

BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

Work-Related Musculoskeletal Disorders, Fatigue and Stress Among Gas Station Workers

| | |
|-------------------------------|--|
| Journal: | <i>BMJ Open</i> |
| Manuscript ID | bmjopen-2023-081853 |
| Article Type: | Original research |
| Date Submitted by the Author: | 08-Nov-2023 |
| Complete List of Authors: | Fan, Jialin; Shenzhen University; Shenzhen Humanities & Social Sciences Key Research Bases of the Center for Mental Health Tan, Xiaotong; Shenzhen University, School of Psychology Smith, Andrew; Cardiff University, School of Psychology Wang, Jing; Shenzhen University |
| Keywords: | Occupational Stress, Fatigue, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY |
| | |

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4
5 **1 Work-Related Musculoskeletal Disorders, Fatigue and Stress Among**
6
7 **2 Gas Station Workers**
8
9

10
11 **3 Jialin Fan^{a,b*}, Xiaotong Tan^a, Andrew P. Smith^c, and Jing Wang^a**
12
13

14 *4 ^aSchool of Psychology, Shenzhen University, Shenzhen, China*

15
16
17 *5 ^bThe Shenzhen Humanities & Social Sciences Key Research Bases of the Center for*
18
19 *6 Mental Health, Shenzhen, China*

20
21
22 *7 ^cCentre of Occupational and Health Psychology, School of Psychology, Cardiff*
23
24 *8 University, 63 Park Place, Cardiff, CF10 3AS, UK.*

25
26
27 *9 * FanJL@szu.edu.cn*
28
29

30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

11 **Work-Related Musculoskeletal Disorders, Fatigue and Stress Among** 12 **Gas Station Workers**

13 **Abstract**

14 **Introduction:** Work-related musculoskeletal disorders (WMSDs) are disorders of the
15 musculoskeletal system that have the highest prevalence among workers worldwide.
16 Workers in gas stations usually work in poor ergonomic working conditions, including
17 prolonged standing and repetitive posturing.

18 **Objective:** the study aimed to investigate the prevalence of WMSDs and fatigue and to
19 identify the predictors of WMSDs among gas station workers.

20 **Design:** The present study was a cross-sectional study.

21 **Setting and participants:** 2,962 gas station workers from an oil and gas company in
22 China.

23 **Results:** The prevalence of WMSDs within the 12 months prior to the study was
24 73.23%, with the highest prevalence in the neck, shoulders, ankles and feet.
25 Furthermore, a correlation was observed between fatigue, stress, and WMSDs. Fatigue
26 and job role were the strongest predictors of WMSDs, with an odds-ratio range of
27 2.211–3.413.

28 **Conclusions:** This research identified the detrimental impact of WMSDs and fatigue
29 on gas station workers, indicating the critical need for interventions to reduce WMSDs
30 and relieve fatigue.

31 **Strengths and limitations of this study**

- 32 ● This study investigated the present condition of WMSDs and occupational risk
33 among gas station workers.
- 34 ● The Nordic Musculoskeletal Questionnaire and Smith Well-being Questionnaire
35 were used to assess WMSDs, fatigue, stress and other work-related risk factors.
- 36 ● Logistic regression was conducted to determine the predictors of the WMSDs.
- 37 ● This was a cross-sectional study, unable to determine the mechanism and aetiology

1
2
3
4 38 of WMSDs.
5
6 39
7
8
9

10 **Introduction**

11
12
13 41 Gas station workers are key figures in the oil industry chain, subject to heavy workloads
14
15 42 and safety-critical tasks, and related occupational stress, fatigue, health problems and
16
17 43 environmental hazards. A recent review emphasised the importance of occupational
18
19 44 health concerns for gas station workers, concluding that shift work and the specific
20
21 45 work environment of gas station workers can adversely affect their sleep, stress levels,
22
23 46 physical and mental health, and turnover intention.¹ The work design of this job role is
24
25 47 varied in different countries and regions; for example, in developed countries such as
26
27 48 the United States, self-service refuelling is common, and gas stations often employ
28
29 49 managers, cashiers and similar staff, while in developing countries such as China, they
30
31 50 still rely on manual refuelling operations, which increases the number of gas station
32
33 51 workers needed. Regardless of the operational mode, very little empirical research has
34
35 52 focused on the occupational health concerns of gas station workers in comparison to
36
37 53 the range of risk factors to which they are exposed.

38
39
40 54 Gas station workers face inevitable occupational stress, and their extensive workloads
41
42 55 require an elevated level of alertness and motivation to fulfil their duties. The duties of
43
44 56 gas station workers encompass refuelling, sales, and communication with customers
45
46 57 and colleagues, alongside additional security responsibilities.² As a service industry,
47
48 58 they also require emotional intelligence to provide exceptional service quality
49
50 59 continually. When job demands exceed workers' abilities and coping skills, they
51
52 60 become a risk factor, generating stress and various health problems.³ Occupational
53
54 61 stress is a severe occupational hazard that generates problematic alcohol use,⁴
55
56 62 depression⁵ and impairment of physical health, psychological well-being and
57
58 63 performance.⁶ It can also lead to sick leave, adversely affecting productivity and placing
59
60 64 a financial burden on employers and society.⁷

1
2
3
4 65 Work-related musculoskeletal disorders (WMSDs) are one of the health problems that
5
6 66 gas station workers have frequently reported, as their work tasks include repetitive,
7
8 67 awkward body movements. WMSDs are common painful disorders affecting the body
9
10 68 structure that are caused by a variety of factors, such as repetitive motion, excessive
11
12 69 force, awkward and/or sustained postures and prolonged sitting and standing.⁸ WMSDs
13
14 70 can also result in physical and mental illness, chronic pain and disability.⁹ WMSDs are
15
16 71 widespread around the world and are the second most common cause of disability in
17
18 72 the workplace.¹⁰ They indirectly decrease industrial efficiency, which results in
19
20 73 significant economic burdens.¹¹ The prevalence of WMSDs and their related
21
22 74 negative effects on workers' productivity, particularly in developing countries, should
23
24 75 be treated seriously to decrease the impact on production and promote workers' well-
25
26 76 being.¹² Many previous studies on the health and well-being of gas station workers
27
28 77 focus primarily on the negative effects of organic solvents such as benzene on
29
30 78 physiological health and the nervous system. However, gas station workers usually
31
32 79 experience poor ergonomic working conditions for long periods, which can contribute
33
34 80 to an increase in WMSDs.

35
36 81 Psychosocial stressors, such as high workload or low time control, may contribute to
37
38 82 an increased risk of musculoskeletal disorders by increasing biomechanical load or
39
40 83 physical stress. Occupational stress is associated with physical symptoms and is
41
42 84 prevalent over time.¹³ A review explored the impact of stressors on the onset of
43
44 85 musculoskeletal disorders related to the neck/shoulder, upper limbs and waist, revealing
45
46 86 that psychosocial factors were independent predictors of musculoskeletal disorders.¹⁴
47
48 87 It indicates that work-related stress may have an impact on the incidence of MSDs.
49
50 88 Despite the existence of work stress issues and physical health problems among gas
51
52 89 station workers, there remains a dearth of clear evidence regarding the impact of work
53
54 90 stress on WMSDs.

55
56
57 91 Occupational fatigue is described as a state of 'extreme tiredness and reduced functional
58
59 92 capacity experienced during or at the end of the workday',¹⁵ and it is a common
60

1
2
3
4 93 occupational health problem in many industries and occupations across the world.
5
6 94 Fatigue has a myriad of negative consequences; for example, fatigue is linked to various
7
8 95 health problems, including sleep disorders, depression, obesity,¹⁶ and musculoskeletal
9
10 96 disorders, and it impacts work efficiency, job satisfaction and turnover intention.^{17 18}
11
12 97 Gas station workers often experience high job demands, heavy workloads and shift
13
14 98 work. Workers experience fatigue more quickly as a result of this condition. Thus, as a
15
16 99 key component of safety, the fatigue of gas station workers should be given more
17
18 100 consideration.

19
20
21 101 WMSDs and fatigue are both major occupational health issues. Musculoskeletal
22
23 102 disorders have been associated with fatigue in nurses and office workers.^{19 20} A
24
25 103 longitudinal study found that burnout could be a risk factor for the development of
26
27 104 musculoskeletal pain in apparently healthy individuals.²¹ Although the relationship
28
29 105 between WMSDs and fatigue has been studied in several occupations, there is currently
30
31 106 a dearth of research related to gas station workers. Gas station employees are exposed
32
33 107 to a multitude of risk factors for WMSDs in the workplace, including prolonged
34
35 108 standing and repetitive motions when filling vehicles. Other factors that contribute to
36
37 109 physical and mental fatigue include heavy workloads, maintaining a positive attitude
38
39 110 when interacting with customers, remaining vigilant to operations that are prone to
40
41 111 causing safety mishaps and working in shifts. Personal characteristics and work-related
42
43 112 factors such as workload should also be considered. It is apparent that there is
44
45 113 insufficient research on WMSDs and fatigue specific to gas station workers, and
46
47 114 relevant risk factors should be further identified.

48
49 115 While WMSDs, occupational stress and fatigue are common issues that negatively
50
51 116 affect the health and safety of gas station workers, few studies have been conducted in
52
53 117 this field, particularly concerning physical and mental health. The current study aimed
54
55 118 to examine the prevalence of WMSDs, determine the association between WMSDs,
56
57 119 stress and fatigue, and investigate the predictors of WMSDs among gas station workers.
58
59 120 It contributes to developing a better understanding of the occupational risk factors that
60

1
2
3
4 121 can result in WMSDs, which is of great significance for better monitoring and
5
6 122 preventing WMSDs, stress and fatigue and enhancing the physical and mental health
7
8 123 of gas station workers.
9

10 124 **Material and methods**

11 125 *Participants and Procedure*

12
13
14
15
16
17 126 Participants were staff from an oil company in China (N = 2,962). The job positions
18
19 127 reported were gas operator (34.98%), cashier (14.45%), front-court manager (24%), gas
20
21 128 station manager (8.85%), convenience store supervisor (6.14%), finance department
22
23 129 staff (3.81%), management and executive staff (2.3%) and other positions (5.47%). It
24
25 130 should be noted that the front-court manager has a unique position in Chinese gas
26
27 131 stations. The duties of this position include but are not limited to 'being responsible for
28
29 132 organising the staff to carry out various operations, management and service work
30
31 133 during the shift', 'being responsible for the normal operation of the gas station during
32
33 134 the shift', which can also be described as 'on-site duty manager'.
34
35

36 135 We conducted an online survey among gas station employees from an oil and gas
37
38 136 company in China, with the approval and cooperation of the company. Participants
39
40 137 were asked to complete an informed consent form, and they were free to withdraw from
41
42 138 the survey at any point. The School of Medicine Ethical Committee at Shenzhen
43
44 139 University reviewed and approved this study.
45
46

47 140 *Measurement of Musculoskeletal Disorders*

48
49
50
51 141 WMSDs were assessed using the Chinese version of the Nordic Musculoskeletal
52
53 142 Questionnaire (NMQ), a self-reported questionnaire that assesses the prevalence of
54
55 143 musculoskeletal disorders in nine areas of the body: the neck, shoulders, elbows, wrists
56
57 144 and hands, hips, knees, lower back, upper back and ankles and feet.²² Participants were
58
59 145 asked to note the occurrence of these symptoms over the past week (weekly prevalence)
60

1
2
3
4 146 and over the past year (annual prevalence). The NMQ was translated for use with
5
6 147 Chinese samples and proved to be reliable and valid.²³ The questionnaire is suitable for
7
8 148 application in a variety of workplaces, and data can be collected quickly and easily with
9
10 149 one study.

11
12
13 150 Considering that musculoskeletal disorders in gas station workers are a long-standing
14
15 151 problem, in this study, the incidence of musculoskeletal disorders in the past year was
16
17 152 used as the evaluation index. WMSDs are defined by reports of discomfort, numbness,
18
19 153 pain and restricted movement in one or more body regions in the past year.

20 21 22 154 *Measurement of Occupational Stress and Fatigue*

23
24
25 155 Occupational stress and fatigue were evaluated using the Smith Well-being
26
27 156 Questionnaire (SWELL).²⁴ The SWELL, which is based on the Demands-Resources-
28
29 157 Individual-Effects (DRIVE) model, was used to assess occupational fatigue, stress at
30
31 158 work, workload, lifestyle, personality, job satisfaction and so on.²⁵ This questionnaire
32
33 159 has been used to assess a variety of occupational groups in previous studies, allowing
34
35 160 the identification of the overall occupational risks. This questionnaire was translated
36
37 161 into Chinese using both forward and back translation.²⁶

38
39
40 162 The SWELL consists of 26 single-item questions, and most of the questions are on a
41
42 163 10-point Likert scale. In the current study, the main variables of interest were stress,
43
44 164 fatigue, work characteristics (i.e., workload, job support and control, noise exposure
45
46 165 and fume exposure) and personal characteristics (i.e., personality and lifestyle).

47 48 49 166 *Analyses*

50
51
52
53 167 Data analysis was conducted using SPSS 25. Descriptive analyses examined the
54
55 168 frequencies of demographic variables, WMSD symptoms (NMQ), stress, fatigue,
56
57 169 personal characteristics and work characteristics. Pearson correlation was used to
58
59 170 examine the associations between stress, fatigue, WMSDs and other variables. Variable
60

1
2
3
4 171 scores were categorised into a high/low group using a median split. Logistic regression
5 172 was then conducted to determine the predictors of the WMSDs.
6
7
8

9 173 **Results**

10 11 12 174 *Descriptive Statistics*

13
14
15 175 Participants' descriptive characteristics and WMSD symptoms are shown in Table 1. A
16 176 total of 2,962 participants completed the online survey. The average age of the
17 177 participants was 36.67 ± 7.55 years; 55.47% of participants were female. According to
18 178 the work content and actual workplace, participants' job roles were divided into
19 179 frontline staff (N = 2,619; 88.42%) and non-frontline staff (N = 343, 11.58%). Frontline
20 180 staff work at gas stations on daily duty, including gas operators, cashiers, front-court
21 181 managers, convenience store supervisors and gas station managers. Non-frontline staff
22 182 include finance department staff, management and executive staff, and other positions
23 183 that work in offices where they are not exposed to gasoline daily and are not required
24 184 to remain in a standing position for long periods.
25
26
27
28
29
30
31
32
33
34
35

36 185 Participants had a mean stress score of 6.30 ± 2.55 and a mean fatigue score of $6.00 \pm$
37 186 2.49 . The results also showed that people with WMSD symptoms had unhealthier
38 187 lifestyles ($t = 14.03, p < 0.001$), more negative personalities ($t = 11.05, p < 0.001$),
39 188 higher levels of fatigue ($t = -20.262, p < 0.001$) and stress ($t = -16.92, p < 0.001$)
40 189 than those without WMSDs symptoms.
41
42
43
44
45
46
47
48

49 190 Additionally, a single item from the SWELL on musculoskeletal problems (Do you
50 191 suffer from musculoskeletal disorders [e.g. arthritis; back pain; sciatica; repetitive strain
51 192 injury]?) was used to gauge the effectiveness of the NMQ. Participants who reported
52 193 WMSDs on the NMQ scored 6.11 ± 2.96 on this question, which was significantly
53 194 higher than healthy participants ($t = 29.24, p < 0.001$).
54
55
56
57
58
59
60

195

196

INSERT TABLE 1 HERE

197

Table 1. Descriptive Characteristics and MSD Symptoms of Participants

198

Prevalence of WMSDs

199 As shown in Table 2 and Figure 1, the prevalence of WMSDs among the respondents
 200 was unevenly distributed among most body regions and centred around three of them,
 201 namely the neck (42.27%), shoulders (35.89%) and ankles and feet (34.71%). The 12-
 202 month prevalence was 73.23%, and significant differences were found for age group
 203 ($\chi^2 = 17.95, p < 0.001$) and job role ($\chi^2 = 50.82, p < 0.001$) but not gender ($\chi^2 =$
 204 $3.59, p = 0.058$).

