TOPSIS BASED ERGONOMIC ANALYSIS ON WORK RELATED MUSCULOSKELETAL DISORDERS OF SEWING MACHINE OPERATORS

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ABSTRACT

This study aims to identify the sequence of sewing machine dominance for different work-related musculoskeletal disorders among the sewing machine operators in the garments industry of Bangladesh. Sewing machine operators in the garments industry suffer from different musculoskeletal problems which are caused by poor working posture as well as repetitive movements. The first objective of this study is to analyses the socio-demographic conditions of the workers. The second objective is to find out a sequence of sewing machines for different Work-related Musculoskeletal Disorders (WMSDs). Some 105 sewing machine operators participate for collecting Socio-demographic & WMSDs information through some preselected questionnaires. TOPSIS method has been utilized to determine the sewing machine sequence for a particular musculoskeletal disorder and also find out the overall responsibility for different musculoskeletal disorders. The results indicated that prevalence of musculoskeletal problems is significant and plain machine is more responsible than any other sewing machine for most of the musculoskeletal problems.

KEYWORDS: *Work-related Musculoskeletal Disorders, Sewing Machine, Garments Industry*

I. INTRODUCTION

This In Bangladesh, Readymade Garment (RMG) sector plays a significant role in the overall economic development. Presently, approximately two million workers among which 80% is female are working in this sector [1]. It is also noteworthy that this is about 76% of the foreign exchange earning sector [2]. North America and countries of Western Europe are the main buyers of the RMG products of Bangladesh. However, still now some of the tasks the garments workers perform at work such as lifting, reaching, packaging, sewing and repeating the same movements can strain their bodies. In few cases, these tasks can result in injuries to the muscles, tendons, nerves, blood vessels, and joints of the neck, shoulders, arms, wrists, legs, and back. This type of injury is recognised as musculoskeletal injury, or MSI or musculoskeletal disorders or MSD which is common in most of the industry in Bangladesh. Particularly, in garments industry, musculoskeletal injuries are also serious and hampers the production and difficult to find out the possible solution. Therefore, Work-related musculoskeletal disorders have great impact on the productivity of the industry in Bangladesh cannot reach to the desired level because of not finding out the satisfactory solutions of this problem. “SD’’ includes clinical syndromes for example carpal tunnel syndrome, sciatica as well as less well standardised conditions such as low back pain and other regional pain syndromes not distinguishable to known pathology. Body regions most commonly involved are the low back, neck, shoulder, forearm, and hand. MSD is widespread in many countries, with substantial costs and impact on quality of life. MSDs are the single largest category of work-related illness, representing a third or more of all registered occupational diseases in the United States, the Nordic countries, and Japan [3]. Workers may observe pain, numbness, tingling, or weakness while on the job. Sometimes it can be an appearance of an injury or disease. To lessen the possibility of an injury or disease, it may be necessary to reduce exposures to physical movements at work that have the potential to place workers at risk of injury or disease). It is necessary to note that each individual's response to a physical exposure is different. The human body is designed to be active, so eliminating all physical activity is also unhealthy. It is also necessary for employers and workers to recognise the signs and symptoms that could indicate an MSD. Signs which can be observed could include swelling, redness, and/or difficulty moving a particular body part. Symptoms which can be felt but not observed could include numbness, tingling, and/or pain.

