risk factors OR Biomechanical risk OR Psychosocial risk | 936,567 | 1,499,696 | 204,184 | 384,482 | 538389 |
| Combined, Limit (1-1-2000 to 30-09-2020) | 142 | 127 | 161 | 54 | 293 |
| **Total after duplication removed** | | | **486** | | |

**Table S2.** Risk of bias questionnaire - Adapted from the Risk of Bias Tool for Prevalence Studies [Hoy et al. (2012)**]**

| **Risk of Bias questions** | **Response:**<br><br>**Yes** (Low risk), **No** (High risk) |
|---|---|
| ***Questions related to external validity*** | |
| 1. Whether the target population in the included studies includes adult construction workers? | |
| 2. Whether the target sample a true or close representative of the target population? | |
| 3. Whether the sampling technique includes some form of randomization? | |
| 4. Whether the non-response bias was minimal or non-selective? | |
| ***Questions related to internal validity*** | |
| 5. Whether the data was collected directly from the participants? | |
| 6. Whether the included studies used a clear definition of work-related musculoskeletal disorders? | |
| 7. Whether the included studies used any reliable and valid scale to assess study outcome? | |
| 8. Whether the included studies used uniform method of data collection for all subjects? | |
| 9. Whether the included studies provide an adequate prevalence period as required? | |
| 10. Whether the included study keep consistency in using numerator and denominator for calculating prevalence rate | |
| **Overall risk of bias score** | **Low risk: ≥7 criteria met; Moderate risk: 5 or 6 criteria met; High risk: ≤4 criteria met** |