205

206

INSERT TABLE 2 HERE

207

Table 2. WMSDs in gas station workers

208

INSERT FIGURE 1 HERE

209

Figure 1. Regions of WMSDs in the previous 12-month period prevalence

210

Associations among Stress, Fatigue and WMSDs

211 Pearson correlation was used to investigate the association among stress, fatigue,
 212 WMSDs (from the SWELL) and work and personal characteristics (Table 3). Stress
 213 showed significant positive correlations with fatigue ($r = 0.61, p < 0.001$) and WMSDs
 214 ($r = 0.40, p < 0.001$). Both stress, fatigue and WMSDs were significantly correlated

1
2
3
4 215 with personal characteristics (lifestyle and personality, $p < 0.001$) and other work
5
6 216 characteristics (job control and support, noise, fumes, $p < 0.001$).
7
8
9

10 217

11
12
13 218 *INSERT TABLE 3 HERE*
14

15
16 219 **Table 3.** Correlation among stress, fatigue, WMSDs, work and personal characteristics
17

18
19
20 220 ***Predictors of WMSDs***
21

22
23 221 Logistic regressions were run to investigate the predictors of WMSDs. The dependent
24
25 222 variable was WMSDs, measured with or without WMSD symptoms over the past year.
26
27 223 The independent variables included in the model were demographic variables (age,
28
29 224 gender and job role), personal characteristics (personality and lifestyle), work
30
31 225 characteristics (workload, job control and support, noise exposure and fume exposure),
32
33 226 stress and fatigue, in which age was continuous, and other variables were categorical.
34
35 227 Table 4 shows the Odds ratio for each of the independent variables.
36

37
38 228 In the final model, the results showed that job role was the strongest predictor of
39
40 229 reported WMSD symptoms, with an odds ratio of 3.413 ($p < 0.001$), which indicated
41
42 230 that the frontline staff were more than three times more likely to report WMSD
43
44 231 symptoms than non-frontline staff. Fatigue was the second strongest predictor of
45
46 232 reported WMSD symptoms, with an odds ratio of 2.211 ($p < 0.001$), which indicated
47
48 233 that participants who reported high fatigue were over two times more likely to report
49
50 234 WMSD symptoms than those reporting low fatigue after controlling demography and
51
52 235 individual difference factors in the model.
53
54
55
56
57
58
59
60

1
2
3
4 236 The logistic regression model also found that stress (OR = 1.327, $p < 0.05$), gender
5
6 237 (female; OR = 0.610, $p < 0.001$), negative personality (OR = 1.322, $p < 0.05$),
7
8 238 unhealthy lifestyle (OR = 2.032, $p < 0.001$), heavy workload (OR = 1.345, $p <$
9
10 239 0.05), lack of job control (OR = 1.636, $p < 0.001$), noise exposure (OR = 1.585, $p <$
11
12 240 0.001) and fume exposure (OR = 1.327, $p < 0.05$) significantly contributed to
13
14 241 WMSDs.
15
16
17
18
19
20
21
22

242

243

INSERT TABLE 4 HERE

244

Table 4. Odds ratio of IVs on WMSDs

245 Discussion

246 This is a cross-sectional study using an online questionnaire to investigate the
247 prevalence of and relationship between WMSDs, stress and fatigue, and the predictors
248 of WMSDs among gas station workers. Participants reported medium-to-high levels of
249 fatigue and stress, and the 12-month prevalence of WMSDs was 73.23%. The neck,
250 shoulders, ankles and feet were the most common body regions affected by
251 musculoskeletal disorders. The present study also showed a significant positive
252 correlation between fatigue, stress and WMSDs, and with higher fatigue and stress,
253 participants were more likely to have WMSDs. In addition, job roles and personal and
254 work characteristics were predictors of WMSDs.

255 In terms of occupational fatigue and stress, the findings suggest that there was indeed a
256 certain occupational health problem among gas station employees. Firstly, fatigue was
257 clearly associated with multiple risk factors, including individual characteristics, work
258 characteristics and environment. Given the nature of the gas station industry, workers

1
2
3
4 259 usually work long hours each day, and most of this is shift work, both of which have
5
6 260 been closely related to fatigue.²⁷ A growing body of literature has demonstrated that
7
8 261 fatigue is common among gas station workers, as well as workers from the oil and gas
9
10 262 industry, such as offshore drilling, the job characteristics of which are similar.²⁸⁻³⁰
11
12 263 Meanwhile, the current study provides evidence of a significant positive association
13
14 264 between job stress and occupational fatigue among gas station workers. These findings
15
16 265 align with previous research conducted on various occupational groups, including
17
18 266 nurses,³¹ call centre employees,³² and drivers,³³ thus confirming a consistent
19
20 267 relationship between stress and fatigue. Nonetheless, this study represents the first
21
22 268 investigation specifically focusing on the stress and fatigue experiences of gas station
23
24 269 workers, highlighting the unique challenges faced by this particular occupational group.
25
26 270 In addition to their primary responsibilities of providing refuelling services, frontline
27
28 271 gas station workers often have additional responsibilities such as safety duties, sales,
29
30 272 and prioritising customer satisfaction. Such multifaceted job demands may contribute
31
32 273 to heightened job stress levels and subsequent fatigue among these workers. Our
33
34 274 findings underscore the need for interventions to reduce stress and fatigue risk factors.

35
36 275 The majority of gas station workers reported having WMSDs in at least one anatomical
37
38 276 region during the 12 months prior to the study, which is in line with previous research
39
40 277 conducted both inside and outside of China.^{34 35} The clustering pattern of WMSDs
41
42 278 observed in this study, notably in the neck (42.27%), shoulders (35.89%) and ankles
43
44 279 and feet (34.71%), is somewhat different from findings in previous studies among gas
45
46 280 station workers. Among Nigerian gas station workers, the reported prevalence pattern
47
48 281 of body regions was highest in the lower back (54%) and shoulders (52%),³⁶ whereas
49
50 282 in Ghana, it was highest in the lower back (43%).³⁴ This is due in part to the larger
51
52 283 proportion of frontline employees in our study, who engage primarily in manual labour.
53
54 284 Although there are variations in the specific sites affected among gas station workers
55
56 285 in different countries, the overall prevalence of moderate to high rates of work-related
57
58 286 musculoskeletal disorders (WMSDs) ranged from 51.2% to 86%.³⁴⁻³⁶ This

1
2
3
4 287 demonstrates that WMSDs are a common issue within the gas station occupation. A
5
6 288 cross-cultural comparison research of workers in similar occupational groups revealed
7
8 289 disparities in the prevalence of self-reported MSD discomfort between Malaysia and
9
10 290 Australia.³⁷ However, there were no significant differences in the frequency and
11
12 291 severity of symptoms across five body regions among those reporting MSD discomfort,
13
14 292 and they shared similar predictors. Therefore, future research seeking to generalize
15
16 293 these findings to comparable job positions in other countries should carefully consider
17
18 294 sociocultural backgrounds as influencing factors.

19
20 295 WMSDs are a multi-factorial disorder linked to various demographic and work-related
21
22 296 features. There is limited literature concerned with WMSDs in this particular field.
23
24 297 Therefore, a comprehensive analysis based on the establishment of a logistic regression
25
26 298 model was run to reveal the presence of multiple influencing factors for WMSDs among
27
28 299 gas station workers, including personal and work characteristics. It's worth noting that
29
30 300 fatigue and job role were found to be major risk factors for WMSDs. There is a clear
31
32 301 relationship between WMSDs and occupational fatigue. This finding is consistent with
33
34 302 previous research that has identified fatigue as a risk factor for WMSDs.³⁸ Fatigued
35
36 303 workers usually perform poorly at work and may eventually face serious health
37
38 304 problems. Ergonomically, the risk factors for gas station workers come from repetitive
39
40 305 actions (such as filling vehicles) and long periods of standing (as with cashiers).
41
42 306 According to previous studies, maintaining an awkward and static posture for extended
43
44 307 periods at work can cause discomfort, pain and chronic fatigue.¹⁷ This is supported by
45
46 308 results from job roles, where frontline workers are more likely to have musculoskeletal
47
48 309 problems than non-frontline workers. Frontline workers are more likely to be exposed
49
50 310 to risk factors at work, such as repetitive motions, poor posture and physical strain.
51
52 311 Adverse symptoms accumulate over time and can cause serious consequences for
53
54 312 physical and mental health.

55
56
57 313 It is worthwhile to note that there was no significant difference in age between those
58
59 314 with and without WMSDs. Similarly, in logistic regression, age was not a significant

1
2
3
4 315 predictor of WMSDs. However, a recent study found that there was a relationship
5
6 316 between age and musculoskeletal disorders complaints.³⁹ In general, increased age
7
8 317 causes workers' physical conditions to deteriorate, and as muscle strength and
9
10 318 endurance decline, the risk of WMSDs increases.⁴⁰ The different results suggest that
11
12 319 some variables might modify the relationship between age and WMSDs, such as body
13
14 320 mass index (BMI), smoking habits and physical activity, which are individual
15
16 321 characteristic variables associated with WMSDs, should be examined in future studies.

17
18 322 According to the logistic regression model, negative personality and unhealthy lifestyle
19
20 323 were considered risk factors for WMSDs. These findings are similar to the results of
21
22 324 other studies.^{41 42} Therefore, at the individual level, adopting a healthy lifestyle may be
23
24 325 able to mitigate the incidence of WMSDs. Personality type and WMSDs appear to be
25
26 326 correlated, and it is suggested that organisations may consider personality type factors
27
28 327 in employee selection and training.

29
30
31 328 The results from this study provide insight into understanding the relationship between
32
33 329 fatigue, stress and WMSDs among gas station workers. These findings have practical
34
35 330 implications for identifying and addressing WMSDs, particularly among frontline
36
37 331 workers who experience severe fatigue and stress. The consequences of WMSDs are
38
39 332 considerable for employees and employers alike. Therefore, several measures can be
40
41 333 taken to prevent the risk of WMSDs. For example, gas station workers should be aware
42
43 334 of risk factors and make positive changes, such as stretching between breaks.
44
45 335 Employers should consider implementing fatigue management strategies and providing
46
47 336 ergonomic workstations to ensure the well-being and safety of their workers.

48
49
50 337 There are a few limitations of this study. First, the study sample was exclusively from
51
52 338 China; therefore, future studies should determine and verify our results in other regions,
53
54 339 including workers from both developed and developing nations and state-owned and
55
56 340 private businesses. Second, this study investigated the prevalence of WMSDs without
57
58 341 clarification of the mechanism and aetiology of WMSDs in participants. Third, due to
59
60

1
2
3
4 342 the limitations of the working environment and the convenience of sampling, this was
5
6 343 a cross-sectional study that used subjective measurement methods. Future studies
7
8 344 should apply objective technologies, such as real-time physiological monitoring and
9
10 345 actigraphy, which lead to more accurate and objective conclusions. A prospective
11
12 346 longitudinal design is also needed to better understand causal relationships between the
13
14 347 variables.

15
16 348 Our study also has several strengths. This study investigated the present condition of
17
18 349 WMSDs and occupational risk among gas station workers and provided evidence of an
19
20 350 association between fatigue, stress and WMSDs. This finding has important
21
22 351 occupational health implications and may inform the prevention of WMSDs among gas
23
24 352 station workers. The research results can provide a reference for empirical studies, in
25
26 353 particular, interventions to address the current situation.

30 354 **Conclusion**

31
32
33 355 There is a high prevalence of WMSDs among workers in the gas station industry, most
34
35 356 frequently in the neck, shoulders, ankles and feet. The gas station workers had a
36
37 357 medium-to-high level of fatigue and stress, and associations between fatigue, stress and
38
39 358 WMSDs were found in this study. The participants who reported high fatigue were
40
41 359 more than two times more likely to report WMSDs. In addition to the risk factor of
42
43 360 fatigue, job role, stress, and personal and work characteristics played essential roles in
44
45 361 the prediction of WMSDs.

