Prevalence of MSDs by Occupation and Body Regions

Tahsin Tasnim

Abstract

Musculoskeletal disorders (MSDs) are common and costly neuromusculoskeletal problems caused or aggravated by work activities and conditions. Because different occupations necessitate different ergonomic environments, trends of MSD prevalence vary by occupation. This study aimed to investigate MSD prevalence by occupation and body region. Figshare and Mendeley repositories were utilized to find 9 datasets. The search used a set of keywords detailing the occupational group and method of MSD measurement, the Nordic Musculoskeletal Questionnaire. After filtering and modifications, the data was analyzed through descriptive statistics, Chi-squared tests for independence, and the Marascuilo procedure. All calculations were performed in Rstudio and Jupyter Notebook. Construction workers (67%), rice cultivators (48%), and keyboardists (44%) had the highest MSD prevalence. Police officers (28%) and truck drivers (11%) had the lowest MSD prevalence. The Chi-squared tests showed a significant relationship between occupational group and location of MSDs ($p<0.001$). The Marascuilo procedure indicated several highly significant differences between occupational groups by body region, such as police officers and nurses in the elbows, and office workers and construction workers in the knees. There was a lack of significant differences in several regions between groups like police officers and factory workers, nurses and rice cultivators, and keyboardists and the reference population. This research explored the relationship between MSD prevalence, body region, and occupational groups internationally. Future research should emphasize similar research globally while accounting for sociodemographic factors. The information should be used to construct improved ergonomic intervention and treatment programs for workers.

Word Count: 243

Introduction

Musculoskeletal disorder (MSD) generally describes neuromusculoskeletal problems resulting in symptoms such as inflammation, weakness, pain, numbness, and tingling [1]. MSDs are caused or aggravated by work activities and conditions including awkward work posture, exposure to vibration, repetitive tasks, long work duration, and insufficient recovery [2, 3]. MSDs are also common; according to the European Agency for Safety and Health at Work (EU-OSHA), approximately every 3/5 workers experienced MSDs in 2019 [4]. MSDs are very costly as well, both directly (medical claims, diagnostic imaging, therapy, interventions) and indirectly (absenteeism, disability claims, misuse of drugs, and behavioral health treatments), potentially amounting to $100 billion/year [5].

Different occupational sectors and occupations have different trends of MSD occurrence due to specific movements, postures, work hours, and ergonomic environments characteristic of particular fields. For example, some areas of work may have a higher MSD occurrence in the ankles and knees, while other areas may have more MSDs in the wrists, elbows, and shoulders. Evaluation of these trends can be done through division of occupational sectors based on movements and other factors involved with the jobs.

Some jobs require workers to typically perform outdoor heavy labor. Construction and building, for example, can be very aggravating on a worker's body. Typical actions include repetitive dragging, throwing, bending, crawling, and carrying heavy weight, which can lead to damaged tissues, cramps and weakness, muscle malfunctioning, as well as fractures and dislocations of bones and joints [6]. Cultivation can lead to MSDs due to awkward posture and bending, repetitive work, long hours, and hard labor involved. The exertion required for farming likely results in osteoarthritis of the hip and knee, and pain in the upper body [7]. For instance, Cambodian farmworkers report having high MSD symptom prevalence (the proportion of a population who have a characteristic in a time period) in at least one limb in the body [8-9].

Other professions similarly require indoor heavy labor. Operating room personnel and nurses work inside buildings but perform strenuous tasks as well. Common activities include patient lifting and transfer, standing for long periods, fixed body posture, and (heavy)

equipment handling. These awkward, repetitive, and forceful movements have been also associated with MSDs, particularly in the lower and upper back, neck, shoulders, ankles, and feet [10-11].

Other jobs do not necessitate strenuous effort and instead use smaller and finer repetitive motions, such as typing for long periods of time. Office work involves numerous MSDs since the work often entails sitting at a desk for a majority of the workday and consistently typing or writing. The constrained posture and repetitive movements of the upper limbs can lead to MSDs such as carpal tunnel syndrome and tendonitis [12]. A high amount of Iranian office workers report experiencing MSDs in at least one limb [13]. Musicians show similar cases, specifically with the repetitious movements and posture involved in playing instruments. For playing-related musculoskeletal disorders (PRMSDs), approximately half of musicians note shoulder pain [14].

MSDs adversely affect the world's working population with pain and disability and must be remedied. While ergonomic intervention programs have been employed and tested, as well as encouraged by organizations like the Center for Disease Control and Prevention, more should be done to improve worker health and decrease MSD-associated costs [9, 15]. The next step is studying prevalence and trends of MSDs in the workforce more extensively in order to better formulate intervention and treatment plans according to the types and locations of MSDs in workers of each sector.

Thus, the purpose of this study is to investigate MSD prevalence within the whole body across multiple occupations worldwide. The objectives of this research are to 1) Compare the occurrence of MSDs across different occupations, 2) Identify associations between specific occupations and MSDs in specific body regions, and 3) Investigate how the occupational groups differ from each other and a reference population within body regions.

Methods

To answer the three objectives of this study, datasets of different occupational groups were collected and analyzed. The term 'occupational group' refers to the samples for each of the occupations and the reference population.

1.1 Datasets

The datasets were taken from Figshare and Mendeley open-access repositories based on certain attributes.

The first and foremost attribute was that the data pertained to MSD prevalence within an occupational group. Several datasets regarding MSD occurrence in occupations measure MSD occurrence using workers' compensation and medical reports. Datasets using workers' compensation and medical reports were not employed for this study since both can be influenced by other factors, such as likelihood of a compensation claim being approved and proximity to medical services. Therefore, the second attribute was the method of reporting MSDs: the Nordic Musculoskeletal Questionnaire (NMQ). The NMQ measures MSD occurrence by having participants report MSD location based on nine body regions (Fig 1) [16]. The multiple defined areas in which MSDs persist allow for more intensive analysis. Additionally, the NMQ is a standardized questionnaire that is used widely in studies investigating MSD prevalence [17].

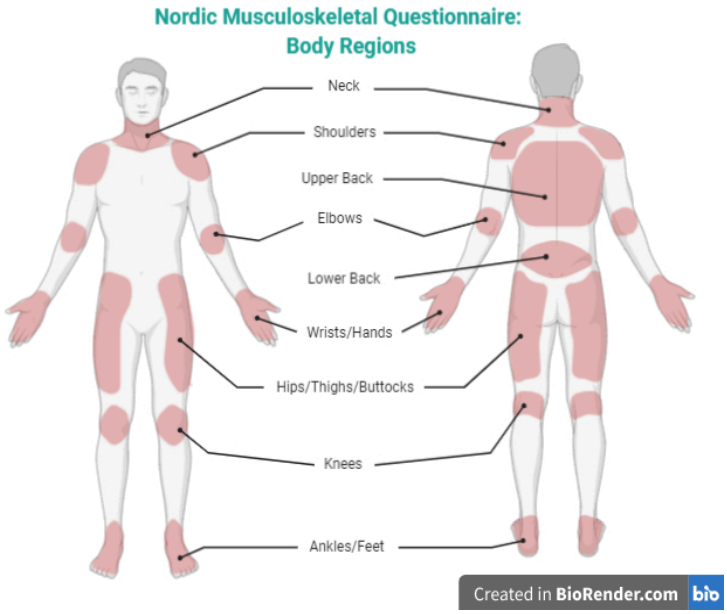


Fig SEQ Figure * ARABIC 1: Nordic Musculoskeletal Questionnaire (NMQ): Body Regions
The 9 specific body regions tested in the standardized NMQs used in the datasets [13].

