The Prevalence and Associated factors of muscles and skeleton systems in The Air conditioning assembly plant

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KEYWORDS
Musculoskeletal disorders/Air-conditioner.

ABSTRACT
This research aimed to study the prevalence and factors related to musculoskeletal disorders among air-conditioner assembly line operators. This study was conducted on a group of 193 operators performing duties at an air-conditioner assembling factory. The interview method aimed at collecting data consisted of individual factors, job characteristic factors, environmental satisfaction factors, working posture factors, psychological factors as well as parts of the body. The interview process was conducted from May to July 2023. After the sample group of operators had been interviewed, the results of the study were summarized as follows; the cross-sectional study revealed that there were five significant factors of musculoskeletal disorders which were individual factors such as gender ($p<0.001$) and education ($p=0.001$), job characteristic factors such as section ($p=0.01$) and work duration ($p<0.001$), environmental factors such as temperature ($p=0.006$), working posture factors such as work with hand above shoulders ($p<0.001$), and psychological factors ($p=0.008$). Moreover, it was found that the lower back (31.6%) and the shoulders (28.5%) were the most of body parts being injured in the air-conditioning assembly work respectively. Therefore, it is clear that these factors were significantly related to musculoskeletal disorders.

There are two main recommendations for this research. Firstly, RULA and REBA analysis should be conducted to assess the risk level of musculoskeletal disorders. Secondly, the number of sample group should be increased. In addition, other study should be done in this point hereinafter, apart from assembly line operators, other work type should be surveyed such as, office operators and forming metal operators.

1. Introduction

Occupational diseases result from improper work activities and inappropriate working arrangement, these factors directly affect operators health towards their injuries. Musculoskeletal System is a part of the occupational diseases which means musculoskeletal pains from incorrect posture from work. Each symptom results in undesirable diseases such as dequatrain's tenosynovitis and chronic tenosynovitis of hand and wrist. These diseases can cause by originate from several types of factors, for example, incorrect working postures in limited working space (1) and chronic fatigue syndrome. Chronic fatigue syndrome normally occurs after working with incorrect or unnatural posture. The symptom will increase their severity if the posture has not been improved. The pains may develop to the long-term disease and they come from many factors, such as working and environmental factors. There are many negative effects from occupational disease. For instance, when operators are sick from occupational disease, the production capacity and work performance can be affected in addition, the more occupational disease occur, the more loss of working day moreover medical investment can be increased. It is clear that occupational diseases play a vital role on operators working life because most of them suffer from this effect and they can become disable to continue working on their jobs.

There were many researches on occupational musculoskeletal diseases in Thailand. Petcharat Keawduangdee et al. studied the prevalence of musculoskeletal disorders in Khon Khaen textile industry in 2010. This data was collected among 323 participants by using Standard Nordic Questionnaire in Thai version. It is found that the prevalence of skeletal and muscle function were shoulder 39.7%, low back 36.3%, and wrist 33.1%, respectively. The most three prevalence of musculoskeletal disorders found were shoulder joints 49.8%, low back 46.6%, and neck 42.6% consecutively. The disorders which led to the work leave were low back 27.5%, hip 21.45%, and shoulder joint 21.4%, respectively (10).

According to the study from Somthad Paanlopditsakul regarding the frequency of musculoskeletal diseases occurrence in electronics industry in 2011, wrist tendonitis 13.03%, trigger finger 9.48%, carpal tunnel syndrome 8.12%, inflamed tennis elbow 1.69% were discovered. The ergonomics was one direct-related factor toward occupational force-exerted activities, and non-neutral posture. Personal, occupational, working, environmental and social factors were also found that they can affect the operators's performance in electronics industry and daily routines (11). Neeranuch Sartrawatit conducted the study on the ergonomic hazards by physical movement during electronic parts sorting in 2015. The study was indicated that 94.90% of musculoskeletal injuries were the result of heavy lifting, 74.04% is sitting for long period, 83.65 % is a

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repetitive motions for long period of time (12). The aches and pains at wrist, back shoulder, upper arm, and head were also found among the operators as those body parts had been strained throughout the day (13).

