Ergonomic Risk Assessment and Postural Analysis of Workers in Small Garment Industries by RULA using Digital Human Modeling

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Abstract

The Garment industry is one of the significant contributors to the overall economic development of India. The unorganised segment of garment industry includes small industries and tailoring firms, mostly catering to domestic and local markets. These units are characterized by several occupational health, safety and ergonomic concerns, such as improper workstation design, excessive noise and humidity, poor lighting and prevalence of musculoskeletal disorders among the workers. The aim of the present study was to identify the risk factors leading to development of work-related MSDs. Also it includes measurement of work environment such as noise, temperature and illumination and analysis of postures by Rapid Upper Limb Assessment (RULA) using CATIA software. Forty workers from different sections like cutting, stitching, finishing, ironing and packing, working in 5 garment manufacturing and tailoring units, were selected for the study. Body part discomfort Questionnaire was administered and postural analysis tools like RULA used to determine postural risks. The environmental parameters were measured using appropriate measuring instruments. Some postures were assessed for risks using RULA in CATIA software. The results indicate a high postural risk among the workers (about 45% in high risk). The study also revealed prevalence of work-related MSDs among workers, ergonomic deficiencies in work place, excessive noise in stitching areas and negligible use of personnel protective equipment. It can be concluded that the workers in these units face various occupational health and ergonomic deficiencies. It was suggested to incorporate several ergonomic interventions to improve the occupational health, safety of the workers leading to improved performance.

Keywords:
Ergonomics, Musculoskeletal disorders (MSDs), RULA, and CATIA

1. Introduction

Ergonomics is the study of interaction between people, machines and the surrounding environment. Ergonomics seeks to minimize adverse effects of the environment upon people and thus enables each person to maximize his/her contribution to a given job (Manzoor et.al. 2019). Occupational health and safety (OHS) seeks to sustain the working capacity of the work force as well as to identify, assess and avoid risks and hazards within the work environment. Ergonomics, as described above, combines all these issues to improve worker competence, health and safety and maintain the industrial production through better design of the work place (Qutubuddin et.al. 2013). Work related musculoskeletal disorders are a leading cause of occupational health related issues on the worker. Work related musculoskeletal disorders or WRMSDs can be described as the disorders of the tendons, muscles, nerves and joints associated with exposure to work risk factors, further resulting in pain and discomfort and functional impairment (Jagadish et.al.2018). WRMSDs are also the most common cause of discomfort among the garment and tailoring workers (Panhale et.al. 2020).

The main activities performed by a garment industry worker or a tailor are cutting the cloth, stitching of the cloth, finishing, ironing the garment and packing. Garment workers are subjected to higher risks and discomfort due to prolonged hours of work and unnatural postures. It is suggested that one of the worst aspects of sewing machine operations in the garment manufacturing industry is the body posture operators are forced to assume throughout the workday. Some factors like repetition, force, contact stress, vibrations and environment contribute to the injury and discomfort. The work is visually demanding and needs a high degree of accuracy and concentration. Several studies have been reported in literature such as (Panhale et.al. 2020) reported an ergonomic evaluation of work stations in garment industry, (Sealetsa 2011) discussed about the ergonomic issues of sewing machine operators in Botswana, (Parimalan 2006) suggested ergonomic interventions to improve work environment in garment units.

Similar studies reported by (Upasana and Vinay 2016, Mukunda et.al.2014, and Vandyck et.al. 2013) highlighted the ergonomic aspects in design of work stations. Another study [10] focused on the ergonomic design of work station for pregnant women. Some studies by (Kalinkara et.al.2011, Qutubuddin et.al.2013 and Aida Sheta et.al 2019) considered the significance of anthropometry data in workstation design. Some studies (Gahlot et.al 2016, Polat and Kalayci 2016, Moussavi et.al 2012) reported the application of RULA technique to assess risks of postures in garment industry. (Shah et.al 2016) reports a study on Prevalence of musculoskeletal disorders among garment industry workers. (Ozlem Kaya 2015) discusses the design of work station and other ergonomic issues in garment industry. The available literature points to various ergonomic techniques being applied in garment industry to assess evaluate and improve the work systems. As observed from the available literature several studies are conducted in garment industry in large scale enterprises, on specific areas like workstation design, prevalence of musculoskeletal disorders (MSDs), and postural analysis or on work environment. Very few papers are available on the complete ergonomic study of small scale or unorganised tailoring firms covering all aspects like postural analysis, prevalence of MSDs and work environment etc. in a single study. The authors feel that a small scale unit in unorganised sector lacks the services of specialists; hence a complete study facilitates the owners to consider the recommendations and implement them for the occupational health, safety and ergonomic concerns of the workers, thus showing signs of improvement in performance and productivity.

1.1 Objective

The objective of the present study is

- To identify the ergonomics deficiencies in the work place and work stations in garment manufacturing/Tailoring units.
- To identify the prevalence of MSD`s among the workers of the garment manufacturing units.
- To analyze the working postures of manual workers in small scale garment industries and tailoring firms by ergonomic assessment tool, Rapid Upper Limb Assessment (RULA) using CATIA V5R20 software.
- To measure the work environment in the garment units such as lighting, noise, temperature and humidity.

2.0 Methods

The present study is conducted in garment making and tailoring units located in Kalaburagi city. A total of 40 workers from 5 units were randomly selected as sample for the study. These units are involved in stitching garments; some of the units are bulk manufacturers of school uniforms and other garments for the local markets. The study comprises of a five stage approach i.e.

- Selection of workplace and sample size of workers,
- Direct observation and interview and Body Part Discomfort Survey.
- Data collection through discussions, questionnaire and photographs of postures, and measurement of environmental parameters.
- Postural analysis using RULA and digital modeling through CATIA and
- Recommendations and suggestions based on findings of the study.

Selection: Garment making units and tailoring firms located in and around Kalaburagi city. The criteria for selection were such units having more than 15 workers with an experience of more than one year. The tasks included fabric cutting, stitching and finishing (over lock, buttonhole, ironing and packing).

Direct Observation: An initial observation and survey of the workplace is carried out to understand the nature of problems and issues related to development of work-related musculoskeletal disorders and discomfort among the workers. Preliminary observations included understanding the work methods, compatibility between the work systems and workers anthropometry, getting feedback about pain/discomfort due to unnatural postures and the overall work environment, safety and occupational health isues.

Data collection: Several methods were used for data collection about the workers and appropriate measurements were carried out. Body part discomfort questionnaire was administered to determine the extent of pain/discomfort in different body parts. Anthropometric measurement of relevant body parts in sitting and standing positions were taken to identify the mismatch between the work systems and workers postural discomfort. Several working postures were videotaped and photographed for further analysis using RULA technique. Measuring instruments such as Sound level meter, lux meter, temperature meter were used to record the work environment.

Data analysis: Rapid Upper Limb Assessment (RULA) is one of the techniques of ergonomic risk assessment of upper extremities disorders (McAtamney & Corlett 1993). The postures to be analyzed are selected after detailed observations and discussions with the workers or supervisors. Such postures which contribute to major discomfort, requiring muscular activity or unstable, awkward or most frequently repeated are selected for assessment. The selected postures are scored for different body regions, muscle use and force using the RULA scoring sheet which is divided into Group A and Group B scores. Finally the RULA score is obtained by from table C in RULA scoring sheet which ranges from a no risk score of 1 to 7 being high risk score. Accordingly RULA score provides the four action level categories to be taken in order to control risks. The tool provides a fast assessment of the posture of the upper limbs, neck and trunk. The RULA scoring sheet for different body parts is given in Figure 1.

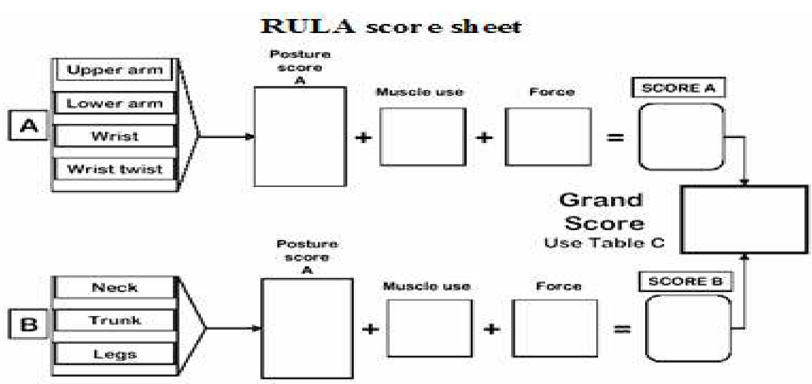


Figure 1: RULA score sheet (source McAtamney & Corlet, 1993)

2.1 Digital Human Modeling (DHM)

Digital Human Modeling (DHM) has rapidly emerged as technology of digital representation of human placed into a virtual environment to enable prediction of safety/performance (Karmakar & Patel 2014). DHM also refers to build, create or design virtual human models (known as human manikins) to represent most complex physical aspects of humans. When designing a new task or ergonomic evaluation of a workplace use of DHM approach makes it possible to study, visualize and analyze the posture or movement in a three dimensional graphical interface (Mohammad et.al. 2013). The common capabilities and functions of DHM includes the ability to move the manikins in predefined motions, Reach analysis, Posture analysis, Push/Pull analysis, Carrying analysis, Rapid Upper Limb Analysis and it have provision to scale 3D manikins by using anthropometric data available (Vaclay et.al). CATIA being the most popular software for RULA assessment method is used to analyse the work postures in the present study.

Digital Human Modeling in CATIA

In the present study, CATIA software is selected for RULA assessment method to analyze the awkward working postures of the selected workers. The photographs of the working postures taken from the industries were converted using Computer Aided Three-dimensional Interactive Application (CATIA) software, to conduct RULA analysis. Later, RULA analysis was done on the manikin with exact replication to assess the workers postural discomfort level (Mohammad et.al. 2013, Vaclay et.al, Manzoor et.al. 2019 [19]. Some of the actual postures and digital models built in CATIA for RULA analysis are shown in Figure 2.

Stitching	Ironing	Cutting	Stitching

Figure 2. Actual working postures of workers and digital models built in CATIA for RULA assessment

3.0 Results and Discussion

3.1 Preliminary Findings

A preliminary survey was carried out to assess the ergonomic problems and