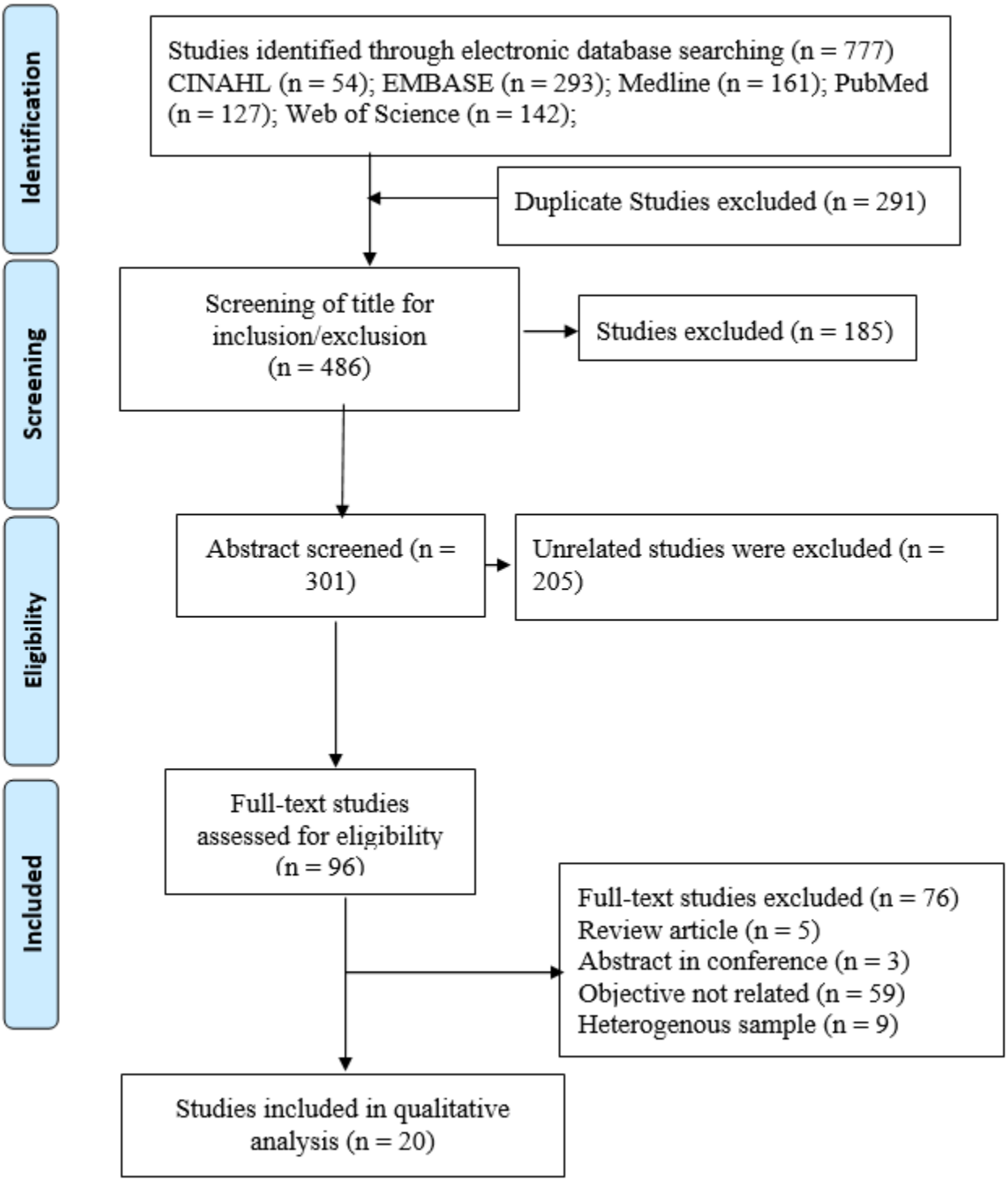


**Figure S1.** Study selection process and results of the literature search

**Table S3.** Contents of self-designed questionnaire to assess physical and/or psychosocial risk factors for Work-related musculoskeletal disorders in construction workers

| Citations | Questions related to physical risks | Questions related to psychosocial risks | Reliability data |
|---|---|---|---|
| Kaneda et al. 2001 | Working and resting hours per day<br>Postures they often maintained during work<br>If they had to handle heavy objects<br>The weights of the objects<br>Whether they wear a lumbar supporter while working | Number of employees at their companies<br>Length of employment<br>Number of working days and holidays per month<br>Whether they suffer stress due to personal relations at work | Not reported |
| Goldsheyder et al. 2002, 2004 | Performing the same task over and over<br>Performing a task very fast for short periods (lifting, grasping, pulling, pushing, etc.)<br>Handling or grasping small objects<br>Taking sufficient breaks during the workday<br>Working in awkward position<br>Working in the same position for long periods of time<br>(standing, bent over, sitting, kneeling, etc.)<br>Bending or twisting your back in awkward way | | Test-retest reliability, Kappa = 0.36 to 0.81 |

| | | |
|---|---|---|
| | Working near or at your physical limits<br>(e.g., when you are out of breath and heartbeat is fast)<br>Working over your head or away from your body<br>Working in hot, cold, humid, wet conditions<br>Continuing to work when in pain<br>Carrying, lifting, or moving heavy materials, equipment<br>Work scheduling (overtime, irregular shifts, length of workday)<br>Using tools (design, weight, vibration, etc.) | |
| Merlino et al. 2003 | Repeated tasks,<br>Work fast for short time<br>Grasp small objects<br>Insufficient breaks<br>Work in cramped position<br>Work in same position<br>Bend back awkwardly | Test-retest reliability, Kappa = 0.46 to 0.68 |

| | | | |
|---|---|---|---|
| | Work near physical limits<br>Reach overhead<br>Inclement conditions<br>Work when hurt<br>Transporting heavy materials<br>Long workday<br>Tool characteristics | | |
| Elders et al. 2004 | Lifting and carrying heavy loads,<br>Awkward working postures in which the back is bent or twisted, and<br>Strenuous arm positions such as working with hands above shoulder level | Psychologically demanding Job<br>Low job control | Not reported |
| Engholm et al. 2005 | Lifting heavy burdens<br>Stooping or twisted posture<br>Hands above shoulders<br>Kneeling | Job satisfaction<br>Low job control<br>Information about future plans<br>Alternating work tasks | Not reported |

| | | | |
|---|---|---|---|
| | Use of vibration tools | Task variation<br>Support from supervisors<br>Support from workmates<br>Job responsibility too heavy<br>Work health hazard anxiety<br>Work psychologically demanding<br>Difficulties to relax during leisure time<br>Hurrying without reason<br>Sleeping problems<br>Stress | |
| Kaminskas et al. 2010 | Awkward work posture,<br>High use of physical force<br>Work in a static posture | | Not reported |
| Ekpenyong et al. 2014 | The presence or absence of awkward posture, awkward movement of the head and arms, | Decision latitude,<br>Psychosocial demands<br>Mental workload, | Test-retest reliability, Kappa = 0.65 to 0.79 |

| | | | |
|---|---|---|---|
| | Working against forces or vibration,<br>Manual materials handling (MMH),<br>Fast work pace | Social support,<br>Job insecurity | |
| Hanklang et al. 2014 | Prolonged working hours<br>Awkward posture<br>Repetitive task | Perceived high job demand<br>Work experience (years) | Interrater reliability (Interclass correlation coefficient): 0.95 |
| Neeraja et al. 2014 | Repetitive gesture<br>Force with the arms or hands<br>Sitting posture<br>Standing posture<br>Walking<br>Arms above the height of the shoulder<br>Repetitive movement with the hands<br>Bent trunk<br>Turned trunk<br>Lifting weights | Job control<br>Psychological demands<br>Social support<br>Job dissatisfaction | Not reported |