Therefore, this research is conducted for studying on the significant of postures that affect musculoskeletal system of operators who work with air-conditioner assembly line. The aim of this study is findings as the database to develop and recruit the right operators, as well as to effectively foster the operator's health. It would also work as the developed scheme to prevent ergonomics complications in the manufacturing plant.

2. Materials and methods

This research is investigated the risk of occupational musculoskeletal disorders among the operators in air-conditioner assembly plant. The population and sample group are interviewed. The appropriate ergonomics tools are used to evaluate the ergonomics in the plant to understand the severity of the occupational pains in departments or sectors. After the situations and the level of risk were acknowledged, the adjustment and solutions must be directed to minimize occupational pains. The ergonomics solution must be modified to substantially enhance working station.

2.1 Population and Sampling

There are 491 air-conditioner assembly operators at the plant from May – July 2023.

2.1.1 Inclusion criteria

The criteria are select qualified operators who are active during data collection period. All operators in this ergonomics evaluation are willing to participate.

Sort the disqualified operators out when they are active in the plant less than 3 months. It also include of operators with pregnancy, chronic musculoskeletal diseases, surgery history from musculoskeletal accidents, congenital musculoskeletal diseases, as well as people who don't corporate in this ergonomic evaluation.

2.2 Sample selection

2.2.1 Sample size calculation

The sample size determination of the group with members could be calculated by the equation below when a large number of population are taken with no replacement (46) (47)

$$s = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)}$$

S = Sample size
N = A number of operators who are active in the studied sectors over 3 months and 491 operators who passed the selection criteria
X^2 = Chi-Square value when df is 1 and confidence level was 95% (X2=3.841)
d = Level of error of the acceptable random sampling (0.05)
P = Variance of populations from previous observation was 0.29, referred from the study of occupational pains and muscle abnormality among the plant operators in the big cities of China by using the highest occupational injuries in electronics cluster (48).

From 491 operators who passed the criteria at 0.05 significant level, 192.62 or about 193 operators would be acknowledged as the sample group populations who had to go through ergonomics evaluation.

2.3 Research Instruments

Abnormal Index (AI) is used as one from of questionnaire to evaluate, also, physical pain and discouragement of operators. This tool is used with standard Nordic Questionnaire which is for conducting the result of the most injured part that is found in the body

2.3.1 Abnormal Index (AI)
2.3.2 Standard Nordic Questionnaire
2.3.3 General Questionnaire.

2.4 Data collection

2.4.1 Procedures before conducting research

2.4.1.1 Submit the requisition for ethic review from ethic committee as this research is involved in the human research.

2.4.1.2 Data collection is an important process as the analysis of the imprecise data probably create errors. Thus, the researcher should have meticulous procedures as the followings;

Complete the questionnaire which composed of individual factor, job' characteristic factor, environmental satisfaction factor, working posture factor, and psychological factor. The evaluation is conducted with sample group during lunch break in order to evaluate their physical pains and discouragement.

Data preparation and analysis

1. Collect and calculate data from the questionnaire and record them on the computer.
2. Inferential statistics are used to evaluate. Chi-square test at 95% confidence level was applied to find the relationship between various injures and many factors used to analyze.

2.5. Data analysis

1. Descriptive Statistics; percentage, mean, and standard deviation are used to analyze questionnaire.
2. Inferential statistics; Chi-square test at 95% confidence level (20, 49)

2.5.1 Descriptive analysis

was used to describe the general characteristics of the study subject and present the prevalence of depression, including frequency, percent, mean, and standard deviation.

3. Results

3.1 Individual Factors

According to the study from 193 samples who are the interior air-conditioner parts operators and the exterior air-conditioner operators, there were 34 males or 17.6% and 159 females or 82.4%. The average age of the sample group were 36.9 ± 5.9 years old. 78 people were in the range of 41-50 years old or 40.4%. The youngest one was 28 years old and the oldest one was 49 years old. The average BMI was 22.5 ± 3.4 kg/m2. The highest BMI was 35.2 kg/m2 and the highest range was 18.50-22.9 kg/m2 for 88 persons or 45.6%. The lowest BMI was ≥ 30 kg/m2for 5 persons or 2.6%. The highest education of the operators found that, 99 persons or 51.3% graduated from high school diploma. 176 persons or 91.2% travels with the company's pick-up buses. Only 4 persons or 2.1% use a private car. The duration of travel was 29.1 minutes in average. The longest duration was 90 minutes and the shortest was 5 minutes. from the sample group, there was no one has experienced the accident related to musculoskeletal disorders. The majority of 167 persons or 86.5% were right-handed person and only 10 persons or 5.2% were left-handed person