A set of keywords was created to search for datasets. The words, “nordic,” “musculoskeletal,” and “pain” served as base keywords, followed by a variation of more keywords to specify the occupational group. All keywords used can be found in Fig 2. Only datasets in which the participants had been employed at their job for at least a year were chosen.

Table 1: Information on the datasets used
There were 9 datasets found, each with varying sample sizes and countries where they took place.

Occupation	Sample Size	Country
Police Officer	142	Brazil
Nurse	162	South Korea
Rice Cultivator	290	Thailand
Office Worker	569	Republic of Ireland
Truck Driver	123	Canada
Construction Worker	80	United Kingdom
Factory Worker	59	Bangladesh
Keyboardist	39	Brazil
Reference Population	3003	New Zealand

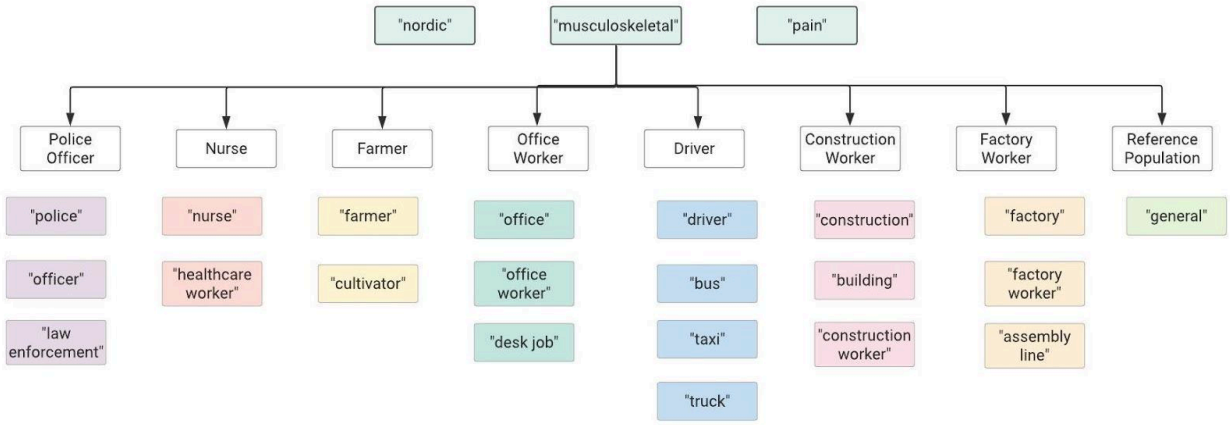


Fig 2: : Keywords used to search for datasets In Figshare and Mendeley open access repositories, the base keywords "nordic," "musculoskeletal," and "pain" followed by various other keywords were used to search for suitable datasets.

1.2 Modifications

The datasets [18-26] (Table 1) were modified and filtered of irrelevant and inconsistent information. Some factors such as age, gender, work hours, BMI, and pain intensity were not consistently reported throughout the studies so they were excluded. The only remaining

information was the number and percentage of people from each dataset that reported pain in each of the nine body regions.

Although a majority of the datasets did not report on body regions besides the nine specified, some datasets would evaluate 10 or 11 body regions ("forearm," "head," and similar parts were added as additional body regions to an adapted NMQ). The additional body regions were added into the nine predetermined body regions or excluded as inconsistent information. Additionally, the datasets had NMQ values for MSDs in both the week and the year prior to the survey; only NMQ values for the year prior were assessed to ensure that the reported MSDs were persistently present in the body.

From Table 2, information regarding specifications of the jobs should be clarified, given that the specifications were available in the datasets and corresponding articles. 'Nurses' refers to nurses of various wards (intensive care, surgery, emergency, obstetrics and gynecology, stem-cell transplantation care, and operation and anesthesia recovery). 'Office Worker' refers to office-based employees in two academic institutions. 'Truck Driver' refers to short and long distance industrial gas delivery truck drivers. 'Construction Workers' refers to various jobs that are typically seen at construction sites (plumber, electrician, carpenter, outdoor trader, bricklayer, scaffolder, laborer, paint fixer, painter and decorator, welder, and plasterer). 'Factory Worker' refers to ready-made garment workers, and 'Keyboardist' refers to instrumentalists who played keyboard at least 3 hours/week.

1.3 Statistical Analysis

Descriptive statistics were utilized to examine the prevalence of MSDs across occupational groups. Chi-square tests were used to identify associations between occupational group and MSDs in the body regions. The Marascuilo procedure was employed to investigate statistically significant differences between MSD prevalence between occupational groups based on MSD location (Fig. 3) [27]. The procedure was done by calculating the test statistic from the percentage of MSD prevalence for one occupational group (p_i) and another group (p_j) within only one body region. The critical value was then calculated using Chi-Square distribution values based on alpha level (1-α) and the number of samples being tested (k), as well as the

sample size for each sample (n_i, n_j). The procedure names two proportions significantly different from each other if the test statistic exceeds the critical value.

$$test\ statistic\ =\ \left|p_i - p_j\right|$$

$$critical\ value\ =\ \sqrt{X^2{}_{1-\alpha,\ k-1}}\sqrt{\frac{p_i\,(1-p_i)}{n_i}} + \sqrt{\frac{p_j\,(1-p_j)}{n_j}}$$

Fig. 3: Calculations for the Marascuilo Procedure
The test statistic is the difference in proportions between populations. The critical value gives the value that the test statistic must overcome to be significant.

All computations were completed with RStudio using built-in packages and Jupyter Notebook using pandas and matplotlib.

Results and Discussion

Three methods were developed to complete the three objectives of the study. Descriptive statistics answered how the occurrence of MSDs compare across different occupational groups. Chi-squared tests answered what the associations are between specific occupations and MSDs in specific body regions. The Marascuilo procedure answered how the occupational groups differ from each other within body regions.

2. 1 Descriptive Statistics

The total sample size was 4,467. Table 2 shows the data used for the analysis. Means of MSD occurrence by occupational group were calculated by adding all existing percentages in each occupation and dividing it by 9, representative of 9 body regions. Means of MSD occurrence by body region were calculated by adding all existing percentages in each body region and dividing it by 9, representative of 9 occupational groups. These means were then divided by 100 in order to find the total MSD prevalence for each occupation and for each region, defined as a ratio.