48 362 **Declarations**

51 363 **Contributors**

52
53
54
55 364 JF contributed to the study's conception and design. JW contributed to the material
56
57 365 preparation and data collection. XT carried out the analyses and drafted the initial
58
59 366 manuscript. All authors have read, critically revised and approved the final version of
60

1
2
3
4 367 this manuscript.
5
6

7 368 ***Competing interests***
8
9

10 369 The author(s) declared no potential conflicts of interest with respect to the research,
11
12 370 authorship and/or publication of this article.
13
14

15 371 ***Funding***
16
17

18 372 This research received no specific grant from any funding agency in the public,
19
20 373 commercial, or not-for-profit sectors.
21
22

23 374 ***Ethics approval and consent to participate***
24
25

26 375 This paper received ethical approval from School of Medicine Ethical Committee at
27
28 376 Shenzhen University: PN-202300036. All participants provided informed consent prior
29
30 377 to completing the first survey.
31
32

33 378 ***Patient and Public Involvement***
34
35

36 379 Patients and/or the public were not involved in the design, or conduct, or reporting, or
37
38 380 dissemination plans of the research.
39
40

41 381 **References**
42
43

- 44 382 1 Yin Y, Tan X, Fan J. Occupational fatigue and health of gas station workers: a review. *Work*
45
46 383 2023;Pre-press:1-20. doi: 10.3233/WOR-220415.
47
48 384 2 Sirdah M, Al Laham NA, Al Madhoun R. Possible health effects of liquefied petroleum gas
49
50 385 on workers at filling and distribution stations of Gaza governorates. *E Mediterr Health J*
51
52 386 2013;19:289-294. doi: 10.26719/2013.19.3.289.
53
54 387 3 Gimaeva ZF, Bakirov AB, Karimova LK, *et al.* Production and genetic risk factors for
55
56 388 cardiovascular diseases among petrochemical industry workers. *Terapevt Arkh* 2018;90:49-
57
58 389 53. doi: 10.26442/terarkh201890149-53.
59
60

- 1
2
3
4 390 4 Frone MR. Work stress and alcohol use: developing and testing a biphasic self-medication
5 391 model. *Work Stress* 2016;30:374-394. doi: 10.1080/02678373.2016.1252971.
- 6
7 392 5 Lee KS, Lee DB, Kwon IS, *et al.* Depressive symptoms and their association with sleep
8 393 quality, occupational stress and fatigue among small-scaled manufacturing male workers.
9 394 *Korean J Occup Environ Med* 2011;23:99-111. doi: 10.35371/kjoem.2011.23.2.99.
- 10
11 395 6 Griffin MA, Clarke S. Stress and well-being at work. In S. Zedeck (Ed.). *APA handbook of*
12 396 *industrial and organisational psychology*. Washington, DC: American Psychological
13 397 Association, 2011:359-397. doi: 10.1037/12171-010.
- 14
15 398 7 Wolvetang S, van Dongen JM, Speklé E, *et al.* Sick Leave Due to Stress, What are the Costs
16 399 for Dutch Employers? *J Occup Rehabil* 2022;32:764-772. doi: 10.1007/s10926-022-10042-
17 400 x.
- 18
19 401 8 Da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a
20 402 systematic review of recent longitudinal studies. *Am J Ind Med* 2010;53:285-323. doi:
21 403 10.1002/ajim.20750.
- 22
23 404 9 Perruccio AV, Yip C, Badley EM, *et al.* Musculoskeletal disorders: a neglected group at
24 405 public health and epidemiology meetings? *Am J Public Health* 2017;107:1584-1585. doi:
25 406 10.2105/AJPH.2017.303990.
- 26
27 407 10 Armijo-Olivo S, Woodhouse LJ, Steenstra IA, *et al.* Predictive value of the DASH tool for
28 408 predicting return to work of injured workers with musculoskeletal disorders of the upper
29 409 extremity. *Occup Environ Med*. 2016;73:807-815. doi: 10.1136/oemed-2016-10379.
- 30
31 410 11 Lozano R, Naghavi M, Foreman K, *et al.* Global and regional mortality from 235 causes of
32 411 death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of
33 412 Disease Study 2010. *Lancet* 2012;380:2095-128. doi: 10.1016/S0140-6736(12)61728-0.
- 34
35 413 12 Kataria KK, Sharma M, Kant S, *et al.* Analysing musculoskeletal risk prevalence among
36 414 workers in developing countries: an analysis of small-scale cast-iron foundries in India.
37 415 *Arch Environ Occup H* 2022;77:486-503. doi: 10.1080/19338244.2021.1936436.
- 38
39 416 13 Nixon AE, Mazzola JJ, Bauer J, *et al.* Can work make you sick? A meta-analysis of the
40 417 relationships between job stressors and physical symptoms. *Work Stress* 2011;25:1-22. doi:
41 418 10.1080/02678373.2011.569175.
- 42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3
4 419 14 Hauke A, Flintrop J, Brun E, *et al.* The impact of work-related psychosocial stressors on the
5
6 420 onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of
7
8 421 54 longitudinal studies. *Work Stress* 2011;25:243-256. doi:
9
10 422 10.1080/02678373.2011.614069.
- 11
12 423 15 Frone MR, Tidwell MO. The meaning and measurement of work fatigue: Development and
13
14 424 evaluation of the Three-Dimensional Work Fatigue Inventory (3D-WFI). *J Occup Health*
15
16 425 *Psychol* 2015;20:273. doi: 10.1037/a0038700.
- 17
18 426 16 Lock AM, Bonetti DL, Campbell A. The psychological and physiological health effects of
19
20 427 fatigue. *Occup Med* 2018;68:502-511. doi: 10.1093/occmed/kqy109.
- 21
22 428 17 Daneshmandi H, Choobineh AR, Ghaem H, *et al.* The effect of musculoskeletal problems
23
24 429 on fatigue and productivity of office personnel: a cross-sectional study. *J Prev Med Hyg*
25
26 430 2017;58:E252-E258. doi: 10.15167/2421-4248/JPMH2017.58.3.785.
- 27
28 431 18 Scanlan JN, Still M. Job satisfaction, burnout and turnover intention in occupational
29
30 432 therapists working in mental health. *Aust Occup Ther J* 2013;60:310-318. doi:
31
32 433 10.1111/1440-1630.12067.
- 33
34 434 19 Haghshenas B, Habibi E, Haji Esmail Hajar F, *et al.* The association between
35
36 435 musculoskeletal disorders with mental workload and occupational fatigue in the office staff
37
38 436 of a communication service company in Tehran, Iran, in 2017. *J Occup Health Epidemiol*
39
40 437 2018;7:20-29. doi: 10.29252/johe.7.1.20.
- 41
42 438 20 Rahman HA, Abdul-Mumin K, Naing L. Psychosocial work stressors, work fatigue, and
43
44 439 musculoskeletal disorders: comparison between emergency and critical care nurses in
45
46 440 Brunei Public Hospitals. *Asian Nurs Res* 2017;11:13-18. doi: 10.1016/j.anr.2017.01.003.
- 47
48 441 21 Armon G, Melamed S, Shirom A, *et al.* Elevated burnout predicts the onset of
49
50 442 musculoskeletal pain among apparently healthy employees. *J Occup Health Psychol*
51
52 443 2010;15:399. doi: 10.1037/a0020726.
- 53
54 444 22 Kuorinka I, Jonsson B, Kilbom A, *et al.* Standardised Nordic questionnaires for the analysis
55
56 445 of musculoskeletal symptoms. *Appl Ergon* 1987;18:233-237. doi: 10.1016/0003-
57
58 446 6870(87)90010-X.
- 59
60 447 23 Yang L, Hildebrandt VH, Yu SF, *et al.* Introduction of Nordic Musculoskeletal

- 1
2
3
4 448 Questionnaire [Ji Rou Gu Ge Ji Huan Diao Cha Biao Jie Shao Fu Diao Cha Biao]. *Ind*
5
6 449 *Health Occup Dis* 2009;35:25-31. Available:
7
8 450 <https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo->
9
10 451 [KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD)
11
12 452 [5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&)
13
14 453 [language=CHS](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-language=CHS).
15
16 454 24 Smith AP, Smith H. An international survey of the wellbeing of employees in the business
17
18 455 process outsourcing industry. *Psychology* 2017;08:160-167. doi:
19
20 456 10.4236/psych.2017.81010.
21
22 457 25 Margrove G, Smith AP. The Demands-Resources-Individual Effects (DRIVE) Model: Past,
23
24 458 Present, and Future Research. In Haque A (ed.). *Handbook of Research On the Complexities*
25
26 459 *and Strategies of Occupational Stress*. Hershey, PA: IGI Global; 2022:13-32. doi:
27
28 460 10.4018/978-1-6684-3937-1.ch002.
29
30 461 26 Fan J, Liu J, Smith AP. The relationship between workload, fatigue and sleep quality of
31
32 462 psychiatric staff. In Longo L, Leva MC (eds). *Human Mental Workload: Models and*
33
34 463 *Applications*. Springer Cham; 2021:151-164. doi: 10.1007/978-3-030-91408-0_10.
35
36 464 27 Ummul S, Rao K. Shift work and fatigue. *IOSR-JESTFT* 2012;1:17-21. doi: 10.9790/2402-
37
38 465 0131721.
39
40 466 28 Alroomi AS, Mohamed S. Predictors of mental health and fatigue among isolated oil and
41
42 467 gas workers. *Safety Reliab*. 2021;40:80-98. doi: 10.1080/09617353.2020.1858390.
43
44 468 29 Pan H. The cause of human fatigue and scenario analysis in the process of marine
45
46 469 transportation. *J Southeast Univ* 2020;36:107-117. doi: 10.3969/j.issn.1003-
47
48 470 7985.2020.01.014.
49
50 471 30 Wang Q, Wang C. Reducing turnover intention: perceived organisational support for
51
52 472 frontline employees. *Front Bus Res China* 2020;14:1-16. doi: 10.1186/s11782-020-00074-
53
54 473 6.
55
56 474 31 Jalilian H, Shouroki FK, Azmoon H, *et al*. Relationship between job stress and fatigue based
57
58 475 on job demand-control-support model in hospital nurses. *Int J Preventive Med* 2019;10:56.
59
60 476 doi: 10.4103/ijpvm.IJPVM_178_17.

- 1
2
3
4 477 32 Kim YK, Cha NH. Correlations among occupational stress, fatigue, and depression in call
5 478 center employees in Seoul. *J Phys Ther Sci* 2015;27:3191-3194. doi: 10.1589/jpts.27.3191.
6
7 479 33 Useche SA, Cendales B, Gómez V. Measuring fatigue and its associations with job stress,
8 480 health and traffic accidents in professional drivers: the case of BRT operators. *EC*
9 481 *Neurology* 2017;4:103-118. Available:
10 482 [https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operator](https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operators&author=S.A.%20Useche&publication_year=2017)
11 483 [s&author=S.A.%20Useche&publication_year=2017](https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operator&author=S.A.%20Useche&publication_year=2017)
12
13 484
14 485
15 486 34 Monney I, Dramani JB, Aruna A, *et al.* Health and safety in high-risk work environments:
16 487 A study of fuel service stations in Ghana. *J Env Occup* 2015;4:132-140. doi:
17 488 10.5455/jeos.20150903100137.
18
19 489 35 Sun J, Zhang JQ, Li W, *et al.* Investigation and analysis of musculoskeletal disorders and
20 490 influencing factors in gas station workers [Jia You Zhan Gong Ren Ji Rou Gu Ge Ji Huan
21 491 Ji Ying Xiang Yin Su Diao Cha Fen Xi]. *Ind Health Occup Dis* 2010;02:105-107. doi:
22 492 10.13692/j.cnki.gywszyzb.2010.02.018.
23
24 493 36 Oluka CD, ObidikeE, Ezeukwu AO, *et al.* Prevalence of work-related musculoskeletal
25 494 symptoms and associated risk factors among domestic gas workers and staff of works
26 495 department in Enugu, Nigeria: a cross-sectional study. *BMC Musculoskelet Dis* 2020;21:1-
27 496 11. doi: 10.1186/s12891-020-03615-5.
28
29 497 37 Maakip I, Keegel T, Oakman J. Predictors of musculoskeletal discomfort: A cross-cultural
30 498 comparison between Malaysian and Australian office workers. *Appl Ergon* 2017;60:52-57.
31 499 doi: 10.1016/j.apergo.2016.11.004.
32
33 500 38 Yan P, Li F, Zhang L, *et al.* Prevalence of work-related musculoskeletal disorders in the
34 501 nurses working in hospitals of Xinjiang Uygur Autonomous Region. *Pain Res Manag*
35 502 2017;51:1-7. doi: 10.1155/2017/5757108.
36
37 503 39 Miftasyah A, Novrikasari N, Hasyim H. Analysis of employment attitude to musculoskeletal
38 504 complaints on operators of Public Fuel Filling Station (SPBU) in Palembang City, 2021.
39 505 *BIRCU-Journal* 2022;5:16524-33. Available: <https://bircu->

- 1
2
3
4 506 journal.com/index.php/birci/article/view/5567.
- 5
6 507 40 Andriani B, Camelia A, Faisya HF. Analysis of working postures with musculoskeletal
7
8 508 Disorders (Msds) complaint of tailors in Ulak Kerbau Baru Village, Ogan Ilir. *JIKM*
9
10 509 2020;11:75-88. doi: 10.26553/jikm.2020.11.1.75-88.
- 11
12 510 41 Baberi F, Jahandideh Z, Akbari M, *et al*. Relationship between personality types and
13
14 511 musculoskeletal disorders among office staff. *Med Lav* 2019;110:293-303. doi:
15
16 512 10.23749/mdl.v110i4.7820.
- 17
18 513 42 Pradeepkumar H, Sakthivel G, Shankar S. Prevalence of work related musculoskeletal
19
20 514 disorders among occupational bus drivers of Karnataka, South India. *Work* 2020;66:73-84.
21
22 515 doi: 10.3233/WOR-203152.
- 23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1. Descriptive Characteristics and MSDs Symptoms of Participants

| Variables | ALL N = 2962 | WMSDs symptoms (NMQ) | | P |
|--|-----------------|----------------------|-----------------|----------------------|
| | | No N = 793 | Yes N = 2169 | |
| Age, mean ± SD | 36.67 ± 7.55 | 36.43 ± 8.31 | 36.76 ± 7.26 | |
| Sex, n (%) | | | | |
| Female | 1643 (55.47%) | 417 (52.59%) | 1226 (56.52%) | 0.058 ^a |
| Male | 1266 (42.74%) | 361 (45.52%) | 905 (41.72%) | |
| Unidentified | 53 (1.79%) | 15 (1.89%) | 38 (1.75%) | |
| Job Role, n (%) | | | | |
| Frontline staff | 2619 (88.42%) | 757 (95.46%) | 1862 (62.86%) | < 0.001 ^a |
| Non-frontline staff | 343 (11.58%) | 36 (4.54%) | 307 (15.65%) | |
| Personal Characteristics, mean ± SD | | | | |
| Lifestyle | 7.76 ± 2.07 | 8.57 ± 1.82 | 7.47 ± 2.07 | < 0.001 ^b |
| Personality | 7.89 ± 1.93 | 8.53 ± 1.82 | 7.66 ± 1.90 | < 0.001 ^b |
| Work Characteristics, mean ± SD | | | | |
| Workload | 6.05 ± 2.48 | 4.86 ± 2.68 | 6.49 ± 2.25 | < 0.001 ^b |
| Job support and control | 7.58 ± 2.13 | 8.03 ± 2.20 | 7.41 ± 2.08 | < 0.001 ^b |
| Noise | 5.37 ± 3.06 | 4.25 ± 3.04 | 5.78 ± 2.96 | < 0.001 ^b |
| Fumes | 7.38 ± 2.92 | 6.89 ± 3.08 | 7.55 ± 2.84 | < 0.001 ^b |
| Outcome, mean ± SD | | | | |
| Stress | 6.30 ± 2.55 | 5.05 ± 2.77 | 6.76 ± 2.30 | < 0.001 ^b |
| Fatigue | 6.00 ± 2.49 | 4.45 ± 2.61 | 6.56 ± 2.19 | < 0.001 ^b |
| MSDs (SWELL) | 6.11 ± 2.96 | 2.88 ± 2.54 | 6.11 ± 2.96 | < 0.001 ^b |