3.2 Job characteristic Factors

Regarding the data of 97 persons or 50.3% of the interior air-conditioner parts department and 96 persons or 49.7% of the exterior air-conditioner parts department, 153 persons or 79.3% worked on day shift and 40 persons or 20.7% work on night shift. It was found that 102 persons or 52.8% have working experiences almost 1 year, 91 persons or 47.2% had working experiences more than 1 year. 175 persons or 91.2% worked over 8 hours a day and 17 persons or 8.8% work less or equal to 8 hours a day. There were 147 operators or 76.2% working for overtime(OT) and 46 persons do not work for OT. There were 6 persons or 3.1% having hobbies. 13 persons or 6.7% work part-time. Most work in the parts jobs, 149 persons or 77.2%. The second was delivery and packaging for 24 persons or 12.4%.

3.3 Environmental satisfaction Factors

Regarding the sample group, 81 persons or 42.0% thought that the light level was appropriate while 70 persons or 36.3% disagreed. 98 persons or 50.8% thought that the sound level was not appropriate while 44 persons or 22.8% thought that it was appropriate. 85 persons or 44.0% agree with the current temperature level while 60 persons or 31.1% disagree. Moreover, 48 persons or 24.9% are neutral. 164 persons or 85.0% thought

that the ventilation was appropriate, 15 persons or 7.8% thought it was acceptable while 14 persons or 7.3% were not satisfied.

3.4 Working Posture Factors

Regarding the samples, for 99 persons or 51.3% the most activities they have done is standing for a long time, the secondary was as persons or 49.2% worked repeatedly, and 89 persons or 46.1% worked by raising and bowing head. The never-done activities are squatting for 136 persons or 70.5%, the secondary was waist twisting for 125 persons or 64.8%, and the uncomfortable posture for 124 persons or 64.2%.

3.5 Psychological Factors

According to the Psychological data with Abnormal Index(AI), the highest result between $0 < AI \leq 2$ has 97 samples or 50.3%. This range means the slightly problem that they could endure. The range $3 < AI \leq 4$ had 45 persons or 23.3% meaning it is the problem and could not deal with it. The range $2<AI\leq3$ had 39 persons or 20.2% meaning requesting carefulness.

3.6 Body parts relating to musculoskeletal disorders

According to the interview with the sample group about the 9 bodily injuries, the body parts they found the abnormalities such as pain, senseless, and exhausted during the recent 12 months was the lower back for 61 persons or 31.6%. Next was a shoulder for 55 persons or 28.5%. The least abnormality was ankle and foot for 10 persons or 5.2%. From the interview with the sample group about the bodily injuries, the body parts they found the abnormalities such as pain, senseless, and exhausted during the recent 7 days, the most injury was the lower back for 46 persons or 23.8%. Next was a shoulder for 35 persons or 18.1%. The least was ankle and foot for 1 person or 0.5%.

3.7 Relationship between musculoskeletal disorders during the operation of the air-conditioner assembly line operators and individual factors, Job characteristic factors, environmental satisfaction factors, working posture factors, and psychological factors

3.7.1 Relationship between individual factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators

From the analysis of the relationship between individual factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators, gender factor was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Age factor was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.045$). Education level was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Travel duration to work was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Left and Right handed person were relate to musculoskeletal disorders with statistical significance at 0.05 ($p<0.019$).

3.7.2 Relationship between Job characteristic factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators

From the analysis of the relationship between Job characteristic factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators, department was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.01$). shift work relate to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Working experience was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.003$). Working hours was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). OT was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Part-time, job was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.048$). Job characteristic factors was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$).