Table 2 : Percentage of participants from each dataset sample size that reported pain in the NMQ body regions.

The prevalence of MSDs in each dataset was measured by the percentage of people that reported pain in that area.

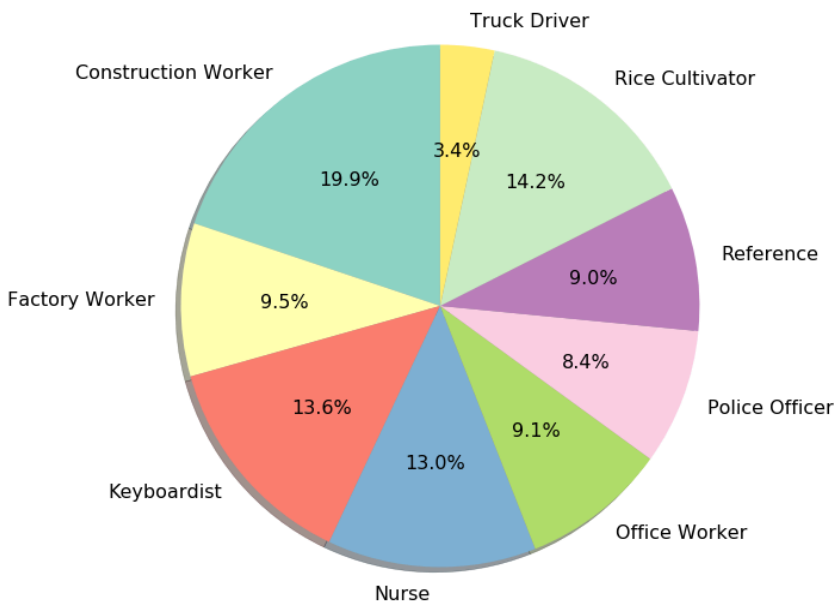
	Occupational Group											
Body Region	Police Officer	Nurse	Rice Cultivator	Office Worker	Truck Driver	Construction Worker	Factory Worker	Keyboardist	Reference Population	**Total MSD Prevalence (Body Region)**	**Mean (Body Region)**	**Standard Deviation (Body Region)**
Neck	25	43	51	58	15	61	49	49	43	394/900	43.78	15.98
Shoulders	25	70	73	57	20	69	47	44	42	447/900	49.67	20.37
Upper Back	33	28	34	32	7	82	33	69	14	332/900	36.89	24.01
Lower Back	47	54	60	50	21	84	56	69	30	471/900	52.33	18.16
Elbows	8	18	27	9	6	68	3	10	19	168/900	18.67	21.35
Wrists/Hands	25	51	39	29	12	75	23	59	54	367/900	40.78	21.11
Hips/Thighs/Glutes	32	24	66	16	9	48	14	36	19	264/900	29.33	19.22
Knees	32	63	41	14	7	76	32	31	31	327/900	36.33	23.08
Ankles/Feet	28	44	40	9	6	40	31	46	20	264/900	29.33	15.46
Total MSD Prevalence	255/900	395/900	431/900	274/900	103/900	603/900	288/900	413/900	272/900			
Mean (Occupation)	28.33	43.89	47.89	30.44	11.44	67.00	32.00	45.89	30.22			
Standard Deviation (Occupation)	10.27	17.74	15.54	20.16	5.94	14.96	17.10	18.91	13.64			

Construction workers had the highest MSD prevalence (mean=67.00%) followed by rice cultivators (mean=47.89%) and keyboardists (mean=43.89%). Literature has shown similar results for construction workers (57-67% prevalence in one study) [28]. Another study investigating PRMSDs in pianists reported a lower percentage of 35.8%. Literature investigating MSDs and associated factors in farmers found a higher prevalence than this study (91%) [29-30].

Although construction workers and rice cultivators involve different movements in work, similar percentages could indicate that more strenuous labor leads to higher prevalence of MSDs [31]. However, keyboard playing involves smaller and finer repetitive movements rather than large, rough motions. The high prevalence of MSDs in keyboardists can show that MSDs persist even when the body is not continually subject to heavy manual labor. It should be noted that the sample size for keyboardists is the lowest among the datasets, creating a greater probability for this sample to be unrepresentative of the population.

The lowest MSD prevalence was seen in truck drivers (mean=11.44%). Only the truck drivers and police officers (mean=28.33%) had lower MSD prevalence than the reference population (mean=30.22%). However, other literature has given much higher MSD prevalence for truck drivers than that found in this study (78.6%) [32]. This comparison could mean that the sample used for this analysis was unrepresentative of the whole population. Misrepresentation could be related to geographical constraint to one area, rather than globally. More research on these occupations worldwide must be completed to reach more accurate answers.

Office workers (mean=30.44%) were the closest to the reference population for MSD prevalence. Literature has shown similar yet higher prevalence of MSDs in office workers (approximately 40%) [33]. The prevalence rates for office workers in comparison to a control suggest that office workers are as likely to experience MSDs as any worker. A summative view of MSD prevalence by occupational group is seen in Fig 4.



There was least variance of MSD prevalence by body region for truck drivers (SD=5.94), while office workers had the greatest variance (SD=20.16), indicating that MSDs are most evenly distributed throughout the body for truck drivers and least evenly distributed in office workers.

Additionally, notable MSD prevalence was observed for all of the occupations in the lower back (mean=55.13%), shoulders (mean=50.63%), and neck (mean=43.88%), while few MSDs were observed in the elbows (mean=18.63%; Fig 5, Fig 6). Other published works studying MSDs in the body follow similar patterns of the lower back, neck, and shoulders having high MSD prevalence and elbows having low MSD prevalence in multiple occupational sectors [34-38].

one another
reached.