Too many research works have been done about MSD in last few years. Alireza *et al*. [4] studied & observed musculoskeletal disorders in Iranian hand-woven carpet industry. Based on those studies, some general principles for workstation design were confronted. The study found that most of the ergonomics disabilities were originated from bad workstation design. R. Nugen [5] recommendations for control interventions to minimise the adverse effects that the plastering task and working conditions has on the musculoskeletal system and decrease the probability of plasterers developing WRMSDs. Dianat *et al*.[6] Worked on musculoskeletal symptoms among 251 Iranian sewing machine operators and emphasise the need for ergonomic interventions to reduce musculoskeletal symptoms in the future. Denis *et al*.[7] reviewed near about 47 different articles on WMSDs from where they recommended three steps or phases of the "*classical*" ergonomic intervention process. The first step is defining the scope of the problems in the work situation studied and eventually orienting the data collection in the diagnostic step. Next the diagnostic or central step is to found causes or determinants for the identified problems, causes to which the changes or work situations should be directly related. Finally the solution-development step, in which solutions to change the work situation were developed. To help define the problem and its relationship to work factors, increasing interest has been directed in many countries to the development of methods to estimate and record musculoskeletal symptoms. The most fruitful way of collecting the necessary data is questionnaires [8]. Musculoskeletal symptoms and ergonomics risk factors among female sewing machine operators were found in Turkey [9]. There was a strong statistical association between years as a sewing machine operator and the development of neck-shoulder disorders [8]. Empowerment of work groups and high competence of supervisors has a preventative effect on the reporting of neck-shoulder symptoms. Physical discomfort can be influenced by non-physical factors such as job satisfaction. The common WMSDs risk factors are: work postures and movements, repetitiveness and pace of work, force of movements, vibration, and temperature [10]. In Bangladesh, Chakrabortty *et al.*[11] gives an overview of the extent of work related musculoskeletal disorders (WMSDs) in the garments sector and suggested practitioners should consider scientific evidence during design and implementation of an intervention, especially in terms of study duration, confounders, outcome measures, and data analysis. So, this study presents an industrial case designed on Bangladeshi perspective to observe the WMSD among sewing operators and provide some recommendations. The rest of this paper is organized as follows: Section 2 methodology. Subsequently, Section 3 presents results Next, Section 4 discusses the calculated results and Some recommendations are presented in section 6 after which a brief conclusion and future works is drawn.

II. METHODOLOGY

The study was conducted in two different selected garments named Style Crafts and A. M. Design Ltd. at Gazipur in Bangladesh. In this study, the data were obtained with a questionnaire and by direct observation. The questionnaire was prepared based on the Work Related Musculoskeletal Questionnaire. Under an analytical cross-sectional study design a total of 105 (male-27 and female-78) participants have been assessed. Sampling technique was simple random for the selection of the participants. The age range of the respondents was 18-40 years; all of the respondent's position was sewing machine operator. For this study four kinds of sewing machines were considered. The types of considered sewing machines were over lock machine, bar tack machine, Kansai special machine and plain machine. Number of operators for each machine has been shown in Table 1. In this study major six areas of discomfort were considered according to the past data analysis. These areas of discomfort are neck stiffness, shoulder stiffness, elbow/forearm numbness, low back pain, leg pain/swelling and chest pain. Frequencies of these discomforts were obtained by asking questions according to the questionnaires. Table 2 shows the frequencies of ergonomic problems with respect to different sewing machines.

Table 1. Considered number of different sewing machine operators

Machine name	Number of operators
Over lock machine	19
Bar tack machine	19
Kansai special machine	18
Plain machine	49
Total	105

Table 2. Frequencies of ergonomic problems respective to different sewing machines

Areas of discomfort	Over lock machine	Bar tack machine	Kansai machine	Plain machine	Total
Neck stiffness	5	3	3	17	28
Shoulder stiffness	7	2	8	10	27
Elbow numbness	15	7	8	20	50
Low back pain	11	10	10	25	56
Leg pain	11	3	2	33	49
Chest pain	11	12	12	2	37
Total	60	37	43	107	247

Finally with the collected data a multi-criteria decision analysis method called Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was applied to find out the order of machines responsible for the WMSDs. For the determination of the machine dominance using TOPSIS, linguistic values were used to assess the ratings and weights for the factors. The criteria for assessing dominance were force, repetition, work posture and local contact stress. Weights of all the criteria were considered the same. Importance of each criterion for each alternative was assigned from 1 to 9 according to the opinion of the operators where 1 was for low importance and it increased to 9 as the importance increased.

III. RESULTS

Questionnaires were set to obtain information about age, sex, marital status, monthly income and education of the sewing machine operators selected for the study. Table 3 shows the socio-demographic information about the machine operators.

Table 3. Socio-demographic information of machine operators (n=105)

Variables		Numbers (n)	*Percentage (%)*
Age	15-30 years	56	53.33%
	30-45 years	49	46.67%
Sex	Male	27	25.71%
	Female	78	74.29%
Marital status	married	73	69.52%
	unmarried	32	30.48%
Monthly income (BDT±)	<6000 taka/month	38	36.19%
	≥6000 taka/month	67	63.81%
Education	Below primary	17	16.19%
	Up to primary	32	30.48%
	Up to SSC or above	56	53.33%

TOPSIS was used to determine the rank of machines which dominated much on the each of the selected ergonomic problems.