3.7.3 Relationship between environmental satisfaction factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operations

From the analysis of the relationship between environmental satisfaction factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators, sound was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.008$). Temperature level was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.006$).

3.7.4 Relationship between working posture factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators

From the analysis of the relationship between working posture factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators, working with hand over shoulders was related to musculoskeletal disorders with statistical significance at 0.05 ($p<0.001$). Working with bouncing hands and using force was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.021$). Working with head rising and bowing was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.009$). Working standing for a long time was related to musculoskeletal disorders with statistical significance at 0.05
($p=0.008$). Working in the same posture for a long time factor was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.031$).

3.7.5 Relationship between psychological factors and musculoskeletal disorders during the operation of the air-conditioner assembly line operators

From the analysis of the relationship between Psychological factors and musculoskeletal disorders among the operation of the air-conditioner assembly line operators, Abnormal Index or AI was related to musculoskeletal disorders with statistical significance at 0.05 ($p=0.008$).

4. Discussion

4.1 Individual factors

According to this study, it is found that the individual factors in genders are associated with the disorders of air-conditioning component assembling line operators. In the sample group, they are more female than male. This is in correspondence with the study of Virote Chanthorn (44) on the operators who working in the workplace that 64.2% of the female operators are injured in air-conditioning component assembling work which is higher than that of the male operators of only 32.4% of disorders. This is possibly due to male muscle mass which is more than female (48) resulting in the male operators to be stronger. Moreover, if they work in the same manner, they may have severe pain more difficult than females. The age of the operators is found to be also correlated with the disorders of the musculoskeletal system. The operators in the age range of 41-50 years old are the most of 69.2%. This may be due to the fact that the studied organization is the large and reliable electronic organization as well as being old (the age of the organization is over 100 years in Thailand).

This also includes the benefits persuading the operators to have confidence and security in their work. It is also the organization with less permanent operators recruitment. As a result, it is lack of staff turnover and the number of operators in the age range of 41-50 years is very large which is in line with the study conducted by Setthasat Chaisaeng (50) on the relationship between quality of life and the relationship of the organization. Regarding the education level, it is found that most operators graduated at the high school level which corresponds to the aforementioned age range showing that the operators use high school degree to apply for the job at earlier stage of the factory's establishment. This is consistent with the data of education in Thailand revealing that most operators in the factory were graduated in high school level (51). The travel duration is related to the disorders of the air-conditioning component assembling line operators. The longer the travel time takes, the more injured the operators are. The operators with the most disorders are those who take the travel duration of over 60 minutes. This is possibly because in traveling, the operators have to sit for a long time. The muscles are not moved resulting in lactic acid accumulation in the muscle fibers leading to the pain (41). Hand skills are also associated with disorders of air-conditioning component assembling line operators. The left-handed opertors have the highest percentage of disorders of 75.0%. Most operators are right-handed and the devices are more likely to be designed for the right-handed operators resulting in a much more traumatic injury to the left-handed operators. This agrees with the study of Suporn Meekiatkulthorn (52) on the disorders of the left-handed operators in assembling the wires in the automotive industry.

4.2 Job characteristic factors

According to this study, it is found that the Job characteristic factors of the departments are related to the disorders of indoor air-conditioning component assembling line operators more than those who work for outdoor system of 67.7%. This is possibly because there are more components in the indoor air-conditioners system resulting in taking longer time in assembling. Moreover, there are more motions causing to more risks in disorders. Working in the daytime has higher percentage of disorders and less working ages cause more

disorders as well. This is possibly due to the work experience agreeing with the study of Bernard (57) stating that more learning and work experiences will result in less risks of disorders. Regarding overtime working, it is found that most operators who over 8 hours. This is possibly because of the high work load and the high returns in overtime working. Most operators have no extra jobs after work and the job characteristics are related to the disorders. The most injured is 62.2%. The cause of large disorders in these job characteristics is that the assembling work is the main work of the factory and there are a lot of operators in this section.

4.3 Environmental satisfaction factors

According to this study, it is found that the environmental satisfaction factors of noise and temperature level are associated with the disorders of air-conditioning component assembling line operators. The inappropriate noise level is 66.3% and the inappropriate temperature level is 73.3 which is the most.