| | | | |
|---|---|---|---|
| | Mechanical pressure with the hands on the object of work | | |
| Egwuonwu et al. 2016 | Awkward posture such as twisting and sideway bending;<br>Repetitive works<br>Vibration from hand tools;<br>Lifting, reaching, and unequal lifting | Time pressures<br>Employment status<br>Supervision and training<br>Family and spousal support<br>Remuneration and wages<br>Job security<br>Working hours<br>Transportation facility<br>Co-workers relationship | Test-retest reliability, Kappa = 0.83 |
| Lee et al. 2005 | | Job content<br>Physical working condition<br>Relationship<br>Organizational problem<br>Uncomfortable working environment | Test-retest reliability, Kappa = 0.80 to 0.87 |

| Poor safety and hygiene in the workplace |
| --- |

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22 **Table S4.** Observation-based assessments (postural assessments) of physical risk factors for work related musculoskeletal disorders (WRMSDs)

| Citations | Construction trade (n = 1011) | Tasks | REBA score (Severity of risk) | RULA score (Severity of risk) | OWAS scores (Worktime Spent in Action Category (%)) | | | | Significant risk of affected body parts OR (95% CI) | Prevalence of WRMSDs |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | | |
| Sain and Meena, 2018 | Brick kiln workers (n = 328) | Spading | 11.7 ± 0.8 (Very high) | 6.4 ± 0.6 (Very high) | | | | | With reference to carrying 12.55 (5.23–30.16) (Fingers) 0.44 (0.22–0.87) (Lower back) 6.27 (2.56–15.40) (Knee) | Neck = 21.2% Shoulder = 57.7% Upper arm = 25.9% Lower arm = 20.0% Wrist = 42.4% Fingers = 16.5% Upper back = 12.9% Lower back = 62.4% Knee = 16.5% |

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| Mould filling | 11.1 ± 0.8 (Very high) | 6.1 ± 0.8 (Very high) | With reference to carrying<br>0.22 (0.07–0.67) (Neck)<br>0.35 (0.17–0.73) (Shoulder)<br>5.45 (2.55–11.65) (Wrist)<br>2.53 (1.07–5.96) (Fingers) | Neck = 14.7%<br>Shoulder = 42.1%<br>Upper arm = 28.4%<br>Lower arm = 20.0%<br>Wrist = 53.7%<br>Fingers = 55.8%<br>Upper back = 12.6%<br>Lower back = 41.1%<br>Knee = 39.0% |
| Mould evacuating | 10.5 ± 0.7 (High) | 5.2 ± 0.7 (High) | With reference to carrying<br>6.11 (2.47–15.15) (Upper back)<br>0.25 0.11–0.57 (lower back) | Neck = 13.1%<br>Shoulder = 40.5%<br>Upper arm = 20.2%<br>Lower arm = 25.0%<br>Wrist = 76.2%<br>Fingers = 32.1%<br>Upper back = 17.9% |

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| | | | | | | | | | Lower back = 56.0%<br>Knee = 15.5% |
| | | Brick carrying | 10.0 ± 0.8 (High) | 5.0 ± 0.9 (High) | | | | | Neck = 29.7%<br>Shoulder = 53.1%<br>Upper arm = 29.7%<br>Lower arm = 18.8%<br>Wrist = 28.1%<br>Fingers = 15.6%<br>Upper back = 45.3%<br>Lower back = 39.1%<br>Knee = 17.2% |
| Gilkey et al. 2007 | Residential Carpenters (n = 94) | Sort wall material | | | 57 | 40 | 3 | 0 | 0.896 (0.414–1.938) (Point prevalence of LBP)<br>1.470 (0.796–2.714) (12-month prevalence of LBP) | r = 0.290* (Lifetime prevalence of LBP) |

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| | | | | | 1.343 (0.733–2.458) (Lifetime prevalence of LBP) | |
| Install floor joists | 29 | 60 | 11 | 0 | 1.452 (0.595–3.544) (Point prevalence of LBP)<br>1.855 (0.934–3.806) (12-month prevalence of LBP)<br>1.693 (0.838–3.418) (Lifetime prevalence of LBP) | r = 0.360* and 0.327* (12-month and lifetime prevalence of LBP, respectively) |
| Sort trusses | 80 | 15 | 5 | 0 | 1.611 (0.634–4.096) (Point prevalence of LBP)<br>0.795 (0.404–1.564) (12-month prevalence of LBP)<br>1.364 (0.709–2.621) (Lifetime prevalence of LBP) | r = 0.222* and 0.333* (Point and lifetime prevalence of LBP, respectively) |
| Sheet floors | 33 | 67 | 0 | 0 | 0.855 (0.342–2.137) (Point prevalence of LBP) | R = 0.356* and 0.300 (12-month and |