Abbreviations: SD, standard deviation

^aChi square test

^bIndependent-samples t-test

Table 2. WMSDs in gas station workers

| | Body Region | | | | | | | | |
|---|------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | Neck | Shoulders | Elbows | Wrists/hands | Hips | Knees | Lower back | Upper back | Ankles/feet |
| 12-month period prevalence (n=2169, 73.23%) | 1252 (42.27%) | 1063 (35.89%) | 249 (8.40%) | 654 (22.08%) | 339 (11.44%) | 655 (22.11%) | 543 (18.33%) | 515 (17.39%) | 1028 (34.71%) |
| Gender | | | | | | | | | |
| Female | 730 (24.65%) | 643 (21.71%) | 141 (4.76%) | 399 (13.47%) | 180 (6.08%) | 339 (11.44%) | 291 (9.82%) | 290 (9.79%) | 527 (17.79%) |
| Male | 500 (16.9%) | 402 (13.57%) | 106 (3.58%) | 249 (8.41%) | 155 (5.23%) | 309 (10.43%) | 241 (8.14%) | 219 (7.39%) | 490 (16.54%) |
| Age | | | | | | | | | |
| ≤ 30 | 231 (7.80%) | 199 (6.72%) | 55 (1.86%) | 143 (4.83%) | 75 (2.53%) | 121 (4.09%) | 116 (3.92%) | 123 (4.15%) | 227 (7.66%) |
| 31–40 | 640 (21.61%) | 532 (17.96%) | 111 (3.75%) | 323 (10.90%) | 168 (5.67%) | 302 (10.20%) | 270 (9.12%) | 248 (8.37%) | 499 (16.85%) |
| 41–50 | 312 (10.53%) | 269 (9.08%) | 70 (2.36%) | 157 (5.30%) | 79 (2.67%) | 184 (6.21%) | 127 (4.29%) | 119 (4.02%) | 251 (8.47%) |
| ≥ 51 | 25 (0.84%) | 19 (0.64%) | 6 (0.20%) | 11 (0.37%) | 6 (0.20%) | 22 (0.74%) | 9 (0.30%) | 7 (0.24%) | 13 (0.44%) |
| Job role | | | | | | | | | |
| Frontline staff | 1002 (33.83%) | 855 (28.87%) | 220 (7.43%) | 583 (19.68%) | 268 (9.05%) | 583 (19.68%) | 445 (15.02%) | 403 (13.61%) | 978 (33.02%) |
| Non-frontline staff | 248 (8.37%) | 206 (6.95%) | 28 (0.95%) | 70 (2.36%) | 70 (2.36%) | 70 (2.36%) | 96 (3.24%) | 110 (2.71%) | 46 (1.55%) |

Table 3. Correlation among stress, fatigue, WMSDs, work and personal characteristics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|-----------------------------|---------|---------|---------|---------|---------|---------|--------|--------|-----|
| (1) Stress | 1 | | | | | | | | |
| (2) Fatigue | 0.61** | 1 | | | | | | | |
| (3) WMSDs | 0.40** | 0.47** | 1 | | | | | | |
| (4) Lifestyle | -0.20** | -0.25** | -0.30** | 1 | | | | | |
| (5) Personality | -0.18** | -0.25** | -0.24** | 0.63** | 1 | | | | |
| (6) Workload | 0.71** | 0.59** | 0.41** | -0.21** | -0.20** | 1 | | | |
| (7) Job control and support | -0.07** | -0.12** | -0.12** | 0.30** | 0.38** | -0.08** | 1 | | |
| (8) Noise | 0.38** | 0.40** | 0.35** | -0.15** | -0.14** | 0.43** | -0.03 | 1 | |
| (9) Fumes | 0.23** | 0.23** | 0.11** | 0.00 | 0.01 | 0.28** | 0.06** | 0.46** | 1 |

**p < 0.001

For peer review only

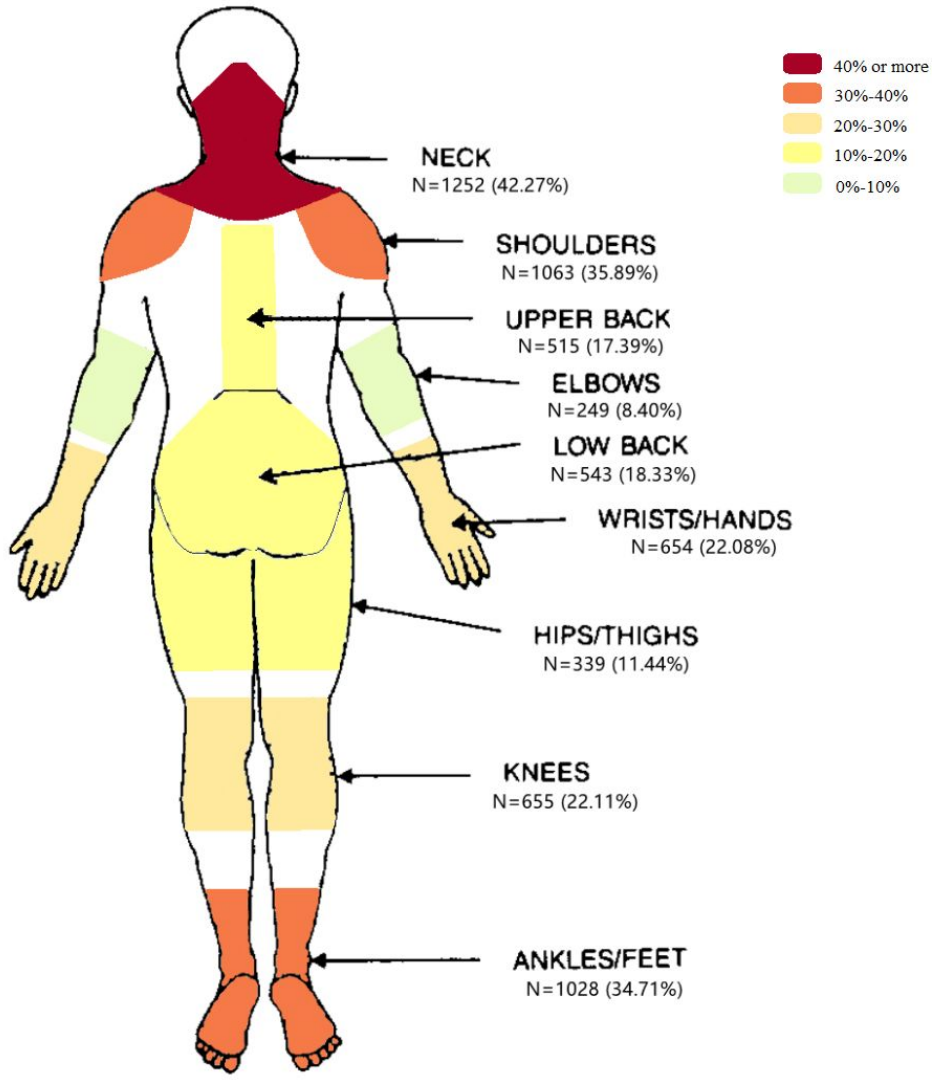
Table 4. Odds ratio of IVs on WMSDs

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---------------------------------|---------|----------------|---------|----------------|---------|----------------|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Demographics | | | | | | |
| Age | 1.009 | [0.998, 1.021] | 1.006 | [0.994, 1.019] | 1.005 | [0.993, 1.018] |
| Gender | 0.689** | [0.574, 0.829] | 0.614** | [0.507, 0.745] | 0.610** | [0.501, 0.742] |
| Job role | 2.595** | [1.794, 3.755] | 3.666** | [2.499, 5.378] | 3.413** | [2.318, 5.023] |
| Personal Characteristics | | | | | | |
| Personality | | | 1.357* | [1.065, 1.728] | 1.322* | [1.035, 1.689] |
| Lifestyle | | | 2.108** | [1.667, 2.666] | 2.032** | [1.603, 2.575] |
| Work Characteristics | | | | | | |
| Workload | | | | | 1.345* | [1.052, 1.720] |
| Job control and support | | | | | 1.636** | [1.323, 2.024] |
| Noise | | | | | 1.478** | [1.199, 1.823] |
| Fumes | | | | | 1.585** | [1.286, 1.954] |
| Stress | | | | | 1.327* | [1.044, 1.688] |
| Fatigue | | | | | 2.211** | [1.755, 2.784] |
| Nagelkerke R² | 0.116 | | 0.208 | | 0.238 | |

Abbreviations: OR, odds ratio; CI, confidence interval

** $P < 0.001$ * $p < 0.05$

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46



view only

Adapted from Kuorinka et al.(1987).

Figure 1. Regions of WMSDs in the previous 12-month period prevalence

For peer review only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

Table 1. Descriptive Characteristics and MSDs Symptoms of Participants

| Variables | ALL N = 2962 | WMSDs symptoms (NMQ) | | P |
|--|-----------------|----------------------|-----------------|----------------------|
| | | No N = 793 | Yes N = 2169 | |
| Age, mean ± SD | 36.67 ± 7.55 | 36.43 ± 8.31 | 36.76 ± 7.26 | |
| Sex, n (%) | | | | |
| Female | 1643 (55.47%) | 417 (52.59%) | 1226 (56.52%) | 0.058 ^a |
| Male | 1266 (42.74%) | 361 (45.52%) | 905 (41.72%) | |
| Unidentified | 53 (1.79%) | 15 (1.89%) | 38 (1.75%) | |
| Job Role, n (%) | | | | |
| Frontline staff | 2619 (88.42%) | 757 (95.46%) | 1862 (62.86%) | < 0.001 ^a |
| Non-frontline staff | 343 (11.58%) | 36 (4.54%) | 307 (15.65%) | |
| Personal Characteristics, mean ± SD | | | | |
| Lifestyle | 7.76 ± 2.07 | 8.57 ± 1.82 | 7.47 ± 2.07 | < 0.001 ^b |
| Personality | 7.89 ± 1.93 | 8.53 ± 1.82 | 7.66 ± 1.90 | < 0.001 ^b |
| Work Characteristics, mean ± SD | | | | |
| Workload | 6.05 ± 2.48 | 4.86 ± 2.68 | 6.49 ± 2.25 | < 0.001 ^b |
| Job support and control | 7.58 ± 2.13 | 8.03 ± 2.20 | 7.41 ± 2.08 | < 0.001 ^b |
| Noise | 5.37 ± 3.06 | 4.25 ± 3.04 | 5.78 ± 2.96 | < 0.001 ^b |
| Fumes | 7.38 ± 2.92 | 6.89 ± 3.08 | 7.55 ± 2.84 | < 0.001 ^b |
| Outcome, mean ± SD | | | | |
| Stress | 6.30 ± 2.55 | 5.05 ± 2.77 | 6.76 ± 2.30 | < 0.001 ^b |
| Fatigue | 6.00 ± 2.49 | 4.45 ± 2.61 | 6.56 ± 2.19 | < 0.001 ^b |
| MSDs (SWELL) | 6.11 ± 2.96 | 2.88 ± 2.54 | 6.11 ± 2.96 | < 0.001 ^b |

Abbreviations: SD, standard deviation

^aChi square test

^bIndependent-samples t-test

Table 2. WMSDs in gas station workers

| | Body Region | | | | | | | | |
|---|------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | Neck | Shoulders | Elbows | Wrists/hands | Hips | Knees | Lower back | Upper back | Ankles/feet |
| 12-month period prevalence (n=2169, 73.23%) | 1252 (42.27%) | 1063 (35.89%) | 249 (8.40%) | 654 (22.08%) | 339 (11.44%) | 655 (22.11%) | 543 (18.33%) | 515 (17.39%) | 1028 (34.71%) |
| Gender | | | | | | | | | |
| Female | 730 (24.65%) | 643 (21.71%) | 141 (4.76%) | 399 (13.47%) | 180 (6.08%) | 339 (11.44%) | 291 (9.82%) | 290 (9.79%) | 527 (17.79%) |
| Male | 500 (16.9%) | 402 (13.57%) | 106 (3.58%) | 249 (8.41%) | 155 (5.23%) | 309 (10.43%) | 241 (8.14%) | 219 (7.39%) | 490 (16.54%) |
| Age | | | | | | | | | |
| ≤ 30 | 231 (7.80%) | 199 (6.72%) | 55 (1.86%) | 143 (4.83%) | 75 (2.53%) | 121 (4.09%) | 116 (3.92%) | 123 (4.15%) | 227 (7.66%) |
| 31–40 | 640 (21.61%) | 532 (17.96%) | 111 (3.75%) | 323 (10.90%) | 168 (5.67%) | 302 (10.20%) | 270 (9.12%) | 248 (8.37%) | 499 (16.85%) |
| 41–50 | 312 (10.53%) | 269 (9.08%) | 70 (2.36%) | 157 (5.30%) | 79 (2.67%) | 184 (6.21%) | 127 (4.29%) | 119 (4.02%) | 251 (8.47%) |
| ≥ 51 | 25 (0.84%) | 19 (0.64%) | 6 (0.20%) | 11 (0.37%) | 6 (0.20%) | 22 (0.74%) | 9 (0.30%) | 7 (0.24%) | 13 (0.44%) |
| Job role | | | | | | | | | |
| Frontline staff | 1002 (33.83%) | 855 (28.87%) | 220 (7.43%) | 583 (19.68%) | 268 (9.05%) | 583 (19.68%) | 445 (15.02%) | 403 (13.61%) | 978 (33.02%) |
| Non-frontline staff | 248 (8.37%) | 206 (6.95%) | 28 (0.95%) | 70 (2.36%) | 70 (2.36%) | 70 (2.36%) | 96 (3.24%) | 110 (2.71%) | 46 (1.55%) |

Table 3. Correlation among stress, fatigue, WMSDs, work and personal characteristics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|-----------------------------|---------|---------|---------|---------|---------|---------|--------|--------|-----|
| (1) Stress | 1 | | | | | | | | |
| (2) Fatigue | 0.61** | 1 | | | | | | | |
| (3) WMSDs | 0.40** | 0.47** | 1 | | | | | | |
| (4) Lifestyle | -0.20** | -0.25** | -0.30** | 1 | | | | | |
| (5) Personality | -0.18** | -0.25** | -0.24** | 0.63** | 1 | | | | |
| (6) Workload | 0.71** | 0.59** | 0.41** | -0.21** | -0.20** | 1 | | | |
| (7) Job control and support | -0.07** | -0.12** | -0.12** | 0.30** | 0.38** | -0.08** | 1 | | |
| (8) Noise | 0.38** | 0.40** | 0.35** | -0.15** | -0.14** | 0.43** | -0.03 | 1 | |
| (9) Fumes | 0.23** | 0.23** | 0.11** | 0.00 | 0.01 | 0.28** | 0.06** | 0.46** | 1 |