4.4 Working posture factors

According to this study, it is found that the working posture factors are associated with the disorders of air-conditioning component assembling line operators. It is found that working with the hand above the shoulder level is related to the disorders of operators. This is because in the operation of the assembly department, it is necessary to reach for the devices that are placed above the shoulder level in some cases and this reach must be done every time it is assembled in the process.

It is found that working with wrist and exertion is associated with disorders due to in some processes, such as testing, plugging the devices or wires to supply the power to test the system and after the test such wires have to be unplugged consuming more force and repetition for several times a day causing the wrist injury.

It is found that in the workplace, the operators have to bend the neck at all times to pick up or assemble the components of the air conditioners which are associated with injury to the operators. Most operators in the assembly process have to always bend the necks as same as the operators assembling the air conditioners and inspectors who have to bend their necks as well because they need to look at the test value from the monitor periodically which may cause the operators' disorders.

It is found that working by standing is related to disorders due to all sections except the office work requiring to stand at all times. In standing for working, the operators often stand still without moving. Due to the assembly process, each operators has clear responsibility. There is no need to walk or change the spots in standing so much. Therefore, most operators will have to stand for a long time.

It is found that working in the same posture continually is related to disorders of operators. Most operators of the assembly department have to work in the same posture repeatedly. In each work, the frequency is not equal. The department with the work in the same posture and high frequency is the wire assembly line because there are a lot of wires and require to be assembled in the defined time causing too repeated posture and high frequency in working as well.

4.5 Psychological factors

According to this study, it is found that the psychological factors are associated with the musculoskeletal disorders of the air-conditioning component assembling line operators. This part of the study was conducted from the Abnormal Index (AI) with the most score range and the too problematic score range. This is possibly because in working, there must be the high accuracy and pressure. As the organization makes various standards, the operators have to perform the complicated work including the strict quality control. This causes the operators to feel that the problems are caused by the strictness and delicacy of operators.

4.6 Parts of the body with the problems of musculoskeletal disorders

According to the study on the sample groups on the parts of the body related to the musculoskeletal disorders, it is found that the parts of the body related to the musculoskeletal disorders of the air-conditioning component assembling line operators is the lower back with the prevalence of 31.6%. The less is the shoulders with the prevalence of 28.5%. This is in accordance with the study of Suwinan Thaweephiriyachinda (55) on the harmful work and the prevalence of abnormalities of musculoskeletal system in relation with the work. The study of Suwinan reveals that the disorders related to the lower back is the most of 74.1%. The less is the shoulders of 70.7%. This is in line with this study and is also correspondent with the study of Wenzhou Yu (48) on the injured parts of the body classified by the characteristics of the industry. The electronic industry causes the highest injury rate of the parts of the body related to the lower back of 29.5%. The less is the shoulders of 23%.

5. Conclusion

The musculoskeletal disorders in the operation of air-conditioning component assembling line operators consist of several factors in relation with the musculoskeletal disorders as follows Individual factors which are genders, ages, educational levels, average traveling time to work (round trip), and hand skills are related to musculoskeletal disorders. No relationship with the musculoskeletal disorders is found in the body mass index (BMI) and types of vehicles taken in traveling to work. Work type factors which are departments, periods of work, working ages, working hours per day, overtime works, extra job apart from permanent works are related to musculoskeletal disorders. No relationship with the musculoskeletal disorders is found in the hobbies. Environmental satisfaction factors which are noise and temperature level are related to musculoskeletal disorders. No relationship with the musculoskeletal disorders is found in the light level and the ventilation. Working posture factors which are working with the hands above the shoulder level, working with the raised wrists, using much force, having to bend the necks, having to stand for a long time continually are related to musculoskeletal disorders. No relationship with the musculoskeletal disorders is found in the work with the hands horizontally far from the body, working with the bended back, working with the moving waist, sitting still for a long time, working in the uncomfortable postures, doing the activities with the bended knees for a long time, working by using a lot of force from the hands and arms, working in the improper posts or unnatural postures such as completely reaching the hands for getting the things and using the devices which are vibrated. Psychological factors are related to musculoskeletal disorders.

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