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| | | | | | | | | 1.829 (0.901–3.716) (12-month prevalence of LBP) 0.945 (0.474–1.920) (Lifetime prevalence of LBP) | lifetime prevalence of LBP, respectively) |
| | | Stand walls | | 17 | 70 | 13 | 0 | 0.664 (0.286–1.538) (Point prevalence of LBP) 0.504 (0.269–0.942) (12-month prevalence of LBP) 1.504 (0.795–2.843) (Lifetime prevalence of LBP) | r = 0.288* (Lifetime prevalence of LBP, respectively) |
| Das, 2014 | Brick Field Workers (n = 216) | Brick carrying | 10 ± 1.0 (High) | | | | | Working posture of this task is of high risk for WRMSDs. | 12-month prevalence of WRMSDs 96.3% |
| | | Brick moulding | 8 ± 0.0 (High) | | | | | Working posture of this task is of high risk for WRMSDs. | 12-month prevalence of WRMSDs |

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| | | | | | 58.4% |
| | | Brick fire | 10 ± 0.0 (High) | Working posture of this task is of high risk for WRMSDs. | 12-month prevalence of WRMSDs<br>47.8% |
| | | Brick stacking | 9.7 ± 0.58 (High) | Working posture of this task is of high risk for WRMSDs. | 12-month prevalence of WRMSDs<br>64.5% |
| Das, 2015 | Brick field workers<br>(n = 148) | Carrying mud | 9 (High) | 1.59 (0.411–6.207) (LBP)<br>Awkward working posture such as bending and twisting the back, 70% prevalence of LBP<br>Repetitive work, 61% prevalence of LBP<br>Constant sitting static work posture, 55% prevalence of LBP | 12-month prevalence:<br>Brick moulders: LBP, 27%<br>Brick carriers: LBP, 25% |
| | | Moulding | 8 (High) | | |
| | | Loading raw bricks | 10 (High) | | |
| | | Carrying raw bricks to kiln | 9 (High) | | |
| | | Unloading raw bricks to kiln | 10 (High) | | |

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| | | Picking burn bricks from kiln | 10 (High) | MMH, 45% prevalence of LBP<br>Lifting of heavy objects, 40% prevalence of LBP | |
| | | Carrying burn bricks from kiln to storage | 9 (High) | | |
| Mungroo et al. 2018 | Construction Roofers (n = 61) | Securing panel in place | 12 (Very high) | Motion/position (awkward body postures such as extended shoulder and bent elbow) vs WRMSDs: 35%<br>Overexertion vs WRMSDs: 28%<br>Vibration vs WRMSDs: 24% | Point prevalence:<br>Back injury (54%), sprains/strains (21%), rotator cuff injury (13%), tendinitis (6%), carpal tunnel syndrome (4%), and epicondylitis (3%). |
| | | Lifting panels | 11 (Very high) | | |
| | | Fastening panels with screws | 9 (High) | | |
| | | Purlin installation | 12 (Very high) | | |
| | | Lifting I-Beam | 10 (High) | | |

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| | | Gutter and Trim installation | 7 (Very high) | | | |
| | | Soffit panel and wall angle installation | 7 (Very high) | | | |
| Chatterjee and Sahu, 2018 | Construction laborer (n = 164) | Sand carrying or filling mixture or lifting materials or sand loading | 8 (High) | 2,1,5,1 (Major strain) | MMH, overhead works, and awkward posture caused high risk of WRMSDs | 12-month prevalence: Neck (47.6%) Shoulder (36.6%) Wrist (36.6%) Elbow (25%) Lower back (69.5%) Knee (28.7%) |
| | | Carrying of construction material or Burrowing soil or Brick carrying | 4 – 6 (Medium) | 1,3,5,1 (Some strain) | | |

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| Cement and sand mixing or sand loading into vessel | 14 (Very high) | 4,1,4,3 (Harmful) |

Note: REBA = Rapid entire body assessment; RULA = Rapid upper limb assessment; OWAS = Ovako working analysis system; WRMSDs = Work-related musculoskeletal disorders; LBP = Low back pain; MMH = Manual material handling; CI = Confidence interval; Action categories: (1) no risk, (2) slight risk, (3) distinct risk, and (4) extreme risk

