IJHSE

Iranian Journal of Health, Safety & Environment, Vol.6, No.1, pp.1175-1189

Ergonomic Risk Factors Evaluation of Work-related Musculoskeletal Disorders by PATH and MMH in a Construction Industry

Morteza Cheraghi[1], Meysam Shahrabi-Farahani [1], Seyyed Ali Moussavi-Najarkola*[2]

1) Dept. of Health, Safety & Environment (HSE), Faculty of Environment, University of Tehran, Tehran, Iran.
2) Occupational and Environmental Health Research Center (OEHRC), Iranian Petroleum Industry Health Research Institute (IPIHRI), petroleum Industry Health Organization (PIHO), Tehran, Iran

**Author for Correspondence:* mosavi58@gmail.com

Received: 22 may 2017, Revised: 12 Oct. 2017, Accepted: 21 Feb.2018

ABSTRACT

One of the prevalent injurious factors and disabilities is work-related musculoskeletal disorders (WMSDs). The aim of this study is to evaluate the risks of ergonomic factors inducing musculoskeletal disorders consequent from industrial construction by means of PATH (Posture, Activity, Tools and Handling) risk evaluation and MMH (Manual Material Handling). A cross-sectional study was conducted on 357 construction workers working in 21 different jobs of construction industry in Parand New City, south-west of Tehran, Iran. Nordic musculoskeletal questionnaire (NMQ) was used to determine the prevalence of musculoskeletal disorders. PATH was served to assess different body part postures such as back, feet, hands, also weight of tools and equipment and catching by hand (hand-catch). Most prevalence of musculoskeletal disorders was around back (30.5%) and knee (28.9%), and in opposed side elbow (4.2%) respectively. The results of Nordic musculoskeletal questionnaire (NMQ) showed that there is meaningful relation through pain of neck, wrist, hand, back and knee with workers age and working experience ($P<0.05$). Also through the different jobs under study in PATH method, there is different significant statistical results ($P<0.05$) in the postures of back, feet and hands, tools & Equipment weight and hand-catch (grabbing or taking by hand). The non-neutral postures were observed in some parts such as back (more than 30%), feet (more than 40%) and hands (more than 15%). PATH can be referred as a sensitive and efficient risk evaluation technique in construction industry, as well as MMH is a complementary method for more precision assessment of manual material handling risks in jobs involved in PATH high scores.

Key words: Risk Evaluation, Ergonomic Risk Factors, Musculoskeletal Disorders, PATH, MMH, Construction Industry

LIST of ABBREVIATIONS

WMSDs: Work-related musculoskeletal disorders;
PATH: Posture, Activity, Tools and Handling;
MMH: Manual Material Handling;
NMQ: Nordic Musculoskeletal Questionnaire;
OWAS: Ovako Working Posture Assessment System;
RULA: Rapid Upper Limb Assessment;
REBA: Rapid Entire Body Assessment;
TRAC: Task Reducing and Analysis on Computer.

INTRODUCTION

Multi-factorial interactions of different risk factors cause work-related musculoskeletal disorders (WMSDs) that can be divided into three basic groups including individual, psychosocial, and physical. Among the physical the most common factors are workload, body posture, repetitive and forceful activities, static muscle load, mechanical stress, vibration and cold [1-4].

Building and construction is one of the oldest activities of mankind [5]. Construction workers are exposed to a variety of ergonomic hazards, including improper postures, repetitive motions, heavy lifting, and vibrations [3, 6-9]. With attention to dynamic nature of industrial construction jobs, workers are effected for long time on improper postures with using force on around joints and muscles in different part of their body. Construction workers also experience an elevated risk of musculoskeletal disorders [10-16].

Nowadays there are different available methods to evaluate risks factors related with musculoskeletal disorders and or risk factors in specific job. These methods are observational method, tools methods (or direct method), questioner method which person reported itself and or are other mental-physiological methods [17]. The direct methods are including electromyography and electro-goniometer. These methods are less applicable because of some problems such as worker ambulation, inconvenience in the work, and more cost in buildings works. But on the other hand observational methods such as PATH [18], TRAC [19], REBA [20], RULA [21] and OWAS [22] could be easily more useful [11].

Emphasizing to more outbreak of development of musculoskeletal disorders that resulted from jobs, Prevention of this kind of disorders are especially important in the recent decades. In order to prevent skeletal-Muscular disorders resulted from work and supporting and providing manpower health, ergonomics as effective approach is helping human, measuring human abilities and then organize and regulate the machinery, work and environment according to them. Nowadays, prevent and control of skeletal-muscular disorders from work, with due attention to too much outbreak of that interested many researchers and research institutes. Therefore the target of this study is evaluating ergonomics risk factors which creating musculoskeletal disorders resulted from work in construction jobs with methods of PATH and MMH.

MATERIALS AND METHODS

Data gathering Methods

This study is cross sectional, descriptive- analytical. The social or people under this study are from all jobs of constructing building in Parand New City 20000-unit housing project which is in south west of Tehran Province, done by KAYSON company as Contractor in the year of 1392, the buildings under study been residential ones with concrete structure.

In order to collect data, modulation of 4 tools are used which contain direct observation or walking-talking through (to consider process and working situation also analysis of jobs and responsibilities), interview (for getting information regarding working condition and body postures), standardized Nordic musculoskeletal questionnaire (in order to determine outbreak rates of pain symptoms and signs of Musculoskeletal disorders of upper organs), PATH Risk evaluation (Posture, Activity, Tools and Handling: PATH) and also evaluating of manual handling risks (Manual Material Handling: MMH) (to defining the level of contact of building employees with risks factor which determinate Musculoskeletal disorders resulted from work and providing ergonomics control solutions in order to improve and correct working situation and also decrease outbreak rate of Musculoskeletal disorders with the target of remove, decrease or eliminate and reach to minimize ergonomic risk factors).

Sample size

Statistical sample size was calculated by using Power SSC software considering maximum 0.05 acceptable errors, expected population 0.4, confidence level 99% and total population 1576 persons, number of random samples got to 335 persons. . In the occupations that the number of personnel was less than 20 persons all of the personnel were taken for the study otherwise according to volume of sample selection, total sample size proposed and calculated was 357 persons.

Also with use of following statistic formula it is possible to calculate number of needed sample for study. Through previous followed study which was related to musculoskeletal disorders, different consequences were observed from disorders outbreak percentage level in different part of body that with minimum level of disorders percent Musculoskeletal in neck areas (28.1%) and using ratio formula, the number of needed sample resulted as following:

$$n = \frac{\left(z_{1-\frac{\alpha}{2}}\right)^2 \times P \times (1-P)}{d^2} = \frac{1.96^2 \times 0.281 \times 0.719}{0.0467^2} = 357 \quad (1)$$

where, n is the sample size [23] that is calculated by knowing $z_{1-\frac{\alpha}{2}}$ as the selected critical value of desired confidence level, P as the estimated proportion of an attribute rate in the present studied population, d as the level of precision.