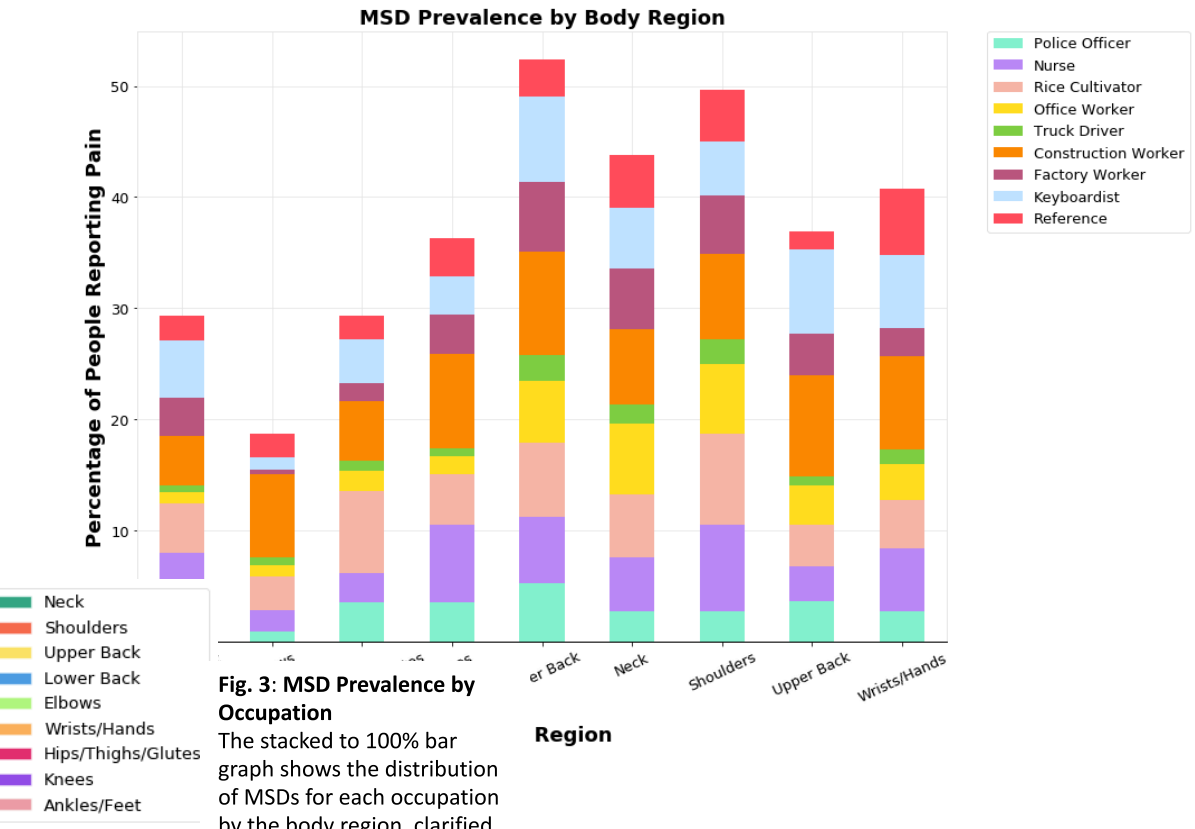


Fig. 3: MSD Prevalence by Occupation
The stacked to 100% bar graph shows the distribution of MSDs for each occupation by the body region, clarified by the color of the stacked bars.

Fig. 5: MSD Prevalence by Occupation
The stacked bar graph shows the prevalence of MSDs for each occupation by the body region, elucidated by the color of the stacked bars for each group.

2.2 Chi-Square Test for Independence

Three chi-square tests were run to show association between the occupation of a participant and the location of the MSDs. One test was run for occupation and MSD location in the whole body, which was significant (df=64, χ^2 statistic=849.41, $p<0.001$). The second test investigated occupation and MSDs in solely the upper body, which also came back significant (df=40, χ^2 statistic=534.18, $p<0.001$). A third test was used to test occupation and MSDs in solely the lower body, which returned significant as well (df=16, χ^2 statistic=101.44, $p<0.001$). The high significance of all of the tests indicate that there is a relationship between occupation and location of MSDs in the body. However, these results only establish an association between the two variables, not causation. In order to investigate the causation aspect, more studies and tests should be conducted.

2.3 Marascuilo Procedure

The Marascuilo procedure found some statistically significant differences between occupational groups in accordance to body regions (Table 3a-i). The values in each table are the difference between the test statistic and critical value in the procedure (ts - cv). Positive values in the table indicate statistical significance, negative values indicate insignificance. The magnitude of significance is positively related to the difference between the test statistic and the critical value. Values highlighted in blue represent high significance, in which the difference between test statistic and critical value is above 0.5. Values highlighted in red represent insignificance. The results of Table 3, centralized around a few occupational groups to avoid repetition, are summarized in the following three paragraphs.

Table 3a: Marascuilo Procedure Statistics Summary: Police The Marascuilo Procedure determined differences between the police off occupational group and the rest of the occupational groups.

	Police v Nurse	Police v Rice Cultivator	Police v Office Worker	Police v Truck Driver	Police v Construction Worker	Police v Factory Worker	Police v Keyboardist	Polic Refer
Neck	0.089	0.169	0.239	0.022	0.27	0.149	0.149	
Shoulders	0.363	0.394	0.229	-0.032	0.352	0.129	0.099	
Upper Back	-0.04	-0.082	-0.082	0.279	0.406	-0.092	0.269	
Lower Back	-0.028	0.033	-0.068	0.171	0.284	-0.007	0.126	
Elbows	**0.543**	0.447	0.031	0.113	0.035	0.416	**0.631**	
Wrists/Hands	0.169	0.05	-0.047	0.055	0.415	-0.063	0.249	
Hips/Thighs/Glutes	-0.007	0.248	0.078	**0.503**	0.065	0.1	-0.053	
Knees	0.217	-0.004	0.1	0.29	0.353	-0.091	-0.081	
Ankles/Feet	0.067	0.028	**0.545**	0.228	0.028	-0.059	0.087	

Table 3b: Marascuilo Procedure Statistics Summary: Nurse The Marascuilo Procedure determined differences between the nurse occupational group and the rest of the occupational groups.

	Police v Nurse	Nurse v Rice Cultivator	Nurse v Office Worker	Nurse v Truck Driver	Nurse v Construction Worker	Nurse v Factory Worker	Nurse v Keyboardist	Nurse v Reference
Neck	0.089	-0.017	0.053	0.196	0.084	-0.037	-0.037	-0.097
Shoulders	0.363	-0.058	0.037	0.416	-0.08	0.136	0.167	0.187
Upper Back	-0.04	-0.03	-0.05	0.331	0.458	-0.04	0.321	0.062
Lower Back	-0.028	-0.037	-0.058	0.241	0.214	-0.077	0.056	0.146
Elbows	**0.543**	0.009	**0.653**	0.334	0.416	0.037	0.013	-0.066
Wrists/Hands	0.169	0.023	0.127	0.308	0.149	0.19	-0.017	-0.068
Hips/Thighs/Glutes	-0.007	0.332	0.002	**0.588**	0.149	0.024	0.031	-0.03
Knees	0.217	0.125	0.408	-0.022	0.041	0.217	0.228	0.228
Ankles/Feet	0.067	-0.056	0.38	0.064	-0.056	0.036	-0.077	0.152

Table 3c: Marascuilo Procedure Statistics Summary: Rice Cultivator The Marascuilo Procedure determined differences between the rice cultivator occupational group and the rest of the occupational groups.