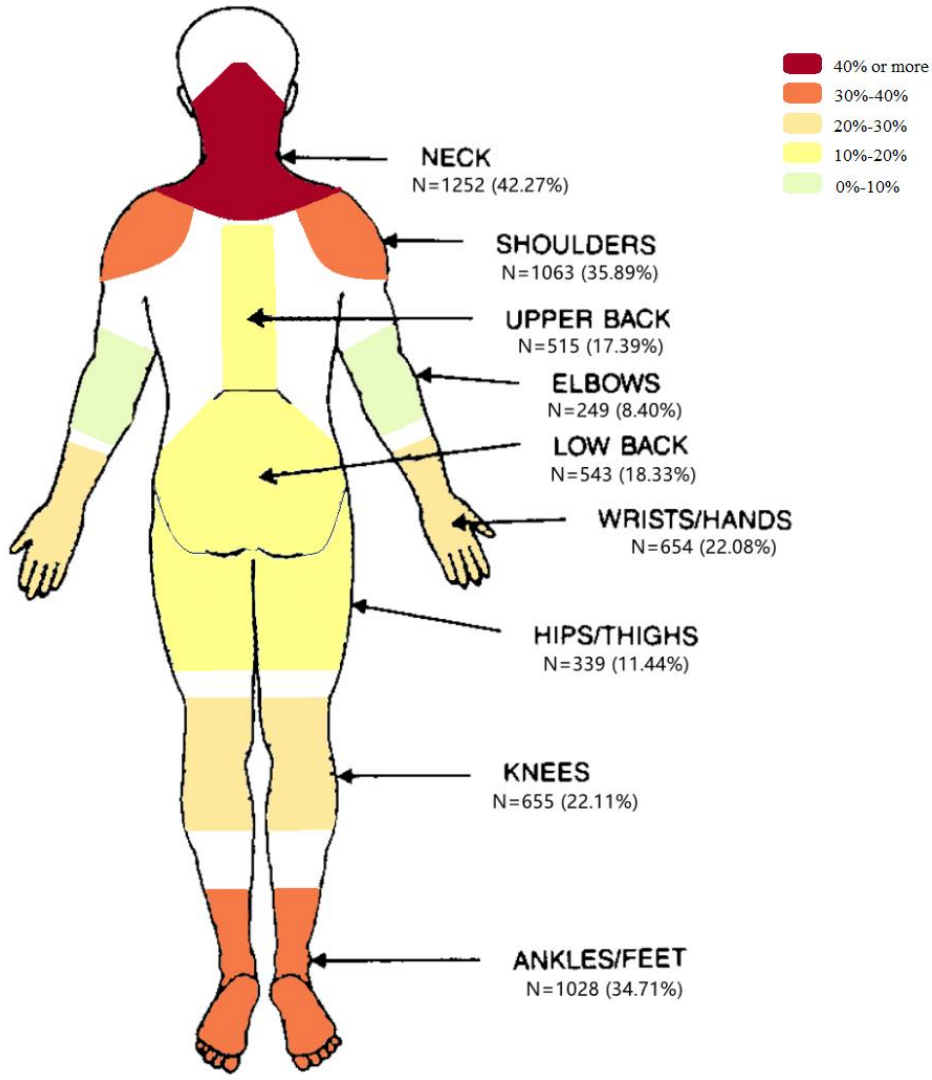
**p < 0.001

Table 4. Odds ratio of IVs on WMSDs

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---------------------------------|---------|----------------|---------|----------------|---------|----------------|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Demographics | | | | | | |
| Age | 1.009 | [0.998, 1.021] | 1.006 | [0.994, 1.019] | 1.005 | [0.993, 1.018] |
| Gender | 0.689** | [0.574, 0.829] | 0.614** | [0.507, 0.745] | 0.610** | [0.501, 0.742] |
| Job role | 2.595** | [1.794, 3.755] | 3.666** | [2.499, 5.378] | 3.413** | [2.318, 5.023] |
| Personal Characteristics | | | | | | |
| Personality | | | 1.357* | [1.065, 1.728] | 1.322* | [1.035, 1.689] |
| Lifestyle | | | 2.108** | [1.667, 2.666] | 2.032** | [1.603, 2.575] |
| Work Characteristics | | | | | | |
| Workload | | | | | 1.345* | [1.052, 1.720] |
| Job control and support | | | | | 1.636** | [1.323, 2.024] |
| Noise | | | | | 1.478** | [1.199, 1.823] |
| Fumes | | | | | 1.585** | [1.286, 1.954] |
| Stress | | | | | 1.327* | [1.044, 1.688] |
| Fatigue | | | | | 2.211** | [1.755, 2.784] |
| Nagelkerke R² | 0.116 | | 0.208 | | 0.238 | |

Abbreviations: OR, odds ratio; CI, confidence interval

** $P < 0.001$ * $p < 0.05$



view only

Adapted from Kuorinka et al.(1987).

Figure 1. Regions of WMSDs in the previous 12-month period prevalence

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

| | Item No | Recommendation | Page No |
|------------------------------|---------|--|---------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 3-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5-6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | 6 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 6 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants | 6 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 6 |
| Study size | 10 | Explain how the study size was arrived at | 6 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 7-8 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | 7-8 |
| | | (b) Describe any methods used to examine subgroups and interactions | |
| | | (c) Explain how missing data were addressed | |
| | | (d) If applicable, describe analytical methods taking account of sampling strategy | |
| | | (e) Describe any sensitivity analyses | |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | 8 |
| | | (b) Give reasons for non-participation at each stage | |
| | | (c) Consider use of a flow diagram | |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 8-9 |
| | | (b) Indicate number of participants with missing data for each variable of interest | |
| Outcome data | 15* | Report numbers of outcome events or summary measures | 8-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 8-11 |

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

| | | | |
|--------------------------|----|--|-------|
| | | (b) Report category boundaries when continuous variables were categorized | |
| | | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 8-11 |
| Discussion | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 11 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 14 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 11-14 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 14 |
| Other information | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 16 |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Work-Related Musculoskeletal Disorders, Fatigue and Stress Among Gas Station Workers in China: a cross-sectional study

| | |
|---------------------------------|--|
| Journal: | <i>BMJ Open</i> |
| Manuscript ID | bmjopen-2023-081853.R1 |
| Article Type: | Original research |
| Date Submitted by the Author: | 21-May-2024 |
| Complete List of Authors: | Fan, Jialin; Shenzhen University; Shenzhen Humanities & Social Sciences Key Research Bases of the Center for Mental Health Tan, Xiaotong; Shenzhen University, School of Psychology Smith, Andrew; Cardiff University, School of Psychology Wang, Jing; Shenzhen University |
| Primary Subject Heading: | Mental health |
| Secondary Subject Heading: | Public health, Mental health |
| Keywords: | Occupational Stress, Fatigue, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY |
| | |

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4
5 **1 Work-Related Musculoskeletal Disorders, Fatigue and Stress Among**
6
7 **2 Gas Station Workers in China: a cross-sectional study**
8
9

10
11 **3 Jialin Fan^{a,b*}, Xiaotong Tan^a, Andrew P. Smith^c, and Jing Wang^a**
12
13

14 **4 *^aSchool of Psychology, Shenzhen University, Shenzhen, China***

15
16
17 **5 *^bThe Shenzhen Humanities & Social Sciences Key Research Bases of the Center for***
18
19 **6 *Mental Health, Shenzhen, China***

20
21
22 **7 *^cCentre of Occupational and Health Psychology, School of Psychology, Cardiff***
23
24 **8 *University, 63 Park Place, Cardiff, CF10 3AS, UK.***

25
26
27 **9 **FanJL@szu.edu.cn***
28
29

30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

10

11 **Abstract**

12 **Introduction:** Work-related musculoskeletal disorders (WMSDs) are disorders of the
13 musculoskeletal system that have the highest prevalence among workers worldwide.
14 Workers in gas stations usually work in poor ergonomic working conditions, including
15 prolonged standing and repetitive posturing.

16 **Objective:** the study aimed to investigate the prevalence of WMSDs and fatigue and to
17 identify the predictors of WMSDs among gas station workers.

18 **Design:** The present study was a cross-sectional study.

19 **Setting and participants:** 2,962 gas station workers from an oil and gas company in
20 China, with ages ranging from 17 to 75 years old, 55.47% female.

21 **Results:** The prevalence of WMSDs within the 12 months prior to the study was
22 73.23%, with the highest prevalence in the neck, shoulders, ankles and feet.
23 Furthermore, a correlation was observed between fatigue, stress, and WMSDs. Fatigue
24 and job role were the strongest predictors of WMSDs, with an odds-ratio range of
25 2.211–3.413.

26 **Conclusions:** This research identified the detrimental impact of WMSDs and fatigue
27 on gas station workers, indicating the critical need for interventions to reduce WMSDs
28 and relieve fatigue.

29 **Strengths and limitations of this study**

- 30 ● This study investigated the present condition of WMSDs and occupational risk
31 among gas station workers.
- 32 ● The Nordic Musculoskeletal Questionnaire and Smith Well-being Questionnaire
33 were used to assess WMSDs, fatigue, stress and other work-related risk factors.
- 34 ● Logistic regression was conducted to determine the predictors of the WMSDs.
- 35 ● This was a cross-sectional study, unable to determine the mechanism and aetiology
36 of WMSDs.

37

38 Introduction

39 Gas station workers are key figures in the oil industry chain, subject to heavy workloads
40 and safety-critical tasks, and related occupational stress, fatigue, health problems and
41 environmental hazards. A recent review emphasised the importance of occupational
42 health concerns for gas station workers, concluding that shift work and the specific
43 work environment of gas station workers can adversely affect their sleep, stress levels,
44 physical and mental health, and turnover intention.¹ The work design of this job role is
45 varied in different countries and regions; for example, in developed countries such as
46 the United States, self-service refuelling is common, and gas stations often employ
47 managers, cashiers and similar staff, while in developing countries such as China, they
48 still rely on manual refuelling operations, which increases the number of gas station
49 workers needed. Regardless of the operational mode, very little empirical research has
50 focused on the occupational health concerns of gas station workers in comparison to
51 the range of risk factors to which they are exposed.

52 Gas station workers face inevitable occupational stress, and their extensive workloads
53 require an elevated level of alertness and motivation to fulfil their duties.¹ The duties
54 of gas station workers encompass refuelling, sales, and communication with customers
55 and colleagues, alongside additional security responsibilities.² As a service industry,
56 they also require emotional intelligence to provide exceptional service quality
57 continually. When job demands exceed workers' abilities and coping skills, they
58 become a risk factor, generating stress and various health problems.³ Occupational
59 stress is a severe occupational hazard that generates problematic alcohol use,⁴
60 depression⁵ and impairment of physical health, psychological well-being and
61 performance.⁶ It can also lead to sick leave, adversely affecting productivity and placing
62 a financial burden on employers and society.⁷

63 Work-related musculoskeletal disorders (WMSDs) are one of the health problems that
64 occupational populations have frequently reported and have a high prevalence.⁸

1
2
3
4 65 WMSDs are common painful disorders affecting the body structure that are caused by
5
6 66 a variety of factors, such as repetitive motion, excessive force, awkward and/or
7
8 67 sustained postures and prolonged sitting and standing.⁹ Moreover, these
9
10 68 musculoskeletal disorders may also be caused by or worsened by work conditions,¹⁰
11
12 69 highlighting the need to consider the role of occupational factors in their development.
13
14 70 WMSDs can also result in physical and mental illness, chronic pain and disability.¹¹
15
16 71 WMSDs are widespread around the world and are the second most common cause of
17
18 72 disability in the workplace.¹² They indirectly decrease industrial efficiency, which
19
20 73 results in significant economic burdens.¹³ The prevalence of WMSDs and their related
21
22 74 negative effects on workers' productivity, particularly in developing countries, should
23
24 75 be treated seriously to decrease the impact on production and promote workers' well-
25
26 76 being.¹⁴ Many previous studies on the health and well-being of gas station workers
27
28 77 focus primarily on the negative effects of organic solvents such as benzene on
29
30 78 physiological health and the nervous system. However, gas station workers usually
31
32 79 experience poor ergonomic working conditions for long periods, as their work tasks
33
34 80 include repetitive, awkward body movements,¹ which can contribute to an increase in
35
36 81 WMSDs.

37
38 82 Psychosocial stressors, such as high workload or low time control, may contribute to
39
40 83 an increased risk of musculoskeletal disorders by increasing biomechanical load or
41
42 84 physical stress. Occupational stress is associated with physical symptoms and is
43
44 85 prevalent over time.¹⁵ A review explored the impact of stressors on the onset of
45
46 86 musculoskeletal disorders related to the neck/shoulder, upper limbs and waist, revealing
47
48 87 that psychosocial factors were independent predictors of musculoskeletal disorders.¹⁶
49
50 88 It indicates that work-related stress may have an impact on the incidence of MSDs.
51
52 89 Despite the existence of work stress issues and physical health problems among gas
53
54 90 station workers, there remains a dearth of clear evidence regarding the impact of work
55
56 91 stress on WMSDs.

1
2
3
4 92 Occupational fatigue is described as a state of 'extreme tiredness and reduced functional
5
6 93 capacity experienced during or at the end of the workday',¹⁷ and it is a common
7
8 94 occupational health problem in many industries and occupations across the world.¹⁸
9
10 95 Fatigue has a myriad of negative consequences; for example, fatigue is linked to various
11
12 96 health problems, including sleep disorders, depression, obesity,¹⁹ and musculoskeletal
13
14 97 disorders, and it impacts work efficiency, job satisfaction and turnover intention.^{20 21}
15
16 98 Gas station workers often experience high job demands, heavy workloads and shift
17
18 99 work. Workers experience fatigue more quickly as a result of this condition. Thus, as a
19
20 100 key component of safety, the fatigue of gas station workers should be given more
21
22 101 consideration.

23
24 102 WMSDs and fatigue are both major occupational health issues. Musculoskeletal
25
26 103 disorders have been associated with fatigue in nurses and office workers.²²⁻²³ A
27
28 104 longitudinal study found that burnout could be a risk factor for the development of
29
30 105 musculoskeletal pain in apparently healthy individuals.²⁴ Although the relationship
31
32 106 between WMSDs and fatigue has been studied in several occupations,²²⁻²³ there is
33
34 107 currently a dearth of research related to gas station workers. Gas station employees are
35
36 108 exposed to a multitude of risk factors for WMSDs in the workplace, including
37
38 109 prolonged standing and repetitive motions when filling vehicles. Other factors that
39
40 110 contribute to physical and mental fatigue include heavy workloads, maintaining a
41
42 111 positive attitude when interacting with customers, remaining vigilant to operations that
43
44 112 are prone to causing safety mishaps and working in shifts. Personal characteristics and
45
46 113 work-related factors such as workload should also be considered. It is apparent that
47
48 114 there is insufficient research on WMSDs and fatigue specific to gas station workers,
49
50 115 and relevant risk factors should be further identified.

51
52
53 116 While WMSDs, occupational stress and fatigue are common issues that negatively
54
55 117 affect the health and safety of gas station workers, few studies have been conducted in
56
57 118 this field, particularly concerning physical and mental health. The current study aimed
58
59 119 to examine the prevalence of WMSDs, determine the association between WMSDs,
60

1
2
3
4 120 stress and fatigue, and investigate the predictors of WMSDs among gas station workers.
5
6 121 It contributes to developing a better understanding of the occupational risk factors that
7
8 122 can result in WMSDs, which is of great significance for better monitoring and
9
10 123 preventing WMSDs, stress and fatigue and enhancing the physical and mental health
11
12 124 of gas station workers.

15 125 **Material and methods**

18 126 *Participants and Procedure*

21 127 Participants were staff from several gas stations in different cities of southern China
22
23 128 within an oil company (N = 2,962, ages ranging from 17 to 75 years old, 55.47%
24
25 129 female). The job positions reported were gas operator (34.98%), cashier (14.45%),
26
27 130 front-court manager (24%), gas station manager (8.85%), convenience store supervisor
28
29 131 (6.14%), finance department staff (3.81%), management and executive staff (2.3%) and
30
31 132 other positions (5.47%). It should be noted that the front-court manager has a unique
32
33 133 position in Chinese gas stations. The duties of this position include but are not limited
34
35 134 to 'being responsible for organising the staff to carry out various operations,
36
37 135 management and service work during the shift', 'being responsible for the normal
38
39 136 operation of the gas station during the shift', which can also be described as 'on-site
40
41 137 duty manager'.