Ergonomic risk factors identification and evaluation

In this paper, three various procedures are utilized for identification and evaluation of ergonomic risk factors as follows:

I) Nordic Musculoskeletal Questionnaire (NMQ)

Kuorinka *et al*. designed and introduced a questionnaire for determining the prevalence of musculoskeletal disorders in occupational health and safety institute of Scandinavian countries that this questionnaire became as the most important occupational surveying questionnaire and so-called as “Nordic Musculoskeletal Questionnaire; NMQ” [24]. In this study, first of all with exploit from NMQ, demographic information of study participants (such as: age, height, weight, work experience and etc.) and also outbreak rate of musculoskeletal disorders of 357 employees of occupations in PARAND

Workshop who minimum having one year experience, were collected.

II) PATH method

PATH (Posture, Activity, Tools and Handling) considered and used by Buchholz *et al*. in 1996 [18] in construction jobs was used in order to evaluate ergonomically risk factors of musculoskeletal disorders. PATH is a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. This method is used in non-repeated jobs for ergonomic evaluation of postures, activities, manual tools and lifting tools. PATH Method is made and established based on using codes in OWAS Method. The paper of getting PATH information has 2 columns. In the first column of this paper the postures of different parts of body (organ, feet and hands), the material weight & Carry able tools and hands activity were registered. In the second column of these paper general activities, specific activities and manual tools used by workers are registered. Body Posture having 5 codes, feet posture 10 codes and hand postures 3 codes and the weights under studying been in 6 different groups [18].

III) Manual materials handling (MMH)

Finally, according to this item that manual handling in construction works is Inevitable, MMH method is used. Meaning that if load weight is over 23kg or 51 Pound, using this method is mandatory. Using MMH method in long term or short term can create side effects such as: rupture, chafe, fracture, heart & blood vessels tensions, musculoskeletal disorders and finally back pain. An equation was developed for the first time in 1981 by National Institute for Occupational Safety and Health (NIOSH) to help safety and health practitioners evaluate lifting demands in the sagittal plane. Then, this equation was developed in 1991 to apply to a larger percentage of lifting tasks. The developed equation (1991 equation) is defined as follows [25]:

$$LI = \frac{L}{RWL} \qquad (2)$$

Where LI is lifting index which defines the physical tension in a specific job, L is load weight or weight of equipment which shall be lifted up and RWL is the Recommended Weight Limit for especial condition to lift the load.

That if lifting tasks with a lifting index is over than one (LI > 1) pose an increased risk for lifting-related low back pain for some fraction of the workforce [25]. The horizontal distance of the hands at the midpoint of hand-grip from midpoint between the ankles, vertical distance of the hands from the floor at the origin of the lift measured vertically from the floor to the mid-point between the hand grasps, vertical travel distance between the origin and the destination of the lift, angle of asymmetry, frequency of lifting, and hand-to-container coupling are defined by a variable in RWL. The horizontal distance of the hands at the midpoint of hand-grip from midpoint between the ankles, vertical distance of the hands from the floor at the origin of the lift measured vertically from the floor to the mid-point between the hand grasps, vertical travel distance between the origin and the destination of the lift, angle of asymmetry, frequency of lifting, and hand-to-container coupling are defined by a variable in RWL. Recommended that if LI is over than one there is hazard probability for lower side of back According to the procedure, in different LI values one the below method must be follow followed:

- In jobs which LI ≤ 1: it is OK and no need to change.
- In jobs which 1 < LI < 3: corrective action is needed to reduce stress.
- In jobs which LI ≥ 3: working system must be changed.

Data analysis

Finally the collected data entered in SPSS version18 software and in descriptive statistic level the indexes such as frequency, percentage, average, variance, minimum and maximum have been used and in inferential statistic level the chi-square test and general linear models have been used for ratings data and P-value less than 0.05 were considered.

RESULTS

In this study, 5000 observations from 357 construction workers in 21 jobs have been done. According to Table 1, average age of studied workers was 33.06±10.40 and their work experience was between 1 to 5 years with the average of 9.08± 9.60 years. According to Table 2, the workers highest frequency were in painting, sentry, ceramic work and driving jobs and respectively includes 71 people (19.9%), 35 people (9.8%), 31 people (8.7%) and 25 people (7%).

As shown in Table 3, the highest incidence of musculoskeletal disorders was in waist area with 109 cases (30.5%) and knee with 103 cases (28.9%) and in return elbow with 15 cases (4.2%) had the lowest incidence.

Table 1: Statistical Indicators demographic characteristics of Parand workshop staff

Factors	Min.	Max.	Variance	Average
Age (years)	18	64	10.40	33.06
Work experience (year)	1	50	9.60	9.08
Height (cm)	155	190	7.02	174.77
Weight (kg)	48	120	11.44	75.08

Table 2: Distribution of Parand workshop staff in terms of jobs

Job	Distribution (%)	Job	Distribution (%)
Painting	71 (19.9%)	Forging	8 (2.2%)
Sentry	35 (9.8%)	Windows installer	11 (3.1%)
Ceramic work	31 (8.7%)	False ceiling	5 (1.4%)
Cooking	13 (3.6%)	Cement work	17 (4.8%)
Safety officer	12 (3.4%)	Executive engineer	16 (4.5%)
Driving	25 (7%)	Electrician	11 (3.1%)
Wall builder	18 (5%)	QC expert	9 (2.5%)
Scaffolding	10 (2.8%)	Piping	9 (2.5%)
Plastering	11 (3.1%)	Technical expert	9 (2.5%)
Administration	21 (5.9%)	Carpentry	8 (2.2%)
Restoration	7 (2%)		

Table 3: Distribution of Parand workshop staff musculo-skeletal disorders in organs nine

Body Parts	Distribution	Percentage
Neck	63	17.6%
Shoulder	63	17.6%
Elbow	15	4.2%
Hand and wrist	57	16%
Back	42	11.8%
Reins	109	30.5%
Hip – thigh	19	5.3%
Knee	103	28.9%
Leg and ankle	49	13.7%

Musculoskeletal disorders assessment showed that:

The most frequency of neck disorders was related to the sentry job with 10 people (2.8%) and driving job with 7 people (1.96%).The most frequency of back, waist, hips and thighs disorders was related to painting job with 27 cases (7.56%) and operate engineer with the frequency of 19 cases (5.32%).The most frequency of large joints (shoulders, elbows, wrist, knees, legs and ankle) disorders was related to painting job with 50 cases (14.01%) and sentry job with 32 cases (8.96%).In the other words, we can say that jobs such as painting, sentry and ceramic work had the higher risk of musculoskeletal disorders incidence that statistically with chi-square test job type has been recognized as an effective risk factor in musculoskeletal disorders incidence ($P<0.05$). Related results are in Table 4.