38 **Table S5.** Subjective assessments of physical and psychosocial risk factors for Work-related musculoskeletal disorders (WRMSDs) in construction workers

| Citations | Types of worker | Risk exposures | Exposure assessment methods and outcome scale | Prevalence of WRMSDs | Association between exposure and effects |
|---|---|---|---|---|---|
| Kaneda et al. 2001 | All trades (n=19,948) | **Physical risk:**<br>Awkward posture such as twisting and bending<br>Squatting<br>Stretching<br>Prolong standing<br>**Psychosocial risk:**<br>Mental stress<br>Living environment | **Exposure assessment**: Self-designed questionnaire<br>**Outcome scale**: Self-administered questionnaire | **Point prevalence:**<br>LBP, 29.3% | **Odds ratios (ORs) for low back pain**<br>Awkward posture such as twisting and bending, OR 1.81 (95%CI 1.46—2.24)<br>Squatting, OR 1.14 (95%CI 0.99—1.32)<br>Stretching, OR 0.89 (95%CI 0.61—1.29)<br>Prolong standing, OR 0.83 (95%CI 0.75—0.92)<br>Living with Family, OR 1.26 (95%CI 1.16—1.37)<br>Living with others, OR 1.09 (95%CI 0.98—1.21)<br>Mental stress was significantly associated with LBP ($t = 16.5$, $p < 0.05$) |
| Goldsheyder et al. 2002 | Mason tenders (n=300); Laborers (n=135) | **Physical risk:**<br>Awkward posture such as twisting or bending<br>MMH<br>Repetitive works<br>Overhead works | **Exposure and outcome assessment**: The modified IOWA construction questionnaire | **12-month prevalence:**<br>WRMSDs: 82%; LBP: 65%; Shoulders pain: 42%; Wrists/hands pain: 41%; Neck pain: 41%; Knee pain: 41%<br>**Point-prevalence:** | Working in awkward position such as twisting or bending, $f = 4.42$, $p=0.036$<br>Working over the head or away from the body, $f= 8.71$, $p=0.003$<br>MMH, $f= 17.91$, $p=0.001$ |

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| | | | | LBP: 33%; Shoulders pain: 21%; Wrists/hands pain: 21%; neck pain: 22%; knee pain: 22% | |
| Merlino et al. 2003 | Apprentice construction workers (n=996) | **Physical risk:**<br>Prolonged works<br>Working in an awkward posture including cramped position<br>Overhead works<br>Repetitive works | **Exposure assessment**: Self-designed questionnaire<br>**Outcome scale**: Nordic musculoskeletal disorder questionnaire | **12-month prevalence:**<br>LBP: 54.4% Wrist/hand pain: 42.4%<br>Knee pain: 38.4%<br>Neck pain: 31.8%<br>Shoulder pain: 27.9% | Prolonged works, OR 2.90 (95%CI 2.23–3.76) [LBP]<br>Work in awkward posture such as twisted position, OR 3.27 (95%CI 2.47–4.37) [LBP]<br>Repetitive works OR 4.53 (95%CI 3.24–6.34) [Wrist/hand pain]<br>Prolonged works, OR 2.71 (95%CI 2.09–3.52) [Wrist/hand pain]<br>Work in awkward posture such as cramped position, OR 1.31 (95%CI 1.04–3.18) [Knee pain]<br>Prolonged works, OR 2.90 (95%CI 2.20–3.78) [Knee pain] |
| Elders et al. 2004 | Scaffolders (n=288) | **Physical risk:**<br>MMH<br>Overhead works<br>Awkward posture such as back is bent and twisted<br>**Psychosocial risk:** | **Exposure assessment**: Self-designed questionnaire<br>**Outcome scale**: Nordic musculoskeletal disorder questionnaire | **12-month prevalence**: LBP: 60%; CLBP: 22% | MMH (Lifting or carrying loads >5 kg), OR 1.05 (95% CI 0.49–2.27)<br>Awkward posture such as back is bent and twisted over 45 degrees, OR 1.47 (95% CI 0.68–3.19)<br>Overhead work, OR 1.93 (95% CI 0.84– |