	Police v Rice Cultivator	Nurse v Rice Cultivator	Rice Cultivator v Office Worker	Rice Cultivator v Truck Driver	Rice Cultivator v Construction Worker	Rice Cultivator v Factory Worker	Rice Cultivator v Keyboardist	Rice Cultivator v Reference
Neck	0.169	-0.017	-0.027	0.275	0.003	-0.078	-0.078	-0.017
Shoulders	0.394	-0.058	0.068	0.447	-0.049	0.168	0.198	0.218
Upper Back	-0.082	-0.03	-0.072	0.269	0.396	-0.082	0.258	0.119
Lower Back	0.033	-0.037	0.003	0.302	0.155	-0.056	-0.003	0.207
Elbows	0.447	0.009	**0.556**	0.239	0.321	-0.058	0.096	-0.002
Wrists/Hands	0.05	0.023	0.008	0.189	0.27	0.071	0.104	0.054
Hips/Thighs/Glutes	0.248	0.332	0.417	0.162	0.085	0.439	0.207	0.385
Knees	-0.004	0.125	0.187	0.197	0.26	-0.004	0.007	0.007
Ankles/Feet	0.028	-0.056	0.421	0.104	-0.096	-0.003	-0.037	0.113

Table 3d: Marascuilo Procedure Statistics Summary: Office Worker The Marascuilo Procedure determined differences between the office worker occupational group and the rest of the occupational groups.

	Police v Office Worker	Nurse v Office Worker	Rice Cultivator v Office Worker	Office Worker v Truck Driver	Office Worker v Construction Worker	Office Worker v Factory Worker	Office Worker v Keyboardist	Office Worker v Reference
Neck	0.239	0.053	-0.027	0.346	-0.066	-0.007	-0.007	0.053
Shoulders	0.229	0.037	0.068	0.282	0.026	0.003	0.033	0.053
Upper Back	-0.082	-0.05	-0.072	0.29	0.416	-0.082	0.279	0.1
Lower Back	-0.068	-0.058	0.003	0.201	0.254	-0.037	0.096	0.106
Elbows	0.031	**0.653**	**0.556**	0.221	0.143	**0.524**	**0.741**	**0.642**
Wrists/Hands	-0.047	0.127	0.008	0.093	0.373	-0.026	0.207	0.157
Hips/Thighs/Glutes	0.078	0.002	0.417	**0.675**	0.234	-0.05	0.116	-0.044
Knees	0.1	0.408	0.187	0.481	**0.544**	0.1	0.09	0.09
Ankles/Feet	**0.545**	0.38	0.421	0.221	0.421	**0.514**	0.36	**0.631**

Table 3e: Marascuilo Procedure Statistics Summary: Truck Driver The Marascuilo Procedure determined differences between the truck driver occupational group and the rest of the occupational groups.

	Police v Truck Driver	Nurse v Truck Driver	Rice Cultivator v Truck Driver	Office Worker v Truck Driver	Truck Driver v Construction Worker	Truck Driver v Factory Worker	Truck Driver v Keyboardist	Truck Driver v Reference
Neck	0.022	0.196	0.275	0.346	0.376	0.255	0.255	0.196
Shoulders	-0.032	0.416	0.447	0.282	0.405	0.182	0.152	0.132
Upper Back	0.279	0.331	0.269	0.29	0.037	0.279	-0.08	0.481
Lower Back	0.171	0.241	0.302	0.201	**0.554**	0.261	0.395	0.005
Elbows	0.113	0.334	0.239	0.221	-0.014	0.207	0.421	0.323
Wrists/Hands	0.055	0.308	0.189	0.093	**0.555**	0.036	0.388	0.338
Hips/Thighs/Glutes	**0.503**	**0.588**	0.162	**0.675**	0.339	**0.697**	0.462	**0.642**
Knees	0.29	-0.022	0.197	0.481	-0.027	0.29	0.3	0.3
Ankles/Feet	0.228	0.064	0.104	0.221	0.104	0.197	0.043	0.313

Table 3f: Marascuilo Procedure Statistics Summary: Construction Worker The Marascuilo Procedure determined differences between the construction worker occupational group and rest of the occupational groups.

	Police v Construction Worker	Nurse v Construction Worker	Rice Cultivator v Construction Worker	Office Worker v Construction Worker	Truck Driver v Construction Worker	Construction Worker v Factory Worker	Construction Worker v Keyboardist	Construction Worker v Reference
Neck	0.27	0.084	0.003	-0.066	0.376	0.023	0.023	0.084
Shoulders	0.352	-0.08	-0.049	0.026	0.405	0.126	0.156	0.176
Upper Back	0.406	0.458	0.396	0.416	0.037	0.406	0.047	**0.608**
Lower Back	0.284	0.214	0.155	0.254	**0.554**	0.195	0.068	0.459
Elbows	0.035	0.416	0.321	0.143	-0.014	0.29	**0.503**	0.406
Wrists/Hands	0.415	0.149	0.27	0.373	**0.555**	0.437	0.069	0.119
Hips/Thighs/Glutes	0.065	0.149	0.085	0.234	0.339	0.256	0.024	0.202
Knees	0.353	0.041	0.26	**0.544**	-0.027	0.353	0.363	0.363
Ankles/Feet	0.028	-0.056	-0.096	0.421	0.104	-0.003	-0.037	0.113

Table 3g: Marascuilo Procedure Statistics Summary: Factory Worker The Marascuilo Procedure determined differences between the factory worker occupational group and the rest of the occupational groups.

	Police v Factory Worker	Nurse v Factory Worker	Rice Cultivator v Factory Worker	Office Worker v Factory Worker	Truck Driver v Factory Worker	Construction Worker v Factory Worker	Factory Worker v Keyboardist	Factory Worker v Reference
Neck	0.149	-0.037	-0.078	-0.007	0.255	0.023	-0.098	-0.037
Shoulders	0.129	0.136	0.168	0.003	0.182	0.126	-0.067	-0.047
Upper Back	-0.092	-0.04	-0.082	-0.082	0.279	0.406	0.269	0.109
Lower Back	-0.007	-0.077	-0.056	-0.037	0.261	0.195	0.036	0.167
Elbows	0.416	0.037	-0.058	**0.524**	0.207	0.29	0.124	0.027
Wrists/Hands	-0.063	0.19	0.071	-0.026	0.036	0.437	0.271	0.22
Hips/Thighs/Glutes	0.1	0.024	0.439	-0.05	**0.697**	0.256	0.138	-0.022
Knees	-0.091	0.217	-0.004	0.1	0.29	0.353	-0.081	-0.081
Ankles/Feet	-0.059	0.036	-0.003	**0.514**	0.197	-0.003	0.056	0.025

Table 3h: Marascuilo Procedure Statistics Summary: Keyboardist The Marascuilo Procedure determined differences between the keyboardist occupational group and the rest of the occupational groups.