Results showed that trunk neutral posture in office jobs, operate engineering, safety officer, quality control expert had allocated 90% of the observations. The maximum and minimum percentages of trunk neutral postures respectively related to light bent mode and sharp bent mode. The most frequency of trunk posture in state of light bend mode observed in jobs such as restoration work (32.5%), cement work (28%) and plastering (25.5%) and in return the most frequency of trunk posture in state of sharp bend mode observed in jobs such as ceramic work (46.6%) and painting (31%) also painting job's trunk posture in state of bending and twisting compared to other jobs was more than 8% (Table 5).

Some jobs of construction industry involved in ergonomic risk factor assessment process can be seen in Fig. 1.

Table 4: prevalence of musculoskeletal disorders in various work groups in construction jobs

Job type	Various body organs		
	Neck	Back, reins, hip and thigh	Large joints
Painting	6(1.67%)	27(7.56%)	50(14.01%)
Sentry	10(2.80%)	17(4.76%)	32(8.96%)
Ceramic work	4(1.12%)	18(5.04%)	25(7.00%)
Cooking	0(0%)	2(0.56%)	3(0.84%)
Safety officer	3(0.84%)	8(2.24%)	16(4.48%)
Driving	7(1.96%)	11(3.08%)	17(4.76%)
Wall builder	4(1.12%)	11(3.08%)	14(3.92%)
Scaffolding	3(0.84%)	6(1.68%)	11(3.08%)
Plastering	0(0%)	2(0.56%)	0(0%)
Administration	6(1.67%)	10(2.80%)	17(4.76%)
Restoration	0(0%)	4(1.12%)	6(1.68%)
Forging	3(0.84%)	5(1.40%)	13(3.64%)
Windows installer	2(0.56%)	5(1.40%)	7(1.96%)
False ceiling	0(0%)	0(0%)	1(0.28%)
Cement work	2(0.56%)	5(1.40%)	3(0.84%)
Executive engineer	5(1.40%)	19(5.32%)	28(7.84%)
Electrician	1(0.28%)	1(0.28%)	5(1.40%)
QC expert	3(0.84%)	10(2.80%)	12(3.36%)
Piping	1(0.28%)	3(0.84%)	14(3.92%)
Technical expert	2(0.56%)	5(1.40%)	2(0.56%)
Carpentry	1(0.28%)	1(0.28%)	11(3.08%)

Chi-squared statistic = 53.81 and significance value =0.044, large joints include shoulders, elbows, wrist, knees, leg and ankle

Table 5: distribution of observations based on trunk postures with PATH method in studied construction jobs

Jobs	Trunk posture				
	Neutral	Light bending	Sharp bending	Bending to side or twisting	Bending and twisting
Painting	332(47.4%)	100(14.3%)	217(31%)	32(4.6%)	19(2.7%)
Ceramic work	132(26.4%)	112(22.4%)	233(46.6%)	16(3.2%)	6(1.2%)
Sentry	155(77.5%)	31(15.5%)	9(4.5%)	1(0.5%)	4(2%)
Driving	188(94%)	0(0%)	0(0%)	12(6%)	0(0%)
Safety officer	191(95.5%)	4(2%)	5(2.5%)	0(0%)	0(0%)
Executive engineer	185(92.5%)	7(3.5%)	8(4%)	0(0%)	0(0%)
Forging	127(63.5%)	29(14.5%)	29(14.5%)	7(3.5%)	8(4%)
False ceiling	134(67%)	32(16%)	32(16%)	2(1%)	0(0%)
Restoration	86(43%)	65(32.5%)	44(22%)	2(1%)	3(1.5%)
Administration	191(95.5%)	5(2.5%)	4(2%)	0(0%)	0(0%)
Plastering	114(57%)	51(25.5%)	30(15%)	4(2%)	1(0.5%)
Scaffolding	112(56%)	31(15.5%)	47(23.5%)	4(2%)	6(3%)
Cement work	110(55%)	56(28%)	14(7%)	16(8%)	4(2%)
Wall builder	142(71%)	36(18%)	14(7%)	8(4%)	0(0%)
Technical expert	100(100%)	0(0%)	0(%)	0(0%)	0(0%)
QC expert	187(93.5%)	6(3%)	7(3.5%)	0(0%)	0(0%)
Piping	219(73%)	36(12%)	33(11%)	8(2.7%)	4(1.3%)
Electrician	202(67.3%)	44(14.7%)	24(8%)	26(8.7%)	4(1.3%)
Carpentry	113(56.5%)	48(24%)	30(15%)	2(1%)	7(3.5%)
Windows installer	81(81%)	11(11%)	8(8%)	0(0%)	0(0%)
Cooking	178(89%)	13(6.5%)	7(3.5%)	0(0%)	2(1%)

Vertical linear models test for ranking data P<0.001
Neutral: bending ahead or to side less than 20 degree or twist less than 20 degree
Light bending ahead: bending ahead between 20 to 45 degree
Sharp bending ahead: bending ahead more than 45 degree
Bending to side or twisting: bending ahead less than 20 degree with bending to side more than 20 degree or bending ahead less than 20 degree with twist more than 20 degree
Bending and twisting: bending ahead and twisting more than 20 degree (Buchholz et al., 1996)

According to Table 6, hands position between different construction jobs statistically showed significant difference ($P<0.05$), so that hands positions in light construction jobs such as sentry, driver, safety officer, operate engineer, administrative affairs and also cement work was in neutral position (two hands below shoulder height) more than 90% and in return hands position in jobs such as scaffolding, blacksmith and painting were mostly in the position of one hand over shoulder height. Totally it could be found that hands in heavy construction jobs such as false ceiling, scaffolding … are in more inappropriate position comparing to other construction jobs.

As shown in Table 7, legs position in different construction jobs had statistically significant difference ($P<0.001$). The most neutral posture percentage observed in windows installer job (83%) and plaster work and cement work had the posture with one or two curved feet in more than 20% of cases, also crawl and sitting on feet on the ground postures were the less between construction jobs postures.

The weight of used tools and objects as a weight group in kilograms in different construction jobs statistically had significant difference ($P<0.001$). On the other words in studied jobs tools and objects with different weight will be used, so that in jobs such as administrative and affaires, driving and sentry significant weight will not carry. In return the most weight carried observed in jobs such as scaffolding, ceramic work, cement work, masonry, piping, and chef …, related results are shown in Table 8.

Hand grip as the final assessment with PATH method showed that scaffolding, plastering and cement work had the most observed frequency of strong hand grip and in return light jobs such as administration, experts and engineers had the less hand grip ($P<0.05$), related results are shown in Table 9.

Finally according to the results presented in table 10, scaffolding and carpentry had the most load profile respectively with 3.13 and 2.08 values and in return sentry had the less load profile with value of 0.01.