3.1 Determining machine dominance for neck stiffness

Weight for each criterion is considered the same. Importance for each criterion is obtained from interviewing the operators in case of neck stiffness problem. Table 4 shows the importance weights for each criterion for neck stiffness. Table 5 shows the weighted normalized matrix for neck stiffness. Table 6 shows the distances between the alternatives and the conditions.

Table 4. Importance weights for each criterion (Neck stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	5	8	4	2
Bar tack	4	6	7	5
Kansai m/c	7	4	6	3
Plain m/c	6	7	7	8

Table 5. Weighted normalized matrix (Neck stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress
Over lock	0.445	0.623	0.327	0.198
Bar tack	0.356	0.467	0.572	0.495
Kansai m/c	0.624	0.311	0.490	0.297
Plain m/c	0.535	0.545	0.572	0.792

Table 6. Deviation between the alternatives and conditions (Neck stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.445	0.623	0.327	0.198	0.667	0.324	0.327
Bar tack	0.356	0.467	0.572	0.495	0.429	0.415	0.492
Kansai m/c	0.624	0.311	0.490	0.297	0.591	0.329	0.358
Plain m/c	0.535	0.545	0.572	0.792	0.118	0.707	0.857
A_b	0.624	0.623	0.572	0.792			
A_w	0.356	0.311	0.327	0.198			

Fig 1 shows the TOPSIS results for the neck stiffness problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value s_{iw} for plain machine is much more than any other alternatives. The values of s_{iw} for Kansai machine and over lock machine are almost the same. So, decision can be made that the sequence of m/c responsible for neck stiffness problem is as follows:
Plain m/c > Bar tack > Kansai m/c > Over Lock.

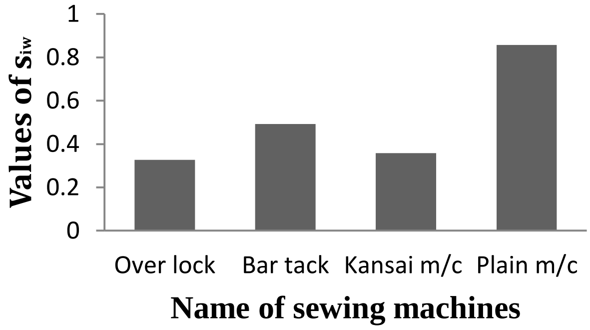

Figure. 1. TOPSIS result for neck stiffness

3.2 Determining machine dominance for shoulder stiffness

Weight for each criterion is considered the same. Importance for each criterion is obtained from interviewing the operators in case of shoulder stiffness problem. Table 7 shows the importance weights for each criterion for shoulder stiffness. Table 8 shows the weighted normalized matrix for shoulder stiffness. Table 9 shows the distances between the alternatives and the conditions.

Table 7. Importance weights for each criterion (Shoulder stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	4	5	8	6
Bar tack	6	7	5	5
Kansai m/c	5	3	3	8
Plain m/c	7	6	7	6

Table 8. Weighted normalized matrix (Shoulder stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress
Over lock	0.356	0.458	0.660	0.473
Bar tack	0.535	0.642	0.412	0.394
Kansai m/c	0.445	0.275	0.247	0.630
Plain m/c	0.624	0.550	0.577	0.473

Table 9. Deviation between the alternatives and conditions (Shoulder stiffness)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.356	0.458	0.660	0.473	0.361	0.459	0.560
Bar tack	0.535	0.642	0.412	0.394	0.354	0.440	0.554
Kansai m/c	0.445	0.275	0.247	0.630	0.581	0.252	0.303
Plain m/c	0.624	0.550	0.577	0.473	0.200	0.512	0.719
A_b	0.624	0.642	0.660	0.630			
A_w	0.356	0.275	0.247	0.394			

Fig 2 shows the TOPSIS results for the shoulder stiffness problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value s_{iw} for plain machine is much more than any other alternatives. The values of s_{iw} for bar tack machine and over lock machine are almost the same. So, decision can be made that the sequence of m/c responsible for shoulder stiffness problem is as follows:

Plain m/c > Over lock > Bar tack > Kansai m/c.