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| | | High job demand and low job control | | | 4.45)<br>High job demand and low job control, OR 2.16 (95% CI 1.12 – 4.21) |
| Goldsheyder et al. 2004 | Cement and concrete workers (n=200) | **Physical risk:**<br>Working in an awkward position such as bending or twisting the back<br>Working in extreme temperature (hot, cold, humid, wet conditions),<br>Prolonged works,<br>MMH<br>Overhead works | **Exposure and outcome assessment**: The IOWA construction questionnaire | **12-month prevalence:**<br>WRMSDs: 77%<br>LBP: 66%<br>Shoulder pain: 47%<br>Neck pain: 44%<br>Knee pain: 38%<br>Wrists/Hands pain: 37%<br>**Point-prevalence:**<br>LBP: 31%<br>Shoulder pain: 30%<br>Neck pain: 36%<br>Knee pain: 18%<br>Wrists/Hands pain: 17% | Working in an awkward position such as bending or twisting the back: Mean score, 5.5 (0-10 scale)<br>Working in extreme temperature: Mean score, 5.3 (0-10 scale)<br>Prolonged works: Mean score, 5.2 (0-10 scale)<br>MMH: Mean score, 5.1 (0-10 scale)<br>Overhead works: Mean score, 5.2 (0-10 scale) |
| Engholm et al. 2005 | Construction workers (n=85,191) | **Physical risk:**<br>Vibration<br>Lifting heavy objects<br>Awkward posture such as stooping or twisted back<br>Overhead work<br>Kneeling<br>**Psychosocial risk:** | **Exposure assessment**: Self-administered questionnaire<br>**Outcome scale**: Self-administered questionnaire | **12-month prevalence:**<br>LBP: 39.9%<br>Shoulder pain: 29.8%<br>Knee pain: 28.2%<br>Neck pain: 23.5%<br>Wrist/hand pain: 13.5%<br>Elbow pain: 12.1%<br>Upper back pain: 9.7% | Awkward posture such as stooping or twisted back, ORs 3.05 (95% CI, 2.73–3.42) and 2.23 (95% CI, 1.89–2.63) [Lower back and Upper back disorders, respectively]<br>Overhead work, ORs 3.66 (95% CI, 3.32–4.04) and 2.93 (95% CI, 2.65–3.24) [Shoulder and neck disorders, respectively] |

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| | Low job satisfaction<br>Low job control<br>Poor information<br>Lack of task variation<br>Poor supervisory support<br>Poor workmate support<br>Job responsibility too heavy<br>Work health hazard anxiety<br>High job demand<br>Sleeping problems<br>Mental stress | Kneeling, OR 3.94 (95% CI 3.55–4.37) [Knee disorders]<br>Lifting heavy objects, OR 1.90 (95% CI 1.72–2.11) [LBP]<br>Lifting heavy objects, ORs 1.62 (95% CI 1.42–1.85) and 1.60 (95% CI 1.40–1.84) [ elbow and wrist or hand disorders, respectively]<br>Vibration, OR 2.21 (95% CI 2.00–2.44) [wrists or hands disorders]<br>Low job satisfaction, OR 1.10 (95% CI 0.94 – 1.29) (Lower back disorders)<br>Low job control, ORs 1.16 (95% CI 1.01 – 1.33), 1.18 (95% CI 1.02 – 1.37), and 1.21 (95% CI 1.03 – 1.41) (Shoulder, elbow, and wrist or hand disorders, respectively).<br>Poor information, ORs 1.30 (95% CI 1.19 – 1.42) and 1.33 (95% CI 1.22 – 1.44) (Neck and shoulder disorders, respectively)<br>Lack of task variation, ORs 1.62 (95% CI 1.43 – 1.83), 1.57 (95% CI 1.39–1.78), and 1.51 (95% CI 1.34–1.70) (Shoulder, neck and lower back disorders, respectively)<br>Poor supervisory support, OR 1.03 (95% CI |

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| | | 0.91–1.16) (Neck disorders)<br>Poor workmate support, ORs 1.23 (95% CI 1.07–1.41), 1.14 (95% CI 1.03–1.28), and 1.12 (0.98–1.28) (Hip, neck, and upper back disorders, respectively)<br>Job responsibility too heavy, OR 1.12 (95% CI 1.03–1.22) (Knee disorders)<br>Work health hazard anxiety, ORs 2.37 (95% CI 2.18–2.59), 2.36 (95% CI 2.17–2.57), and 2.15 (95% CI 1.97–2.35) (Shoulder, lower back, and neck disorders, respectively)<br>High job demand, ORs 1.24 (95% CI 1.05–1.45), 1.20 (95% CI 1.03–1.40), and 1.16 (95% CI 1.00–1.35) (Upper back, Elbow, and wrist or hand disorders, respectively)<br>Sleeping problems, ORs 2.56 (95% CI 2.23–2.95), 2.44 (95% CI 2.15–2.78), and 2.41 (95% CI 2.11–2.74) (Upper back, neck, and shoulder disorders, respectively)<br>Mental stress, ORs 1.34 (95% CI 1.09–1.64), 1.24 (95% CI 1.00–1.53), and 1.19 (95% CI 0.95–1.49) (Wrist or hand, lower back, and upper back, respectively) |