In Table 11 each job with its coding number, frequency, duty descriptions and descriptions coding number are presented.

Table 6: distribution of observations based on hand postures with PATH method in studied construction jobs

Jobs	Hand Posture		
	Two hands under shoulder height	**One hand over shoulder height**	**Two hands over shoulder height**
Painting	482(68.9%)	130(18.6%)	88(12.6%)
Ceramic work	500(100%)	0(0%)	0(0%)
Sentry	190(95%)	5(2.5%)	5(2.5%)
Driving	188(94%)	12(6%)	0(0%)
Safety officer	190(95%)	5(2.5%)	5(2.5%)
Executive engineer	193(96.5%)	2(1%)	5(2.5%)
Forging	111(55.5%)	65(32.5%)	24(12%)
False ceiling	73(36.5%)	17(8.5%)	110(55%)
Restoration	163(81.5%)	30(15%)	7(3.5%)
Administration	189(94.5%)	8(4%)	3(1.5%)
Plastering	165(82.5%)	25(12.5%)	10(5%)
Scaffolding	75(37.5%)	51(25.5%)	74(37%)
Cement work	187(93.5%)	9(4.5%)	4(2%)
Wall builder	163(81.5%)	25(12.5%)	12(6%)
Technical expert	100(100%)	0(0%)	0(0%)
QC expert	194(97%)	2(1%)	4(2%)
Piping	213(71%)	22(7.3%)	65(21.7%)
Electrician	274(91.3%)	21(7%)	5(1.7%)
Carpentry	183(91.5%)	11(5.5%)	6(3%)
Windows installer	43(43%)	37(37%)	20(20%)
Cooking	200(100%)	0(0%)	0(0%)

Vertical linear models test for ranking data P<0.05

Table 7: distribution of observations based on leg postures with PATH method in studied construction jobs

Jobs	Leg postures							
	Neutral	**One leg in the air**	**One or two curved leg**	**Squat**	**Walk**	**Kneel**	**Sit on chair**	**Sit on ground**	**Crawl**
Painting	548(78.2%)	4(0.6%)	59(8.4%)	29(4.1%)	58(8.3%)	0(0%)	0(0%)	2(0.3%)	0(0%)
Ceramic work	256(51.2%)	30(6%)	35(7%)	107(21.4%)	25(5%)	32(6.4%)	0(0%)	1(0.2%)	14(2.8%)
Sentry	103(51.5%)	8(4%)	6(3%)	10(5%)	60(30%)	0(0%)	13(6.5%)	0(0%)	0(0%)
Driving	6(3%)	0(0%)	0(0%)	0(0%)	4(2%)	0(0%)	190(95%)	0(0%)	0(0%)
Safety officer	30(15%)	0(0%)	3(1.5%)	2(1%)	65(32.5%)	0(0%)	100(50%)	0(0%)	0(0%)
Executive engineer	28(14%)	0(0%)	2(1%)	6(3%)	64(32%)	0(0%)	100(50%)	0(0%)	0(0%)
Forging	136(68%)	12(6%)	12(6%)	28(14%)	8(4%)	4(2%)	0(0%)	0(0%)	0(0%)
False ceiling	146(73%)	0(0%)	8(4%)	37(18.5%)	4(2%)	5(2.5%)	0(0%)	0(0%)	0(0%)
Restoration	124(62%)	3(1.5%)	24(12%)	29(19.5%)	10(5%)	0(0%)	0(0%)	0(0%)	0(0%)
Administration	12(6%)	0(0%)	8(4%)	5(2.5%)	5(2.5%)	0(0%)	170(85%)	0(0%)	0(0%)
Plastering	113(56.5%)	7(3.5%)	40(20%)	9(4.5%)	29(14.5%)	0(0%)	0(0%)	2(1%)	0(0%)
Scaffolding	97(48.5%)	9(4.5%)	23(11.5%)	20(10%)	46(23%)	5(2.5%)	0(0%)	0(0%)	0(0%)
Cement work	113(56.5%)	2(1%)	41(20.5%)	10(5%)	28(14%)	0(0%)	0(0%)	6(3%)	0(0%)
Wall builder	112(56%)	3(1.5%)	23(16.5%)	17(8.5%)	22(11%)	5(2.5%)	0(0%)	8(4%)	0(0%)
Technical expert	3(3%)	0(0%)	0(0%)	0(0%)	7(7%)	0(0%)	90(90%)	0(0%)	0(0%)
QC expert	30(15%)	0(0%)	2(1%)	5(2.5%)	63(31.5%)	0(0%)	100(50%)	0(0%)	0(0%)
Piping	232(77.3%)	0(0%)	14(4.7%)	20(3.3%)	25(8.3%)	6(2%)	0(0%)	3(1%)	0(0%)
Electrician	181(60.3%)	3(1%)	32(7.3%)	38(12.7%)	40(13.3%)	5(1.7%)	0(0%)	11(3.7%)	0(0%)
Carpentry	130(65%)	0(0%)	29(14.5%)	14(7%)	12(6%)	5(2.5%)	0(0%)	0(0%)	0(0%)
Windows installer	83(83%)	0(0%)	8(8%)	3(3%)	6(6%)	0(0%)	0(0%)	0(0%)	0(0%)
Cooking	148(74%)	0(0%)	2(1%)	0(0%)	20(10%)	0(0%)	30(15%)	0(0%)	0(0%)

Vertical linear models test for ranking data P<0.001

Table 8: distribution of observations based on carried weight (kg) with PATH method in studied construction jobs

Jobs	Wight of carried tools and objects (kilograms)					
	Carry no weight	Less than 2.5	2.5-5	5-10	10-15	More than 15
Painting	150(21.4%)	497(71%)	0(0%)	6(0.9%)	47(0.7%)	0(0%)
Ceramic work	130(26%)	147(29.4%)	149(29.8%)	41(8.2%)	0(0%)	33(6.6%)
Sentry	200(100%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)
Driving	200(100%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)
Safety officer	123(61.6%)	77(38.5%)	0(0%)	0(0%)	0(0%)	0(0%)
Executive engineer	170(85%)	30(15%)	0(0%)	0(0%)	0(0%)	0(0%)
Forging	54(27%)	103(51.5%)	43(21.5%)	0(0%)	0(0%)	0(0%)
False ceiling	81(40.5%)	79(39.5%)	23(11.5%)	17(8.5%)	0(0%)	0(0%)
Restoration	66(33%)	112(56%)	0(0%)	0(0%)	22(11%)	0(0%)
Administration	167(83.5%)	33(16.5%)	0(0%)	0(0%)	0(0%)	0(0%)
Plastering	56(28%)	115(57.5%)	16(8%)	13(6.5%)	0(0%)	0(0%)
Scaffolding	17(8.5%)	63(31.5%)	68(34%)	0(0%)	0(0%)	52(26%)
Cement work	21(10.5%)	99(49.5%)	57(28.5%)	5(2.5%)	0(0%)	18(9%)
Wall builder	82(41%)	38(19%)	57(28.5%)	5(2.5%)	0(0%)	18(9%)
Technical expert	100(100%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)
QC expert	103(51.5%)	97(48.5%)	0(0%)	0(0%)	0(0%)	0(0%)
Piping	75(25%)	67(22.3%)	32(10.7%)	126(42%)	0(0%)	0(0%)
Electrician	135(45%)	146(48.7%)	15(5%)	4(1.3%)	0(0%)	0(0%)
Carpentry	112(56%)	55(27.5%)	33(16.5%)	0(0%)	0(0%)	0(0%)
Windows installer	15(15%)	15(15%)	35(35%)	35(35%)	0(0%)	0(0%)
Cooking	41(20.5%)	79(39.5%)	28(14%)	35(17.5%)	7(3.5%)	10(5%)