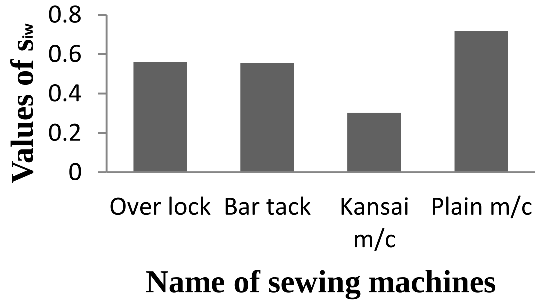

Figure 2. TOPSIS result for shoulder stiffness.

3.3 Determining machine dominance for elbow numbness problem

Table 10 shows the importance weights for each criterion for elbow problem. Table 11 shows the weighted normalized matrix for elbow problem. Table 12 shows the distances between the alternatives and the conditions.

Table 10. Importance weights for each criterion (Elbow problem)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	3	2	6	3
Bar tack	5	6	7	8
Kansai m/c	8	4	3	5
Plain m/c	6	7	8	6

Table 11. Weighted normalized matrix (Elbow problem)

Criteria	Force	Repetition	Work posture	Local contact stress
Over lock	0.259	0.195	0.550	0.259
Bar tack	0.432	0.586	0.642	0.691
Kansai m/c	0.691	0.390	0.275	0.432
Plain m/c	0.518	0.683	0.458	0.518

Table 12 . Deviation between the alternatives and conditions (Elbow problem)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.259	0.195	0.550	0.259	0.787	0.275	0.259
Bar tack	0.432	0.586	0.642	0.691	0.277	0.710	0.719
Kansai m/c	0.691	0.390	0.275	0.432	0.536	0.506	0.486
Plain m/c	0.518	0.683	0.458	0.518	0.306	0.637	0.676
A_b	0.691	0.683	0.642	0.691			
A_w	0.259	0.195	0.275	0.259			

Fig 3 shows the TOPSIS results for the elbow problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value s_{iw} for bar tack machine is more than any other alternatives. The values of s_{iw} for bar tack machine and plain machine are almost the same. So, decision can be made that the sequence of m/c responsible for the elbow problem is as follows:
Bar tack > Plain m/c > Kansai m/c > Over lock.

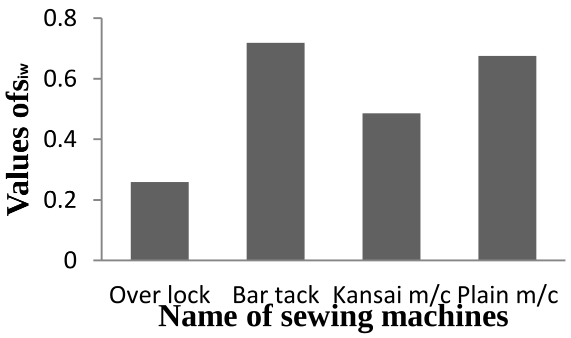

Figure 3. TOPSIS result for elbow problem.

3.4 Determining machine dominance for low back pain

Table 13 shows the importance weights for each criterion for low back pain problem. Table 14 shows the weighted normalized matrix for low back pain problem. Table 15 shows the distances between the alternatives and the conditions.

Table 13. Importance weights for each criterion (Low back pain)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	4	5	8	8
Bar tack	7	4	4	7
Kansai m/c	3	5	6	3
Plain m/c	6	7	9	4

Table 14. Weighted normalized matrix (Low back pain)

Criteria	Force	Repetition	Work posture	Local contact
Over lock	0.381	0.466	0.570	0.681
Bar tack	0.667	0.373	0.285	0.596
Kansai m/c	0.286	0.466	0.427	0.255
Plain m/c	0.572	0.653	0.641	0.341

Table 15. Deviation between the alternatives and conditions (Low back pain)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.381	0.466	0.570	0.681	0.349	0.530	0.603
Bar tack	0.667	0.373	0.285	0.596	0.461	0.511	0.526
Kansai m/c	0.286	0.466	0.427	0.255	0.638	0.170	0.210
Plain m/c	0.572	0.653	0.641	0.341	0.125	0.543	0.813
A_b	0.667	0.653	0.641	0.681			
A_w	0.286	0.373	0.285	0.255			

Fig 4 shows the TOPSIS results for the low back pain problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value s_{iw} for plain machine is more than any other alternatives. The values of s_{iw} for bar tack machine and over lock machine are almost the same. So, decision can be made that the sequence of m/c responsible for the elbow problem is as follows:
Plain m/c > Over lock > Bar tack > Kansai m/c.