	Police v Keyboardist	Nurse v Keyboardist	Rice Cultivator v Keyboardist	Office Worker v Keyboardist	Truck Driver v Keyboardist	Truck Driver v Keyboardist	Factory Worker v Keyboardist	Keyboardist v Reference
Neck	0.149	-0.037	-0.078	-0.007	0.255	0.255	-0.098	-0.037
Shoulders	0.099	0.167	0.198	0.033	0.152	0.152	-0.067	-0.077
Upper Back	0.269	0.321	0.258	0.279	-0.08	-0.08	0.269	0.47
Lower Back	0.126	0.056	-0.003	0.096	0.395	0.395	0.036	0.3
Elbows	**0.631**	0.013	0.096	**0.741**	0.421	0.421	0.124	0.022
Wrists/Hands	0.249	-0.017	0.104	0.207	0.388	0.388	0.271	-0.047
Hips/Thighs/Glutes	-0.053	0.031	0.207	0.116	0.462	0.462	0.138	0.084
Knees	-0.081	0.228	0.007	0.09	0.3	0.3	-0.081	-0.09
Ankles/Feet	0.087	-0.077	-0.037	0.36	0.043	0.043	0.056	0.172

Table 3i: Marascuilo Procedure Statistics Summary: Reference Population The Marascuilo Procedure determined differences between each occupational group and the reference population.

	Police Officer v Reference Population	Nurse v Reference Population	Rice Cultivator v Reference Population	Office Worker v Reference Population	Truck Driver v Reference Population	Construction Worker v Reference Population	Factory Worker v Reference Population	Keyboardist v Reference Population
Neck	0.089	-0.097	-0.017	0.053	0.196	0.084	-0.037	-0.037
Shoulders	0.079	0.187	0.218	0.053	0.132	0.176	-0.047	-0.077
Upper Back	0.109	0.062	0.119	0.1	0.481	**0.608**	0.109	0.47
Lower Back	0.076	0.146	0.207	0.106	0.005	0.459	0.167	0.3
Elbows	**0.533**	-0.066	-0.002	**0.642**	0.323	0.406	0.027	0.022
Wrists/Hands	0.199	-0.068	0.054	0.157	0.338	0.119	0.22	-0.047
Hips/Thighs/Glutes	0.046	-0.03	0.385	-0.044	**0.642**	0.202	-0.022	0.084
Knees	-0.081	0.228	0.007	0.09	0.3	0.363	-0.081	-0.09
Ankles/Feet	-0.003	0.152	0.113	**0.631**	0.313	0.113	0.025	0.172

Significant differences from police officers

There was a particularly significant difference present between police officers and nurses (ts - cv=0.543), keyboardists (ts - cv=0.631), and the reference population (ts - cv=0.533) in the

elbows, police officers and truck drivers (ts - cv=0.503) in the hips/thighs/glutes, and police officers and office workers (ts - cv=0.545) in the ankles and feet.

Significant differences from office workers

There were also significant differences seen between office workers and nurses in the elbows (ts - cv=0.653) in the hips/thighs/glutes. Similar patterns were observed between office workers and rice cultivators (ts - cv=0.556), factory workers (ts - cv=0.524), keyboardists (ts - cv=0.741), and the reference population (ts - cv=0.642) in the elbows. Additionally, significant differences existed between office workers and truck drivers in the hips/thighs/glutes (ts - cv=0.675), construction workers in the knees (ts - cv=0.544), and factory workers (ts - cv=0.514), and the reference population (ts - cv=0.631) in the ankles/feet.

Significant differences from construction workers

Significant differences also showed between construction workers and truck drivers in the lower back (ts - cv=0.554) and wrists/hands (ts - cv=0.555). Construction workers had a highly significant difference with the reference population in the upper back (ts - cv=0.608) and keyboardists in the elbows (ts - cv=0.503).

There was also a highly significant difference between nurses and truck drivers in the hips/thighs/glutes (ts - cv=0.588).

These results suggest that the mentioned groups are significantly different from each other within the specified regions, which indicates that the MSDs reported in those areas are characteristic of one occupation and not the other.

There was a lack of significant differences between police officers and factory workers in 5/9 regions, nurses and rice cultivators in 5/9 regions, rice cultivators and factory workers in 6/9 regions, and office workers and factory workers in 5/9 regions, proposing that MSD prevalence for both sets of workers in those regions are similar. The similarities of the MSD values could be due to like motions pertaining to each region between the occupations.

There was also a lack of significant differences between the reference population and nurses in 4/9 regions, keyboardists in 4/9 regions, and factory workers in 4/9 regions, indicating that MSDs in those locations are not significantly different from that of any other worker. Therefore, the motions performed on these regions could be similar to motions that any worker performs on those regions.

Conclusion

This study explored the relationship between MSD prevalence, body region, and occupations around the world. The prevalence of MSDs within wider occupational sectors is also clarified in this analysis.

Comparison between heavy outdoor labor, heavy indoor labor, and fine, repetitive movements

In every region besides the knees and ankles/feet, outdoor heavy laborers (construction workers and rice cultivators) generally had higher MSD occurrence than indoor heavy laborers (nursing personnel). Workers in occupations that require finer repetitive movements generally had less MSD occurrence than indoor and outdoor heavy laborers as well, in all body regions.

Comparison between non-sedentary and sedentary workers

Non-sedentary workers, such as police officers, nurses, rice cultivators, and construction workers, generally had higher MSD occurrence than sedentary workers, such as office workers, truck drivers, factory workers, and keyboardists. Specifically, non-sedentary workers had higher MSD reports in the lower back, shoulders, and knees, while sedentary workers had higher reports in the lower back, neck, and shoulders.

Another observation is that the lower back, shoulders, neck, and wrists/hands were the locations that had high NMQ values for every occupational group [39-41]. In contrast, MSDs in the elbows were not prevalent in any occupational category except for construction work [38, 42].

These findings give information that will help construct ergonomic intervention programs that address the issues of MSDs by not just occupation, but wider occupational sectors based on similarities in the work. For example, more programs for all sectors could emphasize treatment of the lower back, shoulders, and neck, while putting less focus on areas with less MSD prevalence (the elbows). Additionally, more attention should be given to

ergonomic intervention programs for heavy laborers (indoor and outdoor), as well as non-sedentary workers.

It is essential to keep creating new plans and treatment methods that adjust to the workforce as time and technology progresses. Therefore, it is important to continually study MSD prevalence in the workforce and be aware of the occupations and body regions that tend to have the highest MSD prevalence. Future investigations should advance the study of MSD prevalence by body region and occupations, but should do so especially on a wider, more global scale. Future studies should also investigate MSD prevalence while accounting for other sociodemographic and risk factors involved with work.

References

[1] A. N. Alias et al., "Prevalence of musculoskeletal disorders (MSDS) among primary school female teachers in Terengganu, Malaysia," *International Journal of Industrial Ergonomics*, vol. 77, pp. 1-8, May 2020. Accessed on: July 7, 2020. [Online]. Available: doi:10.1016/j.ergon.2020.102957.

[2] T. Rambabu and K. Suneetha, "Prevalence of work related musculoskeletal disorders among physicians, surgeons and dentists: A comparative study," *Annals of Medical and Health Sciences Research*, vol. 4, n. 4, pp. 578-582, July 2014. [Online]. Available: doi: 10.4103/2141-9248.139327.