44 138 We conducted an online survey among gas station employees from an oil and gas
45
46 139 company in China, with the approval and cooperation of the company. There was no
47
48 140 work experience requirement for participants. The questionnaire was distributed two
49
50 141 months after the regular complete health check-up of employees, and the employees
51
52 142 with known trauma or other musculoskeletal disease, cardiovascular disease, severe
53
54 143 chronic obstructive pulmonary disease, neurological or psychiatric disorders, and
55
56 144 excessive obesity (BMI > 30 kg/m²) were excluded. Participants were asked to
57
58 145 complete an informed consent form, and they were free to withdraw from the survey at

1
2
3
4 146 any point. The School of Medicine Ethical Committee at Shenzhen University reviewed
5
6 147 and approved this study.
7
8

9 148 ***Patient and Public Involvement***

10
11
12 149 Patients and/or the public were not involved in the design, or conduct, or reporting, or
13
14 150 dissemination plans of the research.
15
16

17
18 151 ***Measurement of Musculoskeletal Disorders***

19
20
21 152 WMSDs were assessed using the Chinese version of the Nordic Musculoskeletal
22
23 153 Questionnaire (NMQ), a self-reported questionnaire that assesses the prevalence of
24
25 154 musculoskeletal symptoms in nine areas of the body: the neck, shoulders, elbows, wrists
26
27 155 and hands, hips, knees, lower back, upper back and ankles and feet.²⁵ Participants were
28
29 156 asked to note the occurrence of these symptoms over the past week (weekly prevalence)
30
31 157 and over the past year (annual prevalence). The NMQ was translated for use with
32
33 158 Chinese samples and proved to be reliable and valid.²⁶ The questionnaire is suitable for
34
35 159 application in a variety of workplaces, and data can be collected quickly and easily with
36
37 160 one study.
38
39

40 161 Considering that musculoskeletal disorders in gas station workers are a long-standing
41
42 162 problem, in this study, the incidence of musculoskeletal disorders in the past year was
43
44 163 used as the evaluation index. WMSDs are defined by reports of discomfort, numbness,
45
46 164 pain and restricted movement in one or more body regions in the past year.
47
48

49 165 ***Measurement of Occupational Stress and Fatigue***

50
51
52 166 Occupational stress and fatigue were evaluated using the Smith Well-being
53
54 167 Questionnaire (SWELL).²⁷ The SWELL, which is based on the Demands-Resources-
55
56 168 Individual-Effects (DRIVE) model, was used to assess occupational fatigue, stress at
57
58 169 work, workload, lifestyle, personality, job satisfaction and so on.²⁸ This questionnaire
59
60

1
2
3
4 170 has been used to assess a variety of occupational groups in previous studies, allowing
5
6 171 the identification of the overall occupational risks. This questionnaire was translated
7
8 172 into Chinese using both forward and back translation.²⁹
9

10
11 173 The SWELL consists of 26 single-item questions, and most of the questions are on a
12
13 174 10-point Likert scale. In the current study, the main variables of interest were stress,
14
15 175 fatigue, work characteristics (i.e., workload, job support and control, noise exposure
16
17 176 and fume exposure) and personal characteristics (i.e., personality and lifestyle).
18

19 20 177 *Analyses*

21
22
23 178 Data analysis was conducted using SPSS 25. Descriptive analyses examined the
24
25 179 frequencies of demographic variables, WMSD symptoms (NMQ), stress, fatigue,
26
27 180 personal characteristics and work characteristics. Pearson correlation was used to
28
29 181 examine the associations between stress, fatigue, WMSDs and other variables. Variable
30
31 182 scores were categorised into a high/low group using a median split. Logistic regression
32
33 183 was then conducted to determine the predictors of the WMSDs. Data were mean \pm
34
35 184 standard deviation and statistical significance was set at $p < 0.05$.
36
37

38 185 **Results**

39 40 41 42 186 *Descriptive Statistics*

43
44
45 187 Participants' descriptive characteristics and WMSD symptoms are shown in Table 1. A
46
47 188 total of 2,962 participants completed the online survey. The average age of the
48
49 189 participants was 36.67 ± 7.55 years; 55.47% of participants were female. According to
50
51 190 the work content and actual workplace, participants' job roles were divided into
52
53 191 frontline staff (N = 2,619; 88.42%) and non-frontline staff (N = 343, 11.58%). Frontline
54
55 192 staff work at gas stations on daily duty, including gas operators, cashiers, front-court
56
57 193 managers, convenience store supervisors and gas station managers. Non-frontline staff
58
59 194 include finance department staff, management and executive staff, and other positions
60

195 that work in offices where they are not exposed to gasoline daily and are not required
196 to remain in a standing position for long periods.

197 Participants had a mean stress score of 6.30 ± 2.55 and a mean fatigue score of $6.00 \pm$
198 2.49 . The results also showed that people with WMSD symptoms had unhealthier
199 lifestyles ($t = 14.03, p < 0.001$), more negative personalities ($t = 11.05, p < 0.001$),
200 higher levels of fatigue ($t = -20.262, p < 0.001$) and stress ($t = -16.92, p < 0.001$)
201 than those without WMSDs symptoms.

202 Additionally, a single item from the SWELL on musculoskeletal problems (Do you
203 suffer from musculoskeletal disorders [e.g. arthritis; back pain; sciatica; repetitive strain
204 injury]?) was used to gauge the effectiveness of the NMQ. Participants who reported
205 WMSDs on the NMQ scored 6.11 ± 2.96 on this question, which was significantly
206 higher than healthy participants ($t = 29.24, p < 0.001$).

207

208

INSERT TABLE 1 HERE

209

Table 1. Descriptive Characteristics and MSD Symptoms of Participants

210 ***Prevalence of WMSDs***

211 As shown in Supplementary Table 1 and Figure 1, the prevalence of WMSDs among
212 the respondents was unevenly distributed among most body regions and centred around
213 three of them, namely the neck (42.27%), shoulders (35.89%) and ankles and feet
214 (34.71%). The 12-month prevalence was 73.23%, and significant differences were
215 found for age group ($\chi^2 = 17.95, p < 0.001$) and job role ($\chi^2 = 50.82, p < 0.001$) but
216 not gender ($\chi^2 = 3.59, p = 0.058$).

217

218

INSERT FIGURE 1 HERE

219

Figure 1. Regions of WMSDs in the previous 12-month period prevalence**220 *Associations among Stress, Fatigue and WMSDs***

221 Pearson correlation was used to investigate the association among stress, fatigue,
222 WMSDs (from the SWELL) and work and personal characteristics (Supplementary
223 Table 2). Stress showed significant positive correlations with fatigue ($r = 0.61, p <$
224 0.001) and WMSDs ($r = 0.40, p < 0.001$). Both stress, fatigue and WMSDs were
225 significantly correlated with personal characteristics (lifestyle and personality, $p <$
226 0.001) and other work characteristics (job control and support, noise, fumes, $p <$
227 0.001).

228 *Predictors of WMSDs*

229 Logistic regressions were run to investigate the predictors of WMSDs. The dependent
230 variable was WMSDs, measured with or without WMSD symptoms over the past year.
231 The independent variables included in the model were demographic variables (age,
232 gender and job role), personal characteristics (personality and lifestyle), work
233 characteristics (workload, job control and support, noise exposure and fume exposure),
234 stress and fatigue, in which age was continuous, and other variables were categorical.
235 Table 2 shows the Odds ratio for each of the independent variables.

236 In the final model, the results showed that job role was the strongest predictor of
237 reported WMSD symptoms, with an odds ratio of 3.413 ($p < 0.001$), which indicated
238 that the frontline staff were more than three times more likely to report WMSD
239 symptoms than non-frontline staff. Fatigue was the second strongest predictor of

1
2
3
4 240 reported WMSD symptoms, with an odds ratio of 2.211 ($p < 0.001$), which indicated
5
6 241 that participants who reported high fatigue were over two times more likely to report
7
8 242 WMSD symptoms than those reporting low fatigue after controlling demography and
9
10 243 individual difference factors in the model.

11
12
13
14 244 The logistic regression model also found that stress (OR = 1.327, $p < 0.05$), gender
15
16 245 (female; OR = 0.610, $p < 0.001$), negative personality (OR = 1.322, $p < 0.05$),
17
18 246 unhealthy lifestyle (OR = 2.032, $p < 0.001$), heavy workload (OR = 1.345, $p <$
19
20 247 0.05), lack of job control (OR = 1.636, $p < 0.001$), noise exposure (OR = 1.585, $p <$
21
22 248 0.001) and fume exposure (OR = 1.327, $p < 0.05$) significantly contributed to
23
24 249 WMSDs.

25
26
27
28
29
30 250

31
32
33 251

INSERT TABLE 2 HERE

34
35
36 252

Table 2. Odds ratio of IVs on WMSDs

37
38
39 253 **Discussion**

40
41
42
43 254 This is a cross-sectional study using an online questionnaire to investigate the
44
45 255 prevalence of and relationship between WMSDs, stress and fatigue, and the predictors
46
47 256 of WMSDs among gas station workers. Participants reported medium-to-high levels of
48
49 257 fatigue and stress, and the 12-month prevalence of WMSDs was 73.23%. The neck,
50
51 258 shoulders, ankles and feet were the most common body regions affected by
52
53 259 musculoskeletal disorders. The present study also showed a significant positive
54
55 260 correlation between fatigue, stress and WMSDs, and with higher fatigue and stress,
56
57 261 participants were more likely to have WMSDs. In addition, job roles and personal and
58
59 262 work characteristics were predictors of WMSDs.

1
2
3
4 263 In terms of occupational fatigue and stress, the findings suggest that there was indeed a
5
6 264 certain occupational health problem among gas station employees. Firstly, fatigue was
7
8 265 clearly associated with multiple risk factors, including individual characteristics, work
9
10 266 characteristics and environment. Given the nature of the gas station industry, workers
11
12 267 usually work long hours each day, and most of this is shift work, both of which have
13
14 268 been closely related to fatigue.³⁰ A growing body of literature has demonstrated that
15
16 269 fatigue is common among gas station workers, as well as workers from the oil and gas
17
18 270 industry, such as offshore drilling, the job characteristics of which are similar.³¹⁻³³
19
20 271 Meanwhile, the current study provides evidence of a significant positive association
21
22 272 between job stress and occupational fatigue among gas station workers. These findings
23
24 273 align with previous research conducted on various occupational groups, including
25
26 274 nurses,³⁴ call centre employees,³⁵ and drivers,³⁶ thus confirming a consistent
27
28 275 relationship between stress and fatigue. Nonetheless, this study represents the first
29
30 276 investigation specifically focusing on the stress and fatigue experiences of gas station
31
32 277 workers, highlighting the unique challenges faced by this particular occupational group.
33
34 278 In addition to their primary responsibilities of providing refuelling services, frontline
35
36 279 gas station workers in China often have additional responsibilities such as safety duties,
37
38 280 sales, and prioritising customer satisfaction. Such multifaceted job demands may
39
40 281 contribute to heightened job stress levels and subsequent fatigue among these workers.
41
42 282 Our findings underscore the need for interventions to reduce stress and fatigue risk
43
44 283 factors.

45
46 284 The majority of gas station workers reported having WMSDs in at least one anatomical
47
48 285 region during the 12 months prior to the study, which is in line with previous research
49
50 286 conducted both inside and outside of China.^{37 38} The clustering pattern of WMSDs
51
52 287 observed in this study, notably in the neck (42.27%), shoulders (35.89%) and ankles
53
54 288 and feet (34.71%), is somewhat different from findings in previous studies among gas
55
56 289 station workers. Among Nigerian gas station workers, the reported prevalence pattern
57
58 290 of body regions was highest in the lower back (54%) and shoulders (52%),³⁹ whereas

1
2
3
4 291 in Ghana, it was highest in the lower back (43%).³⁷ This is due in part to the larger
5
6 292 proportion of frontline employees in our study, who engage primarily in manual labour.
7
8 293 Although there are variations in the specific sites affected among gas station workers
9
10 294 in different countries, the overall prevalence of moderate to high rates of work-related
11
12 295 musculoskeletal disorders (WMSDs) ranged from 51.2% to 86%.³⁷⁻³⁹ This
13
14 296 demonstrates that WMSDs are a common issue within the gas station occupation. A
15
16 297 cross-cultural comparison research of workers in similar occupational groups revealed
17
18 298 disparities in the prevalence of self-reported MSD discomfort between Malaysia and
19
20 299 Australia.⁴⁰ However, there were no significant differences in the frequency and
21
22 300 severity of symptoms across five body regions among those reporting MSD discomfort,
23
24 301 and they shared similar predictors. Therefore, future research seeking to generalize
25
26 302 these findings to comparable job positions in other countries should carefully consider
27
28 303 sociocultural backgrounds as influencing factors.

29
30 304 WMSDs are a multi-factorial disorder linked to various demographic and work-related
31
32 305 features. There is limited literature concerned with WMSDs in this particular field.
33
34 306 Therefore, a comprehensive analysis based on the establishment of a logistic regression
35
36 307 model was run to reveal the presence of multiple influencing factors for WMSDs among
37
38 308 gas station workers, including personal and work characteristics. It's worth noting that
39
40 309 fatigue and job role were found to be major risk factors for WMSDs. There is a clear
41
42 310 relationship between WMSDs and occupational fatigue. This finding is consistent with
43
44 311 previous research that has identified fatigue as a risk factor for WMSDs.⁴¹ Fatigued
45
46 312 workers usually perform poorly at work and may eventually face serious health
47
48 313 problems. Ergonomically, the risk factors for gas station workers come from repetitive
49
50 314 actions (such as filling vehicles) and long periods of standing (as with cashiers).
51
52 315 According to previous studies, maintaining an awkward and static posture for extended
53
54 316 periods at work can cause discomfort, pain and chronic fatigue.²⁰ This is supported by
55
56 317 results from job roles, where frontline workers are more likely to have musculoskeletal
57
58 318 problems than non-frontline workers. Frontline workers are more likely to be exposed

1
2
3
4 319 to risk factors at work, such as repetitive motions, poor posture and physical strain.
5
6 320 Adverse symptoms accumulate over time and can cause serious consequences for
7
8 321 physical and mental health.
9

10
11 322 It is worthwhile to note that there was no significant difference in age between those
12
13 323 with and without WMSDs. Similarly, in logistic regression, age was not a significant
14
15 324 predictor of WMSDs. However, a recent study found that there was a relationship
16
17 325 between age and musculoskeletal disorders complaints.⁴² In general, increased age
18
19 326 causes workers' physical conditions to deteriorate, and as muscle strength and
20
21 327 endurance decline, the risk of WMSDs increases.⁴³ The different results suggest that
22
23 328 some variables might modify the relationship between age and WMSDs, such as body
24
25 329 mass index (BMI), smoking habits and physical activity, which are individual
26
27 330 characteristic variables associated with WMSDs, should be examined in future studies.
28

29
30 331 According to the logistic regression model, negative personality and unhealthy lifestyle
31
32 332 were considered risk factors for WMSDs. These findings are similar to the results of
33
34 333 other studies.^{44 45} Therefore, at the individual level, adopting a healthy lifestyle may be
35
36 334 able to mitigate the incidence of WMSDs. Personality type and WMSDs appear to be
37
38 335 correlated, and it is suggested that organisations may consider personality type factors
39
40 336 in employee selection and training.
41

42
43 337 The results from this study provide insight into understanding the relationship between
44
45 338 fatigue, stress and WMSDs among gas station workers. These findings have practical
46
47 339 implications for identifying and addressing WMSDs, particularly among frontline
48
49 340 workers who experience severe fatigue and stress. The consequences of WMSDs are
50
51 341 considerable for employees and employers alike. Therefore, several measures can be
52
53 342 taken to prevent the risk of WMSDs. For example, gas station workers should be aware
54
55 343 of risk factors and make positive changes, such as stretching between breaks.
56
57 344 Employers should consider implementing fatigue management strategies and providing
58
59 345 ergonomic workstations to ensure the well-being and safety of their workers.
60

1
2
3
4 346 There are a few limitations of this study. First, the study absence of data on body
5
6 347 composition, specifically BMI, and the level of habitual physical activity among
7
8 348 participants. The lack of this information presents a challenge in accurately associating
9
10 349 our findings with participants' age and functional status. Second, the study sample was
11
12 350 exclusively from China; therefore, future studies should determine and verify our
13
14 351 results in other regions, including workers from both developed and developing nations
15
16 352 and state-owned and private businesses. Third, this was a cross-sectional study that used
17
18 353 subjective measurement methods. Future studies should apply objective technologies,
19
20 354 which lead to more accurate and objective conclusions. A prospective longitudinal
21
22 355 design is also needed to better understand causal relationships between the variables.