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| Kaminskas et al. 2010 | Construction workers (n=312) | **Physical risk:**<br>Awkward work posture such as twisting or bending the neck or back<br>Force | **Exposure assessment**<br>Self-administered questionnaire<br>**Outcome assessment**: Nordic Musculoskeletal Disorder Questionnaire | **12-month prevalence:**<br>WRMSDs: 52.8% | Awkward work posture such as twisting or bending the neck or back and high use of physical force, are associated with WRMSDs. |
| Ekpenyong et al. 2014 | Ironworkers (n=143); Administrative workers (n=47); Security workers (n=93); Carpenters (n=152); Mechanical workers (n=161); Bricklaying workers (n=183); Electrical | **Physical risk:**<br>Awkward posture such as bending and twisting of the body<br>Force or vibration<br>MMH<br>Fast work pace<br>**Psychosocial risk:**<br>High job demands<br>Low job control<br>Interpersonal conflict<br>Job insecurity | **Exposure assessment**: The job content questionnaire (JCQ) scale<br>**Outcome scale**: Nordic Musculoskeletal Disorder Questionnaire | **12-month prevalence**:<br>WRMSDs: 39.3%<br>Neck and upper limb pain: 48.2%<br>Trunk and waist pain: 25.3%<br>Lower limb pain: 26.5% | Awkward posture such as bending and twisting of the body, OR 2.54 (95% CI = 1.14-10.33) [Heavy task]<br>Force or vibration, OR 4.15 (95% CI = 1.64-10.36) [Heavy task]<br>Fast work pace, OR 4.11 (95% CI = 1.01-16.71) [Heavy task]<br>Fast work pace, OR 2.02 (95% CI = 1.29-3.34) [Light task]<br>MMH, OR 2.61 (95%CI 1.15 – 16.32) [Heavy task]<br>High job demands, ORs 1.59 (95%CI 1.43 – 1.84) and 1.62 (95%CI 1.55, 1.89] [Heavy and light task, respectively]<br>High job insecurity, ORs 1.42 (95%CI 0.130 – 14.3) and 1.35 (95% CI 0.640 – 3.45) [Heavy and light task, respectively] |

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| | workers (n=131); Transportation workers (n=82); Storekeeper (n=67); Earth-movement unit workers (n=141) | | | | |
| Hanklang et al. 2014 | Female Rebar workers (n=272) | **Physical risk:** Awkward posture such as bending of neck or trunk for > 20 degrees Prolonged working hours (> 8 hours per day) Repetitive task (1000 times per day) **Psychosocial risk:** Perceived high job demand Work experience (years) | **Exposure assessment**: An ergonomic assessment check list **Outcome scale**: self-administered questionnaire | **12-month prevalence:** WRMSDs: 57.7% Shoulder/back pain: 46% Wrist/hand pain: 44.1% Neck pain: 40.1% Knee pain: 23.9% | Prolonged work hours, age-adjusted OR 7.63 (95% CI 2.06 – 28.31) Awkward posture such as bending of neck or trunk, age-adjusted OR 43.79 (95% CI 17.09 – 112.2) Work experience (> 5 years), OR 1.79 (95%CI 0.72 – 4.44) Perceived high job demand, OR 1.16 (95%CI 0.34 – 3.98) |

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| Neeraja et al. 2014 | Construction workers (n=288) | **Physical risk:**<br>Repetitive works (e.g., repetitive movements ≥ 1000 times per day)<br>Sitting posture<br>Standing posture<br>Overhead work<br>MMH<br>**Psychosocial risk:**<br>Job control<br>Job demands<br>Social support<br>Low Job satisfaction | **Exposure assessment**:<br>Self-administered questionnaire<br>**Outcome scale**: Nordic Musculoskeletal Disorder Questionnaire | **12-month prevalence:**<br>WRMSDs [elbow, arm, wrist, or hand]: 3.5% (female), 12% (Male)<br>WRMSDs [neck, shoulder or upper back]: 27% (female), 18% (Male) | MMH, OR 2.96 (95% CI 1.81 – 4.85) [Neck, shoulder and upper back WRMSDs]<br>Repetitive works (e.g., repetitive movements ≥ 1000 times per day), OR 2.01 (95% CI 1.25 – 3.24) [Neck, shoulder and upper back WRMSDs]<br>High job demands, OR 2.08 (95% CI 1.20 – 2.62) [Neck, shoulder and upper back WRMSDs]<br>Low job satisfaction, OR 1.83 (95% CI 1.10 – 3.04) [Neck, shoulder and upper back WRMSDs] |
| Egwuonwu et al. 2016 | Road construction workers (n=100) | **Physical risk:**<br>Awkward posture such as twisting and sideway bending;<br>Repetitive works<br>Vibration from hand tools;<br>Lifting, reaching, unequal lifting<br>**Psychosocial risk:**<br>Time pressures | **Exposure assessment**:<br>Organizational factors Questionnaire<br>**Outcome assessment**<br>Dutch Musculoskeletal questionnaire | **12-month prevalence:**<br>WRMSDs: 66%<br>LBP: 55%<br>Neck pain: 45% | Working in awkward posture such as twisting and sideway bending, prolonged working hours (average 9 hours) per day and vibration, were associated with the occurrence of WRMDs.<br>High time pressures, OR 3.52 (95%CI 1.32 – 5.96)<br>Casual employment status, OR 2.78 (95%CI 1.45 – 6.03)<br>Adequate supervision and training, OR 2.34 (95%CI 0.95 – 5.24) |