Vertical linear models test for ranking data $P<0.0001$

Table 9: distribution of observations based on hand grip with PATH method in studied construction jobs

jobs	Hand grip			
	No. of strong	No. of weak	No. of empty	other
Painting	424(60.6%)	174(24.9%)	95(13.8%)	7(1%)
Ceramic work	394(56.3%)	61(8.7%)	43(8.6%)	5(1%)
Sentry	0(0%)	0(0%)	200(100%)	0(0%)
Driving	178(89%)	12(6%)	0(0%)	10(5%)
Safety officer	10(5%)	25(12.5%)	100(50%)	65(32.5%)
Executive engineer	10(5%)	25(12.5%)	100(50%)	65(32.5%)
Forging	80(40%)	72(36%)	41(20.5%)	7(3.5%)
False ceiling	8(4%)	170(85%)	22(11%)	0(0%)
Restoration	22(11%)	135(67.5%)	43(21.5%)	0(0%)
Administration	90(45%)	3(1.5%)	25(12.5%)	82(41%)
Plastering	147(73.5%)	26(13%)	21(10.5%)	6(3%)
Scaffolding	184(92%)	0(0%)	16(8%)	0(0%)
Cement work	173(86.5%)	0(0%)	21(10.5%)	6(3%)
Wall builder	100(50%)	52(26%)	42(21%)	6(3%)
Technical expert	10(10%)	0(0%)	8(8%)	82(82%)
QC expert	88(44%)	38(19%)	10(5%)	65(32.5%)
Piping	158(52.7%)	82(27.3%)	60(20%)	0(0%)
Electrician	185(61.7%)	60(20%)	36(12%)	19(6.3%)
Carpentry	120(60%)	46(23%)	27(13.5%)	7(3.5%)
Windows installer	78(78%)	0(0%)	8(8%)	14(14%)
Cooking	33(16.5%)	92(46%)	72(36%)	3(1.5%)

Vertical linear models test for ranking data $P<0.05$

Table 10: distribution of lifting load combinations profile in studied construction jobs

Jobs	Lifting load profile
Painting	0.4
Ceramic work	1.1
Sentry	0.01
Driving	0.13
Safety officer	0.02
Executive engineer	0.1
Forging	0.1
False ceiling	0.6
Restoration	0.2
Administration	0.1

Jobs	Lifting load profile
Plastering	0.5
Scaffolding	3.13
Cement work	0.5
Wall builder	0.4
Technical expert	0.1
QC expert	0.1
Piping	1.2
Electrician	0.2
Carpentry	2.08
Windows installer	1.4
Cooking	0.7

Table 11: jobs and their duties in PARAND workshop

No.	Job	Job code	Frequency	Duties	Duty code	Activities
1	Painting	PA	71	1.Making primer	PA1	- Opening of the primer bag by hand - Pouring primer by hand into the bucket - Pouring some water into another bucket - Add water to primer - Mixing water and primer with mixer
				2.Priming	PA2	- Do polish - Cleaning surfaces with spatula - Pick up the Primers with spatula - Knead the Primers to the wall with a spatula - Smooth the Primers with spatula - Climb the stool - Coming down from the stool
				3.Making color	PA3	- Open the Paint Bucket - Add paint thinner - Mixing paint thinner and paint with mixer
				4.Paint Primer	PA4	- Pick up a bucket of paint - Pour some paint into the container - Paint rollers dipping into the container - Lifting rollers - Drag rollers to the wall
				5.Paint wall	PA5	- Pick up a bucket of paint - Pour some paint into the container - Paint rollers dipping into the container - Lifting rollers - Drag rollers to the wall
				6.Making Knytex	PA6	- Opening of paint bucket - Opening of perlite bags - Pouring perlite into the bin by hand - Pouring some water into another bucket - Add water to the paint and perlite - Mixing them with mixer
				7.Painting ceilling	PA7	- Pick up knytex bucket - Pouring knytex into paint gun - Pressing the Paint gun lever - Painting
2	Ceramic work	T	31	1.Making mortar	T1	- Opening of the cement bags - Pick up the cement with a shovel - Pouring cement on the sand -Mixing cement with sand - Fill the bucket of water - Water pouring cement and sand - Mixing mortar with a shovel - Pick up the mortar with a shovel - Pouring mortar into wheelbarrows - Carrying wheelbarrows to the desired location
				2.Ceramic cutting	T2	- Lifting grinding - On / off grinding - Ceramics cutting
				3.Ceramic Installation	T3	- Pour the mortar on the surface - Spreading mortar with trowel For infrastructure - Leveling with cotton twine - Ceramic paste - Ceramic hit with plastic mallet - Aligning ceramics
				4.Making slurry	T4	- Opening of plaster and cement bags - Pour water into the container - Add plaster and white cement to water - Mixing plaster and cement with water by mixer - Carry slurry made to the desired location
				Pouring slurry	T5	- Pick up the slurry container - Pouring slurry on the joints between the tiles - Ceramic Cleaning with napkins