23
24 356 Our study also has several strengths. This study investigated the present condition of
25
26 357 WMSDs and occupational risk among gas station workers and provided evidence of an
27
28 358 association between fatigue, stress and WMSDs. This finding has important
29
30 359 occupational health implications and may inform the prevention of WMSDs among gas
31
32 360 station workers. The research results can provide a reference for empirical studies, in
33
34 361 particular, interventions to address the current situation.

362 **Conclusion**

363 There is a high prevalence of WMSDs among workers in the gas station industry, most
364 frequently in the neck, shoulders, ankles and feet. The gas station workers had a
365 medium-to-high level of fatigue and stress, and associations between fatigue, stress and
366 WMSDs were found in this study. The participants who reported high fatigue were
367 more than two times more likely to report WMSDs. In addition to the risk factor of
368 fatigue, job role, stress, and personal and work characteristics played essential roles in
369 the prediction of WMSDs.

1
2
3
4 370 **Declarations**

5
6
7 371 ***Contributors***

8
9
10 372 Conceptualization, JF; material preparation and data collection, JW; analyses, XT;
11 373 original draft preparation, XT; review and editing, XT, JF and AS. All authors have
12 374 read, critically revised and approved the final version of this manuscript. J.F is
13
14 375 responsible for the overall content [as guarantor].

15
16
17
18
19 376 ***Competing interests***

20
21
22
23 377 The author(s) declared no potential conflicts of interest with respect to the research,
24 378 authorship and/or publication of this article.

25
26
27
28 379 ***Funding***

29
30
31 380 This research received no specific grant from any funding agency in the public,
32 381 commercial, or not-for-profit sectors.

33
34
35
36
37 382 ***Data sharing statement***

38
39
40 383 Data are available on reasonable request. Data supporting the findings of this study are
41 384 available from the corresponding author on reasonable request. Access requests will be
42 385 reviewed to ensure compliance with ethical and privacy guidelines. Please contact
43 386 (FanJL@szu.edu.cn) for inquiries regarding data access.

44
45
46
47
48
49 387 ***Ethics approval and consent to participate***

50
51
52 388 This paper received ethical approval from School of Medicine Ethical Committee at
53 389 Shenzhen University: PN-202300036. All participants provided informed consent prior
54 390 to completing the first survey.

391 **References**

- 392 1 Yin Y, Tan X, Fan J. Occupational fatigue and health of gas station workers: a review. *Work*
393 2023;Pre-press:1-20. doi: 10.3233/WOR-220415.
- 394 2 Sirdah M, Al Laham NA, Al Madhoun R. Possible health effects of liquefied petroleum gas
395 on workers at filling and distribution stations of Gaza governorates. *E Mediterr Health J*
396 2013;19:289-294. doi: 10.26719/2013.19.3.289.
- 397 3 Gimaeva ZF, Bakirov AB, Karimova LK, *et al.* Production and genetic risk factors for
398 cardiovascular diseases among petrochemical industry workers. *Terapevt Arkh* 2018;90:49-
399 53. doi: 10.26442/terarkh201890149-53.
- 400 4 Frone MR. Work stress and alcohol use: developing and testing a biphasic self-medication
401 model. *Work Stress* 2016;30:374-394. doi: 10.1080/02678373.2016.1252971.
- 402 5 Lee KS, Lee DB, Kwon IS, *et al.* Depressive symptoms and their association with sleep
403 quality, occupational stress and fatigue among small-scaled manufacturing male workers.
404 *Korean J Occup Environ Med* 2011;23:99-111. doi: 10.35371/kjoem.2011.23.2.99.
- 405 6 Griffin MA, Clarke S. Stress and well-being at work. In S. Zedeck (Ed.). *APA handbook of*
406 *industrial and organisational psychology*. Washington, DC: American Psychological
407 Association, 2011:359-397. doi: 10.1037/12171-010.
- 408 7 Wolvetang S, van Dongen JM, Speklé E, *et al.* Sick Leave Due to Stress, What are the Costs
409 for Dutch Employers? *J Occup Rehabil* 2022;32:764-772. doi: 10.1007/s10926-022-10042-
410 x.
- 411 8 Bonfiglioli, Robertaa; Caraballo-Arias, *et al.* Epidemiology of work-related
412 musculoskeletal disorders. *Current Opinion in Epidemiology and Public Health* 2022;1:18-
413 24. doi: 10.1097/PXH.000000000000003.
- 414 9 Da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a
415 systematic review of recent longitudinal studies. *Am J Ind Med* 2010;53:285-323. doi:
416 10.1002/ajim.20750.
- 417 10 Centers for Disease Control and Prevention. Ergonomics and Musculoskeletal Disorders.
418 2019. Available from: <https://www.cdc.gov/niosh/topics/ergonomics/>
- 419 11 Perruccio AV, Yip C, Badley EM, *et al.* Musculoskeletal disorders: a neglected group at

- 1
2
3
4 420 public health and epidemiology meetings? *Am J Public Health* 2017;107:1584-1585. doi:
5 421 10.2105/AJPH.2017.303990.
6
7 422 12 Armijo-Olivo S, Woodhouse LJ, Steenstra IA, *et al.* Predictive value of the DASH tool for
8
9 423 predicting return to work of injured workers with musculoskeletal disorders of the upper
10
11 424 extremity. *Occup Environ Med.* 2016;73:807-815. doi: 10.1136/oemed-2016-10379.
12
13 425 13 Lozano R, Naghavi M, Foreman K, *et al.* Global and regional mortality from 235 causes of
14
15 426 death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of
16
17 427 Disease Study 2010. *Lancet* 2012;380:2095-128. doi: 10.1016/S0140-6736(12)61728-0.
18
19 428 14 Kataria KK, Sharma M, Kant S, *et al.* Analysing musculoskeletal risk prevalence among
20
21 429 workers in developing countries: an analysis of small-scale cast-iron foundries in India.
22
23 430 *Arch Environ Occup H* 2022;77:486-503. doi: 10.1080/19338244.2021.1936436.
24
25 431 15 Nixon AE, Mazzola JJ, Bauer J, *et al.* Can work make you sick? A meta-analysis of the
26
27 432 relationships between job stressors and physical symptoms. *Work Stress* 2011;25:1-22. doi:
28
29 433 10.1080/02678373.2011.569175.
30
31 434 16 Hauke A, Flintrop J, Brun E, *et al.* The impact of work-related psychosocial stressors on the
32
33 435 onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of
34
35 436 54 longitudinal studies. *Work Stress* 2011;25:243-256. doi:
36
37 437 10.1080/02678373.2011.614069.
38
39 438 17 Frone MR, Tidwell MO. The meaning and measurement of work fatigue: Development and
40
41 439 evaluation of the Three-Dimensional Work Fatigue Inventory (3D-WFI). *J Occup Health*
42
43 440 *Psychol* 2015;20:273. doi: 10.1037/a0038700.
44
45 441 18 Lock AM, Bonetti DL, Campbell AD. The psychological and physiological health effects
46
47 442 of fatigue. *Occup Med* 2018;68:502-11. doi: 10.1093/occmed/kqy109.
48
49 443 19 Lock AM, Bonetti DL, Campbell A. The psychological and physiological health effects of
50
51 444 fatigue. *Occup Med* 2018;68:502-511. doi: 10.1093/occmed/kqy109.
52
53 445 20 Daneshmandi H, Choobineh AR, Ghaem H, *et al.* The effect of musculoskeletal problems
54
55 446 on fatigue and productivity of office personnel: a cross-sectional study. *J Prev Med Hyg*
56
57 447 2017;58:E252-E258. doi: 10.15167/2421-4248/JPMH2017.58.3.785.
58
59 448 21 Scanlan JN, Still M. Job satisfaction, burnout and turnover intention in occupational
60

- 1
2
3
4 449 therapists working in mental health. *Aust Occup Ther J* 2013;60:310-318. doi:
5 450 10.1111/1440-1630.12067.
- 6
7 451 22 Haghshenas B, Habibi E, Haji Esmaeil Hajar F, *et al.* The association between
8 452 musculoskeletal disorders with mental workload and occupational fatigue in the office staff
9 453 of a communication service company in Tehran, Iran, in 2017. *J Occup Health Epidemiol*
10 454 2018;7:20-29. doi: 10.29252/johe.7.1.20.
- 11
12 455 23 Rahman HA, Abdul-Mumin K, Naing L. Psychosocial work stressors, work fatigue, and
13 456 musculoskeletal disorders: comparison between emergency and critical care nurses in
14 457 Brunei Public Hospitals. *Asian Nurs Res* 2017;11:13-18. doi: 10.1016/j.anr.2017.01.003.
- 15
16 458 24 Armon G, Melamed S, Shirom A, *et al.* Elevated burnout predicts the onset of
17 459 musculoskeletal pain among apparently healthy employees. *J Occup Health Psychol*
18 460 2010;15:399. doi: 10.1037/a0020726.
- 19
20 461 25 Kuorinka I, Jonsson B, Kilbom A, *et al.* Standardised Nordic questionnaires for the analysis
21 462 of musculoskeletal symptoms. *Appl Ergon* 1987;18:233-237. doi: 10.1016/0003-
22 463 6870(87)90010-X.
- 23
24 464 26 Yang L, Hildebrandt VH, Yu SF, *et al.* Introduction of Nordic Musculoskeletal
25 465 Questionnaire [Ji Rou Gu Ge Ji Huan Diao Cha Biao Jie Shao Fu Diao Cha Biao]. *Ind*
26 466 *Health Occup Dis* 2009;35:25-31. Available:
27 467 [https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&language=CHS)
28 468 [KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&language=CHS)
29 469 [5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&language=CHS)
30 470 [language=CHS.](https://kns.cnki.net/kcms2/article/abstract?v=0VgOIWnPAthMzMo-KWmM1p7kktuhZCG2kehZzbefk5Zw8nAOZHSwEoRQRiicMmR1ABuzHuolVqiVLgD5F7gRarkLe1Hp09NuHktn1vQhikPMcIosDr7re1RV4WqImOP0&uniplatform=NZKPT&language=CHS)
- 31
32 471 27 Smith AP, Smith H. An international survey of the wellbeing of employees in the business
33 472 process outsourcing industry. *Psychology* 2017;08:160-167. doi:
34 473 10.4236/psych.2017.81010.
- 35
36 474 28 Margrove G, Smith AP. The Demands-Resources-Individual Effects (DRIVE) Model: Past,
37 475 Present, and Future Research. In Haque A (ed.). *Handbook of Research On the Complexities*
38 476 *and Strategies of Occupational Stress*. Hershey, PA: IGI Global; 2022:13-32. doi:
39 477 10.4018/978-1-6684-3937-1.ch002.
- 40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3
4 478 29 Fan J, Liu J, Smith AP. The relationship between workload, fatigue and sleep quality of
5
6 479 psychiatric staff. In Longo L, Leva MC (eds). *Human Mental Workload: Models and*
7
8 480 *Applications*. Springer Cham; 2021:151-164. doi: 10.1007/978-3-030-91408-0_10.
9
10 481 30 Ummul S, Rao K. Shift work and fatigue. *IOSR-JESTFT* 2012;1:17-21. doi: 10.9790/2402-
11
12 482 0131721.
13
14 483 31 Alroomi AS, Mohamed S. Predictors of mental health and fatigue among isolated oil and
15
16 484 gas workers. *Safety Reliab.* 2021;40:80-98. doi: 10.1080/09617353.2020.1858390.
17
18 485 32 Pan H. The cause of human fatigue and scenario analysis in the process of marine
19
20 486 transportation. *J Southeast Univ* 2020;36:107-117. doi: 10.3969/j.issn.1003-
21
22 487 7985.2020.01.014.
23
24 488 33 Wang Q, Wang C. Reducing turnover intention: perceived organisational support for
25
26 489 frontline employees. *Front Bus Res China* 2020;14:1-16. doi: 10.1186/s11782-020-00074-
27
28 490 6.
29
30 491 34 Jalilian H, Shouroki FK, Azmoon H, *et al.* Relationship between job stress and fatigue based
31
32 492 on job demand-control-support model in hospital nurses. *Int J Preventive Med* 2019;10:56.
33
34 493 doi: 10.4103/ijpvm.IJPVM_178_17.
35
36 494 35 Kim YK, Cha NH. Correlations among occupational stress, fatigue, and depression in call
37
38 495 center employees in Seoul. *J Phys Ther Sci* 2015;27:3191-3194. doi: 10.1589/jpts.27.3191.
39
40 496 36 Useche SA, Cendales B, Gómez V. Measuring fatigue and its associations with job stress,
41
42 497 health and traffic accidents in professional drivers: the case of BRT operators. *EC*
43
44 498 *Neurology* 2017;4:103-118. Available:
45
46 499 [https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operator](https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operators&author=S.A.%20Useche&publication_year=2017)
47
48 500 [s&author=S.A.%20Useche&publication_year=2017](https://scholar.google.com/scholar_lookup?title=Measuring%20Fatigue%20and%20its%20Associations%20with%20Job%20Stress%2C%20Health%20and%20Traffic%20Accidents%20in%20Professional%20Drivers%3A%20The%20Case%20of%20BRT%20Operator&author=S.A.%20Useche&publication_year=2017)
49
50 501
51 502
52
53 503 37 Monney I, Dramani JB, Aruna A, *et al.* Health and safety in high-risk work environments:
54
55 504 A study of fuel service stations in Ghana. *J Env Occup* 2015;4:132-140. doi:
56
57 505 10.5455/jeos.20150903100137.
58
59 506 38 Sun J, Zhang JQ, Li W, *et al.* Investigation and analysis of musculoskeletal disorders and
60