[3] O. Lotter et al., "Is Repetitive Workload a Risk Factor for Upper Extremity Musculoskeletal Disorders in Surgical Device Mechanics? A Cross-Sectional Analysis," *International Journal of Environmental Research and Public Health*, vol. 17, n. 4, pp. 1383, Feb 2020. [Online]. Accessed on: July 7, 2020. [Online]. Available: doi: 10.3390/ijerph17041383.

[4] J. de Kok, P. Vroonhof, J. Snijders, G. Roullis, M. Clarke, K. Peereboom, P. van Dorst, and I. Isus, "Work-related musculoskeletal disorders: prevalence, costs and demographics in the EU," EU, Nov. 15, 2019. Accessed on: July 8, 2020. [Online]. Available: https://osha.europa.eu/en/publications/msds-facts-and-figures-overview-prevalence-costs-and-demographics-msds-europe/view

[5] J. Nobel, C. Sherman, E. Sasser, and L. Pickering, "Preventing and Treating Musculoskeletal Disorders: New Strategies for Employers." Northeast Business Group on Health, Sep. 2017. Accessed on July 15, 2020. [Online]. Available: https://nebgh.org/wp-content/uploads/2018/02/NEBGH_MSD-Report_FINAL.pdf.

[6] M. Ijaz et al., "Quantitative and qualitative assessment of musculoskeletal disorders and socioeconomic issues of workers of brick industry in Pakistan," *International Journal of Industrial Ergonomics*, vol. 76, pp. 1-9, Feb. 2020. Accessed on: July 8, 2020. [Online]. Available: doi: 10.1016/j.ergon.2020.102933.

[7] T. Luangwilai and W. Siriwong, "Musculoskeletal disorders among rice farmers in Phimai District, Nakhon Ratchasima Province, Thailand*," Journal of Health Research*, vol. 33, n. 6, pp. 494–503, Apr. 2019. Accessed on: July 6, 2020. [Online]. Available: doi: 10.1108/JHR-01-2019-0009.

[8] A. Thetkathuek et al., "A Cross-sectional Study of Musculoskeletal Symptoms and Risk Factors in Cambodian Fruit Farm Workers in Eastern Region, Thailand," S*afety and Health at Work*, vol. 9, n. 2, pp. 192–202, June 2018. Accessed on: July 8, 2020. [Online]. Available: doi: 10.1016/j.shaw.2017.06.009

[9] “What is Prevalence?,” National Institute of Mental Health, Nov 2017. Accessed on: July 17, 2020 [Online]. Available: https://www.nimh.nih.gov/health/statistics/what-is-prevalence.shtml.

[10] R. Tavakkol et al., “The global prevalence of musculoskeletal disorders among operating room personnel: A systematic review and meta-analysis,” *Clinical Epidemiology and Global Health*, pp. 1-9, Mar. 2020. Accessed on: July 8, 2020. [Online]. Available: doi: 10.1016/j.cegh.2020.03.019.

[11] A. K. Akodu and Z. O. Ashalejo, “Work-related musculoskeletal disorders and work ability among hospital nurses,” *Journal of Taibah University Medical Sciences*, vol. 14, n. 3, pp. 252–261, June 2019. Accessed on: July 8, 2020. [Online]. Available: doi: 10.1016/j.jtumed.2019.02.009.

[12] A. Barr, et al., "Work-related musculoskeletal disorders of the hand and wrist: epidemiology, pathophysiology, and sensorimotor changes," *The Journal of Orthopaedic and Sports Physical Therapy*, vol. 34, n. 10, pp. 610–627, Oct. 2004. Accessed on: July 9, 2020. [Online]. Available: doi: 10.2519/jospt.2004.34.10.

[13] F. Mohammadipour, et al., "Work-related Musculoskeletal Disorders in Iranian Office Workers: Prevalence and Risk Factors," *Journal of Medicine and Life*, vol. 11, n. 4, pp. 328–333, Dect. 2018. Accessed on: July 9, 2020. [Online]. Available: doi: 10.25122/jml-2018-0054.

[14] F. B. Kochem and J. G. Silva, “Prevalence of Playing-related Musculoskeletal Disorders in String Players: A Systematic Review,” *Journal of Manipulative and Physiological Therapeutics*, vol. 41, n. 6, pp. 540–549, Aug. 2018. Accessed on: July 12, 2020. [Online]. Available: doi: 10.1016/j.jmpt.2018.05.001.

[15] M. Soler-Font et al., "Multifaceted intervention for the prevention and management of musculoskeletal pain in nursing staff: Results of a cluster randomized controlled trial," *PLoS ONE*, vol. 14, n. 11, pp. 1-16, Nov. 2019. Accessed on: July 12, 2020. [Online]. Available: doi: 10.1371/journal.pone.0225198

[16] I. Kuorinka et al., “Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms,” *Applied Ergonomics*, vol. 18, n. 3, pp. 233–237, Sep. 1987. Accessed on: July 10, 2020. [Online]. Available: doi: 10.1016/0003-6870(87)90010-x

[17] L. López-Aragón et al., "Applications of the Standardized Nordic Questionnaire: A Review," *Sustainability*, vol. 9, n. 9, pp. 1514, Aug. 2017. Accessed on: July 10, 2020. [Online]. Available: doi: 10.3390/su9091514

[18] D. Kee and S. R. Seo, “Musculoskeletal disorders among nursing personnel in Korea,” *International Journal of Industrial Ergonomics*, vol. 37, n. 3, pp. 207–212, Mar. 2007. Accessed on: July 6, 2020. [Online]. Available: doi: 10.1016/j.ergon.2006.10.020

[19] M. D. Hossain et al., “Prevalence of work related musculoskeletal disorders (WMSDs) and ergonomic risk assessment among readymade garment workers of Bangladesh: A cross sectional study,” *PLoS ONE*, vol. 13, n. 7, July 2018. Accessed on: July 9, 2020. [Online]. Available: doi: 10.1371/journal.pone.0200122

[20] J. D. Collins and L. W. Osullivan, “Musculoskeletal disorder prevalence and psychosocial risk exposures by age and gender in a cohort of office based employees in two academic institutions,” *International Journal of Industrial Ergonomics*, vol. 46, pp. 85–97, Mar. 2015. Accessed on: July 9, 2020. [Online]. Available: doi: 10.1371/journal.pone.0200122

[21] C. S. Santos et al., “Index of severity of musculoskeletal symptoms in keyboardists,” *Fisioterapia em Movimento*, vol. 32, Dec. 2019. Accessed on: July 9, 2020. [Online]. Available: doi: 10.1590/1980-5918.032.ao47.