3	Sentry	G	35	1.Traffic control	G1	- Stop the car when leaving - Vehicle inspection - Inspection personnel
				2.Equipment Control	G2	- Patrolling the area - Patrolling the floors - Control of the means available in the building
4	Driving	D	25	1.Movement of persons	D1	- Picking up people - Drive the vehicle to the desired location - Getting off people
				2.Materials Handling	D2	- Load materials - Transport materials - Unloading of materials at the desired location
5	Safety officer	SO	12	1.Monitor the work	SO1	- Presence in work areas - Control Equipment and Tools - Ensure the work safely - On-site training to workers
				2.Repoting	SO2	- Writing by hand - Using the computer and typing reports
6	Executive engineer	EE	16	1.Monitor the work	EE1	- Presence in work areas - Providing equipment and materials - Run technical office agendas
				2.Repoting	EE2	- Writing by hand - Using the computer and typing reports
7	Forging	B	8	1.Structure building	B1	- Providing iron - Measured by the meter - Metal cutting with saw - Iron cutting with grinding - Welding - Polishing - Painting
				2.Structure Installation	B2	- Marking - Installation of corners with Hilti - Put the iron structure in their position - Alignment - Pre-welding - Ensure the alignment - Welding
8	False ceiling	K	5	1.Installation of support	K1	- Measuring with meter - Cutting support to appropriate size - Climb the stool - Screw up part of the support - Aligning Support - Screw the rest of the support - Coming down from the stool
				2.Panel Placement	K2	- Measuring with meter - Cutting the panels to size - Replacing panel on support
9	Restoration	R	7	1.Making mastic	R1	- Open cement bag - Open cans of concrete adhesive - Open Primers bags - Open Limestone bags - Pouring cement and limestone on Primers powder - Add water - Mixing them with a spatula - Stirring the mortar made with spatula
				2.Mastic Press	R2	- Dipping spatula into mortar bucket - Pick up the spatula - Drag spatula on the wall - Climb the stool - Coming down from the stool
10	Administration	CLE	21	1.Work with Computer	CLE1	- Typing Letter and Report - Record personnel data in computer
				2.Work with Hands	CLE2	- Put the documents in the binder - Documentation

						- Answering the Phone
11	Plastering	PLA	11	1.Making plaster	PLA1	- Fill the bucket of water - Pour water into the container - Open bag of plaster - Pick up the plaster with shovel - Add plaster to water - Mixing it by hand
				2.Plastering	PLA2	- Pick up the plaster with a trowel - Rubbing plaster to the wall with a trowel - Smooth the plaster with a trowel - Smooth plaster with aluminum tube - Cleaning rod with spatula - Cleaning tube with spatula
12	Scaffolding	S	10	1.Scaffolding assembly	S1	- Stand erect a scaffold basis - Installation of bracing and cross - Lifting platform - Put the platform on the basis - Basic installation on the upper floor - installation of cross and bracings - Lifting platform - Handoff platform to upper floor people - Put the platform on the basis - Install inhibits
				2.Scaffold Dismantling	S2	- Open bracing and cross - Separating the platform from the base - Separate base - Lifting platforms and scaffolding accessories separately - Giving them to people in the lower floors - Open inhibitory
13	Cement work	CEM	17	1.Making Mortar	CEM1	- Opening of cement bags - Pick up the cement with a shovel - Pouring cement on the sand - Mixing cement with sand - Fill the bucket of water - Water pouring cement and sand - Mixing mortar with a shovel - Pick up the mortar with a shovel - Pouring mortar into wheelbarrows - Carrying wheelbarrows to the desired location
				2.Cement working	CEM2	- Pick up cement with the trowel - Cement splashing to the wall with a trowel - Smooth the cement with a trowel - Smooth with aluminum tube
14	Wall builder	M	18	1.Material Preparation	M1	- Opening of cement bags - Pick up cement with the trowel - Pouring cement on the sand - Mixing cement with sand - Fill the bucket of water - Water pouring cement and sand - Mixing mortar with a shovel - Pick up the mortar with a shovel - Pouring mortar into wheelbarrows - Carrying wheelbarrows to the desired location - Breaking bricks with ax
				2.Brick picking	M2	-Pick up the mortar with a trowel -Pour the mortar on the ground - Brick pick - Alignment
15	Technical expert	TE	9	1.Work with Computer	TE1	-Preparing agendas for carrying out activities -Typing reports and letters
16	QC expert	QCE	9	1.Monitoring the work	QCE1	- Presence in work areas -To ensure the best possible quality of work
				2.Reporting	QCE2	- Writing by hand - Using the computer and typing reports
17	Piping	PLU	9	1.Destruction	PLU1	- Chipping pneumatic Pick up - On / off chipping

						- Destruction of a small section of the floor
				2.Support Installation	PLU2	- Measuring with Meter - Cutting support to appropriate size - Climb the stool -Clinch part of the support -Aligning Support -Clinch the rest of the support -Coming down from the stool
				3.Pipe installation	PLU3	-Pipe cutting -Assembly of pipes and elbows -Piping installation - Climb the stool -Coming down from the stool
18	Electrician	E	11	1.Carving	E1	-On / off grinding -Cutting brick wall -Removing redundancies with mallet and chisel
				2.Tubing	E2	-Holes the wall with a pen -Cutting Tube -Connecting tube with glue -Tube Connecting elbow -Put the tube in place -Pulling Tubes
				3.Wiring	E3	-Enter a spring in the tube -Pulling Springs -Wire Stripping -Close the wire to spring -Open the wire from spring -Wire Cutting
19	Carpentry	CAR	8	1.Door Preparation	CAR1	- Measuring with Meter -Removing additional parts of the door with the chipper -Unload lock place with the cavern -Lock installation -Bringing the hinges on the door
				2.Door Installation	CAR2	-Pick up the Door -Replacing door hinges -Adjusting the door
20	Windows installer	DM	11	1.Window Installation	DM1	-Putting in place the required window -Pick up drills -Holes the wall -Pick up cordless screwdriver -Screw the window to the wall
21	Cooking	CAT	13	1.Preparation of raw materials	CAT1	-Wash raw materials -Clean rice and beans -Peel off the vegetables -chopping
				2. Cooking	CAT2	-Cook raw materials -Frying raw materials -Mixing the desired ingredients together -Cooking

Fig. 1: Some jobs of construction industry involved in ergonomic risk factor assessment process.

DISCUSSION

In this study according to average age and work experience of construction workers it can be said that the studied sample was relatively young and at the same time experienced then their comments about work situation and the prevalence of musculoskeletal disorders assessing can be trustable and valid. Study showed that the most prevalence of musculoskeletal disorders was in waist area, knee, neck and shoulder and generally the most prevalence was in large joints with 80.4% and after that back and buttocks with 47.6% which is consistent with the findings of other studies [26, 27]. Increasingly, the prevalence of musculoskeletal had significant difference in different jobs that this difference can result from jobs requirements while doing and work arrangement [17, 18]. In this regard some studies [27] showed that the prevalence of musculoskeletal disorders in the upper extremities and posture pressure of various tasks had meaningful relation. In many studies interventions for improving disorders in different jobs under different situations have been done [28-30]. High prevalence of musculoskeletal disorders in these mentioned body regions can be related to the repeated activities, highly force exertions, long-term static works, highly muscle activity and mobility, excessive pressure exertion on low back, insufficient rest intervals among work intervals for muscular recovery after muscle contractions, vertical pressure on L4/L5 and L5/S1 lumbar vertebrates, personal genetic susceptibility to WMSDs, inadequate nutrition program or regime, awkward postures during construction works, incorrect design of construction equipments and hand tools, repetitive tasks, and other additional and effective factors (sharp-edged objects, precision work, , etc.), environmental parameters such as exposure to cold, heat, vibration including hand-arm vibration (HAV) or whole body (WBV) vibration, personal or social psychological problems, etc.[30].