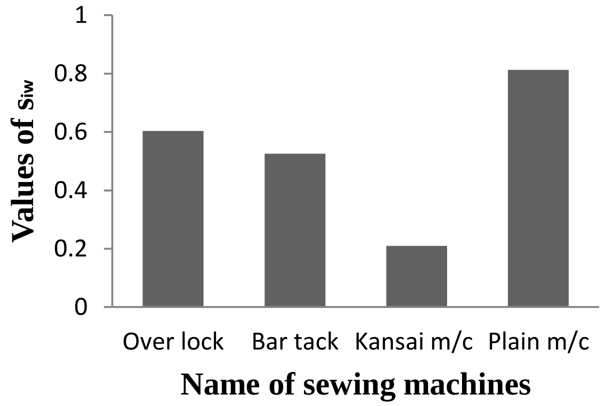

Figure 4. TOPSIS result for low back pain problem

3.4 Determining machine dominance for leg pain

Table 16 shows the importance weights for each criterion for leg pain problem. Table 17 shows the weighted normalized matrix for leg pain problem. Table 18 shows the distances between the alternatives and the conditions.

Table 16. Importance weights for each criterion (Leg pain)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	8	5	2	4
Bar tack	5	9	5	7
Kansai m/c	7	5	7	6
Plain m/c	4	3	8	6

Table 17. Weighted normalized matrix (Leg pain)

Criteria	Force	Repetition	Work posture	Local contact stress
Over lock	0.645	0.423	0.168	0.342
Bar tack	0.403	0.761	0.420	0.598
Kansai m/c	0.564	0.423	0.587	0.513
Plain m/c	0.322	0.254	0.671	0.513

Table 18. Deviation between the alternatives and conditions (Leg pain)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.645	0.423	0.168	0.342	0.658	0.365	0.357
Bar tack	0.403	0.761	0.420	0.598	0.349	0.627	0.642
Kansai m/c	0.564	0.423	0.587	0.513	0.368	0.540	0.595
Plain m/c	0.322	0.254	0.671	0.513	0.607	0.531	0.467
A_b	0.645	0.761	0.671	0.598			
A_w	0.322	0.254	0.168	0.342			

Fig 5 shows the TOPSIS results for the leg pain problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value of s_{iw} for bar tack machine is more than any other alternatives. The values of s_{iw} for bar tack machine and Kansai machine are almost the same. So, decision can be made that the sequence of m/c responsible for the elbow problem is as follows:
Bar tack > Kansai m/c > Plain m/c > Over lock.

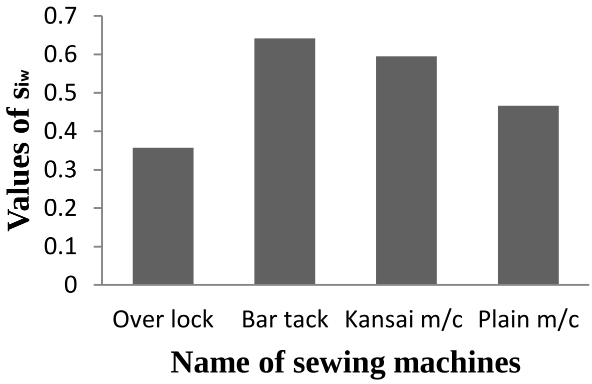

Figure 5. TOPSIS result for leg pain problem

3.5 Determining machine dominance for chest pain

Table 19 shows the importance weights for each criterion for chest pain problem. Table 20 shows the weighted normalized matrix for chest pain problem. Table 21 shows the distances between the alternatives and the conditions.