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| | | Employment status<br>Supervision and training<br>Family and spousal support<br>Remuneration and wages<br>Job security<br>Working hours<br>Transportation facility<br>Co-workers relationship | | | Family and spousal support, OR 1.58 (95%CI 0.78–4.67)<br>Adequate remuneration and wages, OR 2.53 (95%CI 1.45 – 5.56)<br>Guaranteed job security, OR 3.12 (95%CI 1.32 – 6.26)<br>Adequate working hours, OR 1.28 (95%CI 0.67 – 3.65)<br>Adequate transportation facility, OR 3.07 (95%CI 1.58 – 6.06)<br>Cordial co-workers' relationship, OR 2.46 (95%CI 0.96 – 4.79) |
| Wang et al. 2017 | Multiple trades (n=82,630) | **Physical risk:**<br>Vibration<br>Overexertion involving outside sources<br>Other exertions or bodily reactions | **Exposure assessment**: Not reported<br>**Outcome scale**: Not reported | **12-month prevalence** of WRMSDs: 24.6 to 25.9% | Vibration vs WRMSDs: 0.3%<br>Overexertion involving outside sources vs WRMSDs: 65.3%<br>Other exertions or bodily reactions vs WRMSDs: 27.6% |
| Jensen and Kofoed 2002 | Floor layers (n=102) and apprentice floor layers (n=180) | **Physical risk:**<br>High physical work strain<br>**Psychosocial risk:**<br>High job demand<br>Presence of mental stress | **Exposure assessment**: Semi-structured interview<br>**Outcome scale**: Nordic Musculoskeletal Disorder Questionnaire | **12-month prevalence:**<br>Knee pain: 56% (Floor layers) and 48% (apprentice floor layers)<br>LBP: 61% (Floor layers) and 57% (apprentice | Physical work strain (high versus low): OR = 9.1, 95% CI = 1.05 – 78.8 (Knee pain)<br>High job demand (high versus low): OR = 2.5, 95% CI = 1.02 – 6.03 (Knee pain)<br>Mental stress (yes versus no): OR = 2.3, 95% CI = 0.98 – 5.2 (Knee pain) |

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| | | | | floor layers) | Physical work strain (high versus low): OR = 5.6, 95% CI = 1.07 – 29.5 (LBP)<br>Psychological work strain (high versus low): OR = 2.0, 95% CI = 0.82 – 4.8 (LBP)<br>Mental stress (yes versus no): OR = 3.4, 95% CI = 1.5 – 8.2 (LBP) |
| Lee et al. 2005 | Construction workers (n=1,814) | Psychosocial risk<br>Job content<br>Physical working condition<br>Relationship<br>Organizational problem<br>Uncomfortable working environment<br>Poor safety and hygiene in the workplace | **Exposure assessment**: Self-administered questionnaire<br>**Outcome scale**: Nordic Musculoskeletal Disorder Questionnaire | **12-month prevalence:**<br>Neck pain: 27.2%<br>Shoulder pain: 32.6%<br>Upper back pain: 15.1%<br>Elbow pain: 19.9%<br>Hand and wrist pain: 26.7% | Job content vs no stress: OR = 1.8, 95% CI = 1.5 – 2.3 and OR = 1.6, 95% CI = 1.1 – 2.5 (WRMSDs in Male and Female, respectively)<br>Physical working condition vs no stress: OR = 2.5, 95% CI = 1.7 – 3.9 and OR = 2.2, 95% CI = 1.1 – 4.6 (WRMSDs in Male and Female, respectively)<br>Relationship vs no stress: OR = 3.3, 95% CI = 1.7 – 6.7 and OR = 1.9, 95% CI = 0.8 – 4.2 (WRMSDs in Male and Female, respectively)<br>Organizational problem vs no stress: OR = 1.6, 95% CI = 1.1 – 2.1 and OR = 1.9, 95% CI = 1.2 – 3.0 (WRMSDs in Male and Female, respectively)<br>Uncomfortable vs comfortable working environment: OR = 1.5, 95% CI = 1.0 – 2.1 |

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| | and OR = 0.7, 95% CI = 0.3 – 1.6 (WRMSDs in Male and Female, respectively)<br>Safety and hygiene of the job (Unsatisfied vs satisfied): OR = 1.1, 95% CI = 0.8 – 1.7 and OR = 3.0, 95% CI = 1.4 – 6.4 (WRMSDs in Male and Female, respectively) |

Note: LBP = Low back pain; MMH = Manual material handling; WRMSDs = Work-related musculoskeletal disorders; CI = Confidence interval

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