In addition to job type, other factors such as the worker's age and work experience had an important role in prevalence of musculoskeletal disorders so it is necessary that in studies in which the main goal is to create intervention and control or improvement the symptoms of MSDs disorders, these factors as disturbance variables must become under control of the researcher.

The results of trunk, legs and hands postures assessment with PATH method in different construction jobs showed that job type was different in the different postures so it could be said that each job with the proportion of working conditions and operational requirements faces a series of undesirable postures. In the trunk and hand postures neutral position was found more than 90% of cases in light construction jobs such as administration, engineering and experts and in return in the jobs such as cement work, plastering, restoration and painting trunk posture had the most undesirable situation in the case of bending or bending and twisting. Heavy construction jobs such as false celling, scaffolding, etc. had inappropriate hand situation comparing to other jobs.

Regarding the leg posture, windows installer job with 83% had the most neutral posture percentage and in return plastering and cement work jobs had one or two curved leg posture in more than 20% of cases, and then are can be said that undesirable posture can be a significant factor in prevalence of musculoskeletal disorders. The main reason of undesirable and fixed postures can be non-adjustable work stations [31]. Within most studies done in different jobs [31-37], the effect of work posture was checked and its effect on musculoskeletal disorders was confirmed. Also in line with present study, Buchholz *et al.* in 1996 [18] presented PATH method to ergonomic assessing of hard works and non-routine works. Results showed that non-neutral trunk postures are different in various jobs so the workers spend lots of their time with non-neutral trunk postures. Buchholz *et al.* (2003) in another study showed that leg, trunk and hand postures statistically had significant difference between various duties of reinforcement job [17].

Most of construction jobs need frequent kneeling, squatting or bending because they are near ground surface. Kneeling on hard surfaces will push large direct pressure on knee, squatting will push stress on tendons, ligaments and cartilage in joints. Working in both mentioned situations for long period of time will cause knee disorders specially osteoarthritis. In construction jobs brick pickers mostly bend to pick bricks, blocks and mortar and put them on wall. This will cause body lots of twisting and bending and also more situations like this. Then certainly it can be considered significant relation between job type and work posture and consequently undesirable posture are known as a significant factor in prevalence of musculoskeletal disorders.

Wight of tools and objects and also hand grip in different construction jobs had significant deference so light construction jobs such as experts, administrative affairs, sentry and drivers will not carry significant weight and in return scaffolding, cement work, ceramic work, plastering … will carry the most weighted tools and in more than 50% of cases had strong hand grip.

According to studies done, work groups that in their work there is static contraction, long time static loads and undesirable postures and will involve neck and shoulder muscles, are extremely at risk of neck and shoulder musculoskeletal disorders [38]. In line with this study, a study showed that in jobs such as painting and false ceiling that a part of work is done over head height, the combination of hand non-neutral postures and weight of tools will cause more load to musculoskeletal system [39]. So using low weight tools as much as possible is advised in these situations. Some studies also showed that manual material handling in group will push less pressure on workers than when it is done individually [40].

Finally results from MMH method showed that according to the load profile index most manual material handling was in scaffolding job (3.13), this can be because of scaffold platforms with over 23 kilograms weight. On the other words due to the variables defined, scaffolding load profile was more than 3 so the change in work system is needed, carpentry load profile was 2.08 and corrective actions are needed to reduce stress. Therefore it is recommended to use lifting equipment such as trap handler in scaffolding job to transfer scaffold platforms to upper floors.

Therefore the lack of health and safety rules and guidelines for jobs and also government's inability to cover different jobs from the perspective of occupational health [34] can enumerate as the reasons of lack of attention to occupational health and safety so, it is recommended to create and implement a training program in connection with musculoskeletal disorders and the ways to prevent it for all jobs.

Some examinations such as optometry and different musculoskeletal diagnosis tests, including standard clinical provocation tests (Finkelstein's test, Phalen's test and Tinel's test), joint stress test, Allen test, Mills test, Impingement test, Speed's test, Yergason test, biceps resistance test, Roos test, Adsons test, elevated arm stress test, foramina test, and the like can help to reach this preventive purpose [30].

CONCLUSION

PATH can be referred as a sensitive and efficient risk evaluation technique in construction industry, as well as MMH is a complementary method for more precision assessment of manual material handling risks in jobs involved in PATH high scores.

ETHICAL ISSUES

Ethical issues including plagiarism have been taken into account by the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTION

All authors work equally.

FUNDING/ SUPPORTS

This study was done by authors' supports.

ACKNOWLEDGEMENT

The authors are grateful to all employees and employers of construction industry for their sincerely cooperation in any steps of this project.

REFERENCES

[1] Kee D, Karwowski W. A Comparison of Three Observational Techniques for Assessing Postural Loads in Industry. International Journal of Occupational Safety and Ergonomics. 2007;13(1):3-14. doi: 10.1080/10803548.2007.11076704.

[2] Kumar S. Theories of musculoskeletal injury causation. Ergonomics. 2001;44(1):17-47. doi: 10.1080/00140130120716.

[3] Lee T-H, Han C-S. Analysis of Working Postures at a Construction Site Using the OWAS Method. International Journal of Occupational Safety and Ergonomics. 2013;19(2):245-50. doi: 10.1080/10803548.2013.11076983.

[4] Paquet VL, Punnett L, Buchholz B. Validity of fixed-interval observations for postural assessment in construction work. Applied Ergonomics. 2001;32(3):215-24. doi: https://doi.org/10.1016/S0003-6870(01)00002-3.

[5] Forde MS, Punnett L, Wegman DH. Prevalence of Musculoskeletal Disorders in Union Ironworkers. Journal of Occupational and Environmental Hygiene. 2005;2(4):203-12. doi: 10.1080/15459620590929635.