[22] M. V. G. B. Serra et al., “Musculoskeletal disorders, stress perception and physical activity in police officers,” *Fisioterapia e Pesquisa*, vol. 27, n. 1, pp. 22–27, Jan 2020. Accessed on: July 9, 2020. [Online]. Available: doi: 10.1590/18092950/18029227012020

[23] S. Eaves et al., “Building healthy construction workers: Their views on health, wellbeing and better workplace design,” *Applied Ergonomics*, vol. 54, pp. 10–18, May 2016. Accessed on: July 6, 2020. [Online]. Available: doi: 10.1016/j.apergo.2015.11.004

[24] F. Sekkay et al., “Risk factors associated with self-reported musculoskeletal pain among short and long distance industrial gas delivery truck drivers,” *Applied Ergonomics*, vol. 72, pp. 69–87, Oct. 2018. Accessed on: July 13, 2020. [Online]. Available: doi: 10.1016/j.apergo.2018.05.005

[25] T. Luangwilai and W. Siriwong "FACTORS ASSOCIATED WITH MUSCULOSKELETAL DISORDERS AMONG RICE FARMERS IN TARNLALORD SUB-DISTRICT PHIMAI DISTRICT NAKHON RATCHASIMA PROVINCE THAILAND," *Chulalongkorn University*, pp. 1-77, 2013. Accessed on: July 13, 2020. [Online]. Available: doi: 10.14457/CU.the.2013.819

[26] B. Widanarko et al., “Prevalence of musculoskeletal symptoms in relation to gender, age, and occupational/industrial group,” *International Journal of Industrial Ergonomics*, vol. 41, no. 5, pp. 561–572, Sep. 2011. Accessed on: July 10, 2020. [Online]. Available: doi: 10.1016/j.ergon.2011.06.002

[27] 7.4.7.4. Comparing multiple proportions: The Marascuillo procedure. Accessed on: July 16, 2020. [Online]. Available:

https://www.itl.nist.gov/div898/handbook/prc/section4/prc474.htm#:~:text=The Marascuilo procedure enables us,are several populations under investigation.&text=Assume we have samples of,, k) from k populations.

[28] J. Boschman et al., "Musculoskeletal disorders among construction workers: a one-year follow-up study," *BMC Musculoskeletal Disorders*, vol 13, n. 196, pp. 1-9, Oct. 2012. Accessed on: July 10, 2020. [Online]. Available: doi: 10.1186/1471-2474-13-196

[29] C. Ling et al., "Playing-Related Musculoskeletal Disorders Among Classical Piano Students at Tertiary Institutions in Malaysia: Proportion and Associated Risk Factors," *Medical Problems of Performing Artists*, vol. 33, n. 2, pp. 82–89, June 2018. Accessed on: July 10, 2020. [Online]. Available: doi: https://doi.org/10.21091/mppa.2018.2013

[30] Jo, H., Baek et al., "Farmers' Cohort for Agricultural Work-Related Musculoskeletal Disorders (FARM) Study: Study Design, Methods, and Baseline Characteristics of Enrolled Subjects," *Journal of epidemiology*, vol. 26, n. 1, pp. 50–56, 2016. Accessed on: July 13, 2020. [Online]. Available: doi: 10.2188/jea.JE20140271.

[31] L. Lunde et al., "Musculoskeletal health and work ability in physically demanding occupations: study protocol for a prospective field study on construction and health care workers," *BMC Public Health*, vol. 14, pp. 1-11, Oct. 2014. Accessed on: July 13, 2020. [Online]. Available: doi: 10.1186/1471-2458-14-1075

[32] A. Mozafari et al., "Work-related musculoskeletal disorders in truck drivers and official workers" *Acta medica Iranica*, vol. 53, n. 7, pp. 432-8, July 2015. Accessed on: July 15, 2020. [Online]. Available: PMID: 26520631

[33] H. Daneshmandi et al., "The effect of musculoskeletal problems on fatigue and productivity of office personnel: a cross-sectional study," *Journal of Preventive Medicine and Hygiene*, vol. 58. n. 3, pp. E252–E258, Sep. 2017. Accessed on: July 15, 2020. [Online]. Available: PMID: 29123372

[34] Y. A. Alogaibi et al., "Prevalence of musculoskeletal disorders (back, neck and shoulders' pain) among dental personnel in Jeddah – Saudi Arabia," *Journal of Dental Health Oral Disorders & Therapy*, vol. 9, n. 5, pp. 399-405, Sep. 2018. Accessed on: July 16, 2020. [Online]. Available: doi: 10.15406/jdhodt.2018.09.00416

[35] A. Shariat et al., "Prevalence Rate of Neck, Shoulder and Lower Back Pain in Association with Age, Body Mass Index and Gender Among Malaysian Office Workers," *Work*, vol. 60, n. 2, pp. 191 – 199, Jan. 2018. Accessed on: July 16, 2020. [Online]. Available: doi:10.3233/WOR-2738

[36] A. D. Algarni et al., "The Prevalence of and Factors Associated with Neck, Shoulder, and Low-Back Pains among Medical Students at University Hospitals in Central Saudi Arabia," *Pain*

Res Treat, vol. 2017, Nov. 2017. Accessed on: July 16, 2020. [Online]. Available: doi:10.1155/2017/1235706

[37] S. Alavi et al., "Risk Factors for Upper Extremity Musculoskeletal Disorders Among Office Workers in Qom Province, Iran," *Iranian Red Crescent medical journal*, vol. 18 n.10., Oct 2016. Accessed on: July 16, 2020. [Online]. Available: doi: 10.5812/ircmj.29518

[38] D. Ohlendorf, D et al., "Prevalence of Muscular Skeletal Disorders among Qualified Dental Assistants," *International Journal of Environmental Research and Public Health*, vol. 17, n. 10, May 2017. Accessed on: July 16, 2020. [Online]. Available: doi: 10.3390/ijerph17103490

[39] S. T. Al-Otaibi, "Prevention of occupational Back Pain," *Journal of Family & Community Medicine*, vol. 22, n. 2, pp. 73–77. Aug. 2015. Accessed on: July 10, 2020. [Online]. Available: doi: 10.4103/2230-8229.155370

[40] V. R. Dave et al., "Risk factors of occupation related back pain and neck pain among patients attending tertiary care hospital, Ahmedabad, India," *Journal of Preventive Medicine and Hygiene*, vol. 60, n. 4, pp. E419–E427, Dec. 2019. Accessed on: July 11, 2020. [Online]. Available: doi: 10.15167/2421-4248/jpmh2019.60.4.1069

[41] K. Fredriksson et al., "Work environment and neck and shoulder pain: the influence of exposure time. Results from a population based case-control study," *Occupational and Environmental Medicine*, vol. 59, n. 3, pp. 182-188, Mar 2002. Accessed on: July 11, 2020. [Online]. Available: doi:10.1136/oem.59.3.182

[42] A. Soroush et al., "Musculoskeletal Disorders as Common Problems among Iranian Nurses: A Systematic Review and Meta-analysis Study," *International Journal of Preventive Medicine*, vol. 9, n. 27, Mar 2018. Accessed on: July 11, 2020. [Online]. Available: doi: 10.4103/ijpvm.IJPVM_235_16