Table 19. Importance weights for each criterion (Chest pain)

Criteria	Force	Repetition	Work posture	Local contact stress
Weights	0.25	0.25	0.25	0.25
Over lock	7	8	4	6
Bar tack	4	7	5	7
Kansai m/c	6	6	3	8
Plain m/c	8	7	6	6

Table 20. Weighted normalized matrix (Chest pain)

Criteria	Force	Repetition	Work posture	Local contact stress
Over lock	0.545	0.569	0.431	0.441
Bar tack	0.311	0.497	0.539	0.515
Kansai m/c	0.467	0.426	0.323	0.588
Plain m/c	0.623	0.497	0.647	0.441

Table 21. Deviation between the alternatives and conditions (Chest pain)

Criteria	Force	Repetition	Work posture	Local contact stress	d_{ib}	d_{iw}	s_{iw}
Over lock	0.545	0.596	0.431	0.441	0.273	0.295	0.519
Bar tack	0.311	0.497	0.539	0.515	0.346	0.239	0.409
Kansai m/c	0.467	0.426	0.323	0.588	0.387	0.214	0.355
Plain m/c	0.623	0.497	0.647	0.441	0.164	0.455	0.735
A_b	0.623	0.569	0.647	0.588			
A_w	0.311	0.426	0.323	0.441			

Fig 6 shows the TOPSIS results for the chest pain problem. In the figure s_{iw} value for each alternative is shown. It is clear that the value of s_{iw} for plain machine is more than any other alternatives. The values of s_{iw} for bar tack machine and Kansai machine are almost the same. So, decision can be made that the sequence of m/c responsible for the elbow problem is as follows:

Plain m/c > Over lock > Bar tack > Kansai m/c.

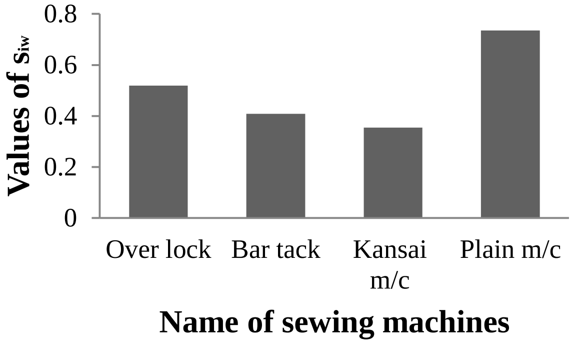

Figure 6. TOPSIS result for chest pain problem

IV. Discussion And Recommendations

Workers of different ages are working in the garments of Bangladesh. Most of the workers are female. For this reason this study obtained 74.29% female workers in the sample. Both economic and educational conditions of the garments workers in Bangladesh are not up to the mark. In this study, lower educational attainment has also been reported by others to be associated with higher rates of pain and dysfunction among garment workers [12,13]. In the present study, it has been found that a high prevalence of WMSD among garments workers especially among the sewing machine operators. The majority of WMSDs were perceived as work-related which is comparable with Boschman *et al*. [14] follow up study among the construction workers. Force, awkward posture, local contact stress and repetition of works are identified as major WMSDs risk factors. Sewing operators suffer from musculoskeletal disorders, which have been attributed to poor working postures as well as to the repetitive hand and arm movements. Their posture is restrained by both the visual and the manual aspects of the task and the design of the sewing machine and table has a considerable influence on the posture adopted [15]. This study has found that plain machine is mostly responsible for most of the WMSDs. Because plain machine is the most common machine and most is used in maximum in the garments industry. This study found that plain machine was more responsible than any other machines for neck stiffness, shoulder stiffness, back pain problem and chest pain problem. It also found that for elbow numbness and leg pain bar tack machine was more responsible than any other machines. Kansai special machine and over lock machine were less responsible for the work-related musculoskeletal disorders. Limited operations are performed by using Kansai special machine. As a result it is less responsible for most of the work-related musculoskeletal disorders.

V. Conclusion And Future Work

Musculoskeletal problems are very extensive in garments industries and it’s a great challenge to extinguish this problem. Proper steps should be taken to improve this situation. This has found out the main musculoskeletal disorders and causes and recommendations are suggested which could be very helpful in mitigating the musculoskeletal problems and improving the sewing section of the garments industry. In Bangladesh, garment sector is the major export sector and a main source of foreign exchange. So if the musculoskeletal problems in the garments industry can be reduced, this sector will be much more lucrative for Bangladesh and this paper can put some contribution to it. Future research should consider the following: (1) the physical and nonphysical work environment should be assessed (2) data analysis should be conducted adjusting for covariates and confounders, different lengths of follow-up, and level of exposure. (3) AHP, Fuzzy or ANN should be utilised to determine the optimum value.

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