[6] Kroemer AD, Kroemer KHE. Office Ergonomics: Ease and Efficiency at Work, Second Edition: CRC Press; 2016.
[7] Schneider SP. Musculoskeletal Injuries in Construction: A Review of the Literature. Applied Occupational and Environmental Hygiene. 2001;16(11):1056-64. doi: 10.1080/104732201753214161.
[8] Tak S, Buchholz B, Punnett L, Moir S, Paquet V, Fulmer S, *et al.* Physical ergonomic hazards in highway tunnel construction: Overview from the Construction Occupational Health Program. Applied Ergonomics. 2011;42(5):665-71. doi: https://doi.org/10.1016/j.apergo.2010.10.001.
[9] Violante F, Kilbom A, Armstrong TJ. Occupational Ergonomics: Work Related Musculoskeletal Disorders of the Upper Limb and Back: Taylor & Francis; 2000.
[10] Dalkilinç M, Bumin G, Kayihan H. The effects of ergonomic training and preventive physiotherapy in musculo-skeletal pain. The Pain Clinic. 2002;14(1):75-79. doi: 10.1163/156856902760189214.
[11] Forde MS, Buchholz B. Task content and physical ergonomic risk factors in construction ironwork. International Journal of Industrial Ergonomics. 2004;34(4):319-33. doi: https://doi.org/10.1016/j.ergon.2004.04.011.
[12] Goldsheyder D, Nordin M, Weiner SS, Hiebert R. Musculoskeletal symptom survey among mason tenders. American Journal of Industrial Medicine. 2002;42(5):384-96. doi: 10.1002/ajim.10135.
[13] Holmström E, Engholm G. Musculoskeletal disorders in relation to age and occupation in Swedish construction workers. American Journal of Industrial Medicine. 2003;44(4):377-84. doi: 10.1002/ajim.10281.
[14] Latza U, Karmaus W, Stürmer T, Steiner M, Neth A, Rehder U. Cohort study of occupational risk factors of low back pain in construction workers. Occupational and Environmental Medicine. 2000;57(1):28-34.
[15] O'Reilly SC, Muir KR, Doherty M. Occupation and knee pain: a community study. Osteoarthritis and Cartilage. 2000;8(2):78-81. doi: https://doi.org/10.1053/joca.1999.0274.
[16] Sandmark H, xe, xe, ne, Hogstedt C, Ving, *et al.* Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scandinavian Journal of Work, Environment & Health. 2000;26(1):20-25.
[17] Buchholz B, Paquet V, Wellman H, Forde M. Quantification of Ergonomic Hazards for Ironworkers Performing Concrete Reinforcement Tasks During Heavy Highway Construction. AIHA Journal. 2003;64(2):243-50. doi: 10.1080/15428110308984814.
[18] Buchholz B, Paquet V, Punnett L, Lee D, Moir S. PATH: A work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Applied Ergonomics. 1996;27(3):177-87. doi: https://doi.org/10.1016/0003-6870(95)00078-X.
[19] van der Beek AJ, van Gaalen LC, Frings-Dresen MHW. Working postures and activities of lorry drivers: a reliability study of on-site observation and recording on a pocket computer. Applied Ergonomics. 1992;23(5):331-36. doi: https://doi.org/10.1016/0003-6870(92)90294-6.
[20] Hignett S, McAtamney L. Rapid Entire Body Assessment (REBA). Applied Ergonomics. 2000;31(2):201-05. doi: https://doi.org/10.1016/S0003-6870(99)00039-3.
[21] McAtamney L, Nigel Corlett E. RULA: a survey method for the investigation of work-related upper limb disorders. Applied Ergonomics. 1993;24(2):91-9. doi: https://doi.org/10.1016/0003-6870(93)90080-S.
[22] Karhu O, Kansi P, Kuorinka I. Correcting working postures in industry: A practical method for analysis. Applied Ergonomics. 1977;8(4):199-201. doi: https://doi.org/10.1016/0003-6870(77)90164-8.
[23] Cochran WG. Sampling Techniques, 3Rd Edition: Wiley India Pvt. Limited; 2007.
[24] Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, *et al.* Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics. 1987;18(3):233-7. doi: https://doi.org/10.1016/0003-6870(87)90010-X.
[25] Waters TR, Putz-Anderson V, Garg A, Fine LJ. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics. 1993;36(7):749-76. doi: 10.1080/00140139308967940.
[26] Chee H-L, Rampal KG, Chandrasakaran A. Ergonomic Risk Factors of Work Processes in the Semiconductor Industry in Peninsular Malaysia. INDUSTRIAL HEALTH. 2004;42(3):373-81. doi: 10.2486/indhealth.42.373.
[27] Hartmann B, Fleischer AG. Physical load exposure at construction sites. Scandinavian Journal of Work, Environment & Health. 2005;31:88-95.
[28] Branson B, Bray K, Gadbury-Amyot C, Holt L, Keselyak N, Mitchell T, *et al.* Effect of magnification lenses on student operator posture. Journal of dental education. 2004;68(3):384-89.
[29] Maillet JP, Millar AM, Burke JM, Maillet MA, Maillet WA, Neish NR. Effect of magnification loupes on dental hygiene student posture. Journal of dental education. 2008;72(1):33-44.

[30] Osuna T. Magnification use in dental hygiene. Access Magazine ; supplemental issue, 2003:1-8.

[31] Moussavi-Najarkola SA, Mirzaei R. Assessment of musculoskeletal loads of electric factory workers by rapid entire body assessment. Health Scope. 2012;1(2):71-79.

[32] Aarås A, Horgen G, Bjørset H-H, Ro O, Walsøe H. Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. A 6 years prospective study—Part II. Applied Ergonomics. 2001;32(6):559-71. doi: https://doi.org/10.1016/S0003-6870(01)00030-8.

[33] Amick BCI, Robertson MM, DeRango K, Bazzani L, Moore A, Rooney T, *et al.* Effect of Office Ergonomics Intervention on Reducing Musculoskeletal Symptoms. Spine. 2003;28(24):2706-11. doi: 10.1097/01.brs.0000099740.87791.f7. PubMed PMID: 00007632-200312150-00015.

[34] Deeb JM. Administrative controls as an ergonomic intervention. The Occupational Ergonomics Handbook: Intervantions, Controls, and Applications in Occupationals Ergonomics London: Taylor & Francis. 2006:366-73.

[35] Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. Journal of Electromyography and Kinesiology. 2004;14(1):13-23. doi: https://doi.org/10.1016/j.jelekin.2003.09.015.

[36] Rosecrance JC, Cook TM. The Use of Participatory Action Research and Ergonomics in the Prevention of Work-Related Musculoskeletal Disorders in the Newspaper Industry. Applied Occupational and Environmental Hygiene. 2000;15(3):255-62. doi: 10.1080/104732200301575.

[37] Winkelstein B. Mechanisms for pain and Injury in musculoskeletal disorders. Fundamental and assessment tools for occupational ergonomics. 2006;2:406-07.

[38] Burgess-Limerick R. Issues associated with force and weight limits and associated threshold limit values in the physical handling work environment. Issues Paper. 2003;2. avilable at: http://ergonomics.uq.edu.au/download/threshold.pdf

[39] Earle?Richardson G, Fulmer S, Jenkins P, Mason C, Bresee C, May J. Ergonomic Analysis of New York Apple Harvest Work Using a Posture-Activities-Tools-Handling (PATH) Work Sampling Approach. Journal of Agricultural Safety and Health. 2004;10(3):163. doi: https://doi.org/10.13031/2013.16473.

[40] Armstrong TJ. Analysis and design of jobs for control of work related musculoskeletal disorders (WMSDs). Occupational ergonomics: work-related musculoskeletal disorders of the upper limb and back 1st ed London & New York: Taylor & Francis. 2000:51-81.