- 1
2
3
4 507 influencing factors in gas station workers [Jia You Zhan Gong Ren Ji Rou Gu Ge Ji Huan
5 508 Ji Ying Xiang Yin Su Diao Cha Fen Xi]. *Ind Health Occup Dis* 2010;02:105-107. doi:
6 509 10.13692/j.cnki.gywsyzyb.2010.02.018.
- 7
8
9 510 39 Oluka CD, ObidikeE, Ezeukwu AO, *et al.* Prevalence of work-related musculoskeletal
10 511 symptoms and associated risk factors among domestic gas workers and staff of works
11 512 department in Enugu, Nigeria: a cross-sectional study. *BMC Musculoskelet Dis* 2020;21:1-
12 513 11. doi: 10.1186/s12891-020-03615-5.
- 13
14
15 514 40 Maakip I, Keegel T, Oakman J. Predictors of musculoskeletal discomfort: A cross-cultural
16 515 comparison between Malaysian and Australian office workers. *Appl Ergon* 2017;60:52-57.
17 516 doi: 10.1016/j.apergo.2016.11.004.
- 18
19
20 517 41 Yan P, Li F, Zhang L, *et al.* Prevalence of work-related musculoskeletal disorders in the
21 518 nurses working in hospitals of Xinjiang Uygur Autonomous Region. *Pain Res Manag*
22 519 2017;51:1-7. doi: 10.1155/2017/5757108.
- 23
24
25 520 42 Miftasyah A, Novrikasari N, Hasyim H. Analysis of employment attitude to musculoskeletal
26 521 complaints on operators of Public Fuel Filling Station (SPBU) in Palembang City, 2021.
27 522 *BIRCU-Journal* 2022;5:16524-33. Available: [https://bircu-](https://bircu-journal.com/index.php/birci/article/view/5567)
28 523 [journal.com/index.php/birci/article/view/5567](https://bircu-journal.com/index.php/birci/article/view/5567).
- 29
30
31 524 43 Andriani B, Camelia A, Faisya HF. Analysis of working postures with musculoskeletal
32 525 Disorders (Msds) complaint of tailors in Ulak Kerbau Baru Village, Ogan Ilir. *JIKM*
33 526 2020;11:75-88. doi: 10.26553/jikm.2020.11.1.75-88.
- 34
35
36 527 44 Baberi F, Jahandideh Z, Akbari M, *et al.* Relationship between personality types and
37 528 musculoskeletal disorders among office staff. *Med Lav* 2019;110:293-303. doi:
38 529 10.23749/mdl.v110i4.7820.
- 39
40
41 530 45 Pradeepkumar H, Sakthivel G, Shankar S. Prevalence of work related musculoskeletal
42 531 disorders among occupational bus drivers of Karnataka, South India. *Work* 2020;66:73-84.
43 532 doi: 10.3233/WOR-203152.
- 44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1. Descriptive Characteristics and MSDs Symptoms of Participants

| Variables | ALL N = 2962 | WMSDs symptoms (NMQ) | | P |
|--|-----------------|----------------------|-----------------|----------------------|
| | | No N = 793 | Yes N = 2169 | |
| Age, mean ± SD | 36.67 ± 7.55 | 36.43 ± 8.31 | 36.76 ± 7.26 | |
| Sex, n (%) | | | | |
| Female | 1643 (55.47%) | 417 (52.59%) | 1226 (56.52%) | 0.058 ^a |
| Male | 1266 (42.74%) | 361 (45.52%) | 905 (41.72%) | |
| Unidentified | 53 (1.79%) | 15 (1.89%) | 38 (1.75%) | |
| Job Role, n (%) | | | | |
| Frontline staff | 2619 (88.42%) | 757 (95.46%) | 1862 (62.86%) | < 0.001 ^a |
| Non-frontline staff | 343 (11.58%) | 36 (4.54%) | 307 (15.65%) | |
| Personal Characteristics, mean ± SD | | | | |
| Lifestyle | 7.76 ± 2.07 | 8.57 ± 1.82 | 7.47 ± 2.07 | < 0.001 ^b |
| Personality | 7.89 ± 1.93 | 8.53 ± 1.82 | 7.66 ± 1.90 | < 0.001 ^b |
| Work Characteristics, mean ± SD | | | | |
| Workload | 6.05 ± 2.48 | 4.86 ± 2.68 | 6.49 ± 2.25 | < 0.001 ^b |
| Job support and control | 7.58 ± 2.13 | 8.03 ± 2.20 | 7.41 ± 2.08 | < 0.001 ^b |
| Noise | 5.37 ± 3.06 | 4.25 ± 3.04 | 5.78 ± 2.96 | < 0.001 ^b |
| Fumes | 7.38 ± 2.92 | 6.89 ± 3.08 | 7.55 ± 2.84 | < 0.001 ^b |
| Outcome, mean ± SD | | | | |
| Stress | 6.30 ± 2.55 | 5.05 ± 2.77 | 6.76 ± 2.30 | < 0.001 ^b |
| Fatigue | 6.00 ± 2.49 | 4.45 ± 2.61 | 6.56 ± 2.19 | < 0.001 ^b |
| MSDs (SWELL) | 6.11 ± 2.96 | 2.88 ± 2.54 | 6.11 ± 2.96 | < 0.001 ^b |

Abbreviations: SD, standard deviation

^aChi square test

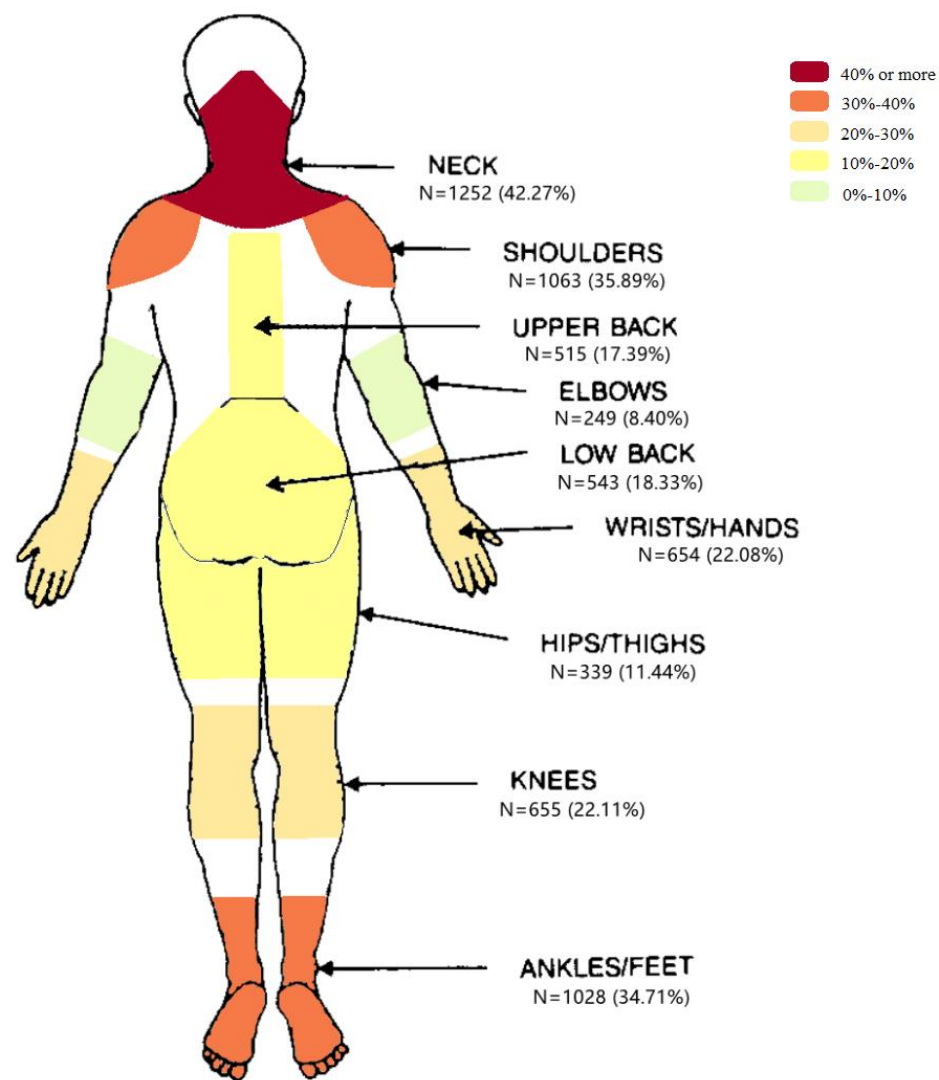
^bIndependent-samples t-test

Table 2. Odds ratio of IVs on WMSDs

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---------------------------------|---------|----------------|---------|----------------|---------|----------------|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Demographics | | | | | | |
| Age | 1.009 | [0.998, 1.021] | 1.006 | [0.994, 1.019] | 1.005 | [0.993, 1.018] |
| Gender | 0.689** | [0.574, 0.829] | 0.614** | [0.507, 0.745] | 0.610** | [0.501, 0.742] |
| Job role | 2.595** | [1.794, 3.755] | 3.666** | [2.499, 5.378] | 3.413** | [2.318, 5.023] |
| Personal Characteristics | | | | | | |
| Personality | | | 1.357* | [1.065, 1.728] | 1.322* | [1.035, 1.689] |
| Lifestyle | | | 2.108** | [1.667, 2.666] | 2.032** | [1.603, 2.575] |
| Work Characteristics | | | | | | |
| Workload | | | | | 1.345* | [1.052, 1.720] |
| Job control and support | | | | | 1.636** | [1.323, 2.024] |
| Noise | | | | | 1.478** | [1.199, 1.823] |
| Fumes | | | | | 1.585** | [1.286, 1.954] |
| Stress | | | | | 1.327* | [1.044, 1.688] |
| Fatigue | | | | | 2.211** | [1.755, 2.784] |
| Nagelkerke R² | | | | | | |
| | | 0.116 | | 0.208 | | 0.238 |

Abbreviations: OR, odds ratio; CI, confidence interval

** $P < 0.001$ * $p < 0.05$



view only

Adapted from Kuorinka et al.(1987).

Figure 1. Regions of WMSDs in the previous 12-month period prevalence

Supplementary Table 1. WMSDs in gas station workers

| | Body Region | | | | | | | | |
|---|------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | Neck | Shoulders | Elbows | Wrists/hands | Hips | Knees | Lower back | Upper back | Ankles/feet |
| 12-month period prevalence (n=2169, 73.23%) | 1252 (42.27%) | 1063 (35.89%) | 249 (8.40%) | 654 (22.08%) | 339 (11.44%) | 655 (22.11%) | 543 (18.33%) | 515 (17.39%) | 1028 (34.71%) |
| Gender | | | | | | | | | |
| Female | 730 (24.65%) | 643 (21.71%) | 141 (4.76%) | 399 (13.47%) | 180 (6.08%) | 339 (11.44%) | 291 (9.82%) | 290 (9.79%) | 527 (17.79%) |
| Male | 500 (16.9%) | 402 (13.57%) | 106 (3.58%) | 249 (8.41%) | 155 (5.23%) | 309 (10.43%) | 241 (8.14%) | 219 (7.39%) | 490 (16.54%) |
| Age | | | | | | | | | |
| ≤ 30 | 231 (7.80%) | 199 (6.72%) | 55 (1.86%) | 143 (4.83%) | 75 (2.53%) | 121 (4.09%) | 116 (3.92%) | 123 (4.15%) | 227 (7.66%) |
| 31–40 | 640 (21.61%) | 532 (17.96%) | 111 (3.75%) | 323 (10.90%) | 168 (5.67%) | 302 (10.20%) | 270 (9.12%) | 248 (8.37%) | 499 (16.85%) |
| 41–50 | 312 (10.53%) | 269 (9.08%) | 70 (2.36%) | 157 (5.30%) | 79 (2.67%) | 184 (6.21%) | 127 (4.29%) | 119 (4.02%) | 251 (8.47%) |
| ≥ 51 | 25 (0.84%) | 19 (0.64%) | 6 (0.20%) | 11 (0.37%) | 6 (0.20%) | 22 (0.74%) | 9 (0.30%) | 7 (0.24%) | 13 (0.44%) |
| Job role | | | | | | | | | |
| Frontline staff | 1002 (33.83%) | 855 (28.87%) | 220 (7.43%) | 583 (19.68%) | 268 (9.05%) | 583 (19.68%) | 445 (15.02%) | 403 (13.61%) | 978 (33.02%) |
| Non-frontline staff | 248 (8.37%) | 206 (6.95%) | 28 (0.95%) | 70 (2.36%) | 70 (2.36%) | 70 (2.36%) | 96 (3.24%) | 110 (2.71%) | 46 (1.55%) |

Supplementary Table 2. Correlation among stress, fatigue, WMSDs, work and personal characteristics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|-----------------------------|---------|---------|---------|---------|---------|---------|--------|--------|-----|
| (1) Stress | 1 | | | | | | | | |
| (2) Fatigue | 0.61** | 1 | | | | | | | |
| (3) WMSDs | 0.40** | 0.47** | 1 | | | | | | |
| (4) Lifestyle | -0.20** | -0.25** | -0.30** | 1 | | | | | |
| (5) Personality | -0.18** | -0.25** | -0.24** | 0.63** | 1 | | | | |
| (6) Workload | 0.71** | 0.59** | 0.41** | -0.21** | -0.20** | 1 | | | |
| (7) Job control and support | -0.07** | -0.12** | -0.12** | 0.30** | 0.38** | -0.08** | 1 | | |
| (8) Noise | 0.38** | 0.40** | 0.35** | -0.15** | -0.14** | 0.43** | -0.03 | 1 | |
| (9) Fumes | 0.23** | 0.23** | 0.11** | 0.00 | 0.01 | 0.28** | 0.06** | 0.46** | 1 |

**p < 0.001

For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

| | Item No | Recommendation | Page No |
|------------------------------|---------|--|---------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 3-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5-6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | 6 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 6 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants | 6 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 6 |
| Study size | 10 | Explain how the study size was arrived at | 6 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 7-8 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | 7-8 |
| | | (b) Describe any methods used to examine subgroups and interactions | |
| | | (c) Explain how missing data were addressed | |
| | | (d) If applicable, describe analytical methods taking account of sampling strategy | |
| | | (e) Describe any sensitivity analyses | |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | 8 |
| | | (b) Give reasons for non-participation at each stage | |
| | | (c) Consider use of a flow diagram | |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 8-9 |
| | | (b) Indicate number of participants with missing data for each variable of interest | |
| Outcome data | 15* | Report numbers of outcome events or summary measures | 8-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 8-11 |

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

| | | | |
|--------------------------|----|--|-------|
| | | (b) Report category boundaries when continuous variables were categorized | |
| | | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 8-11 |
| Discussion | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 11 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 14 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 11-14 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 14 |
| Other information | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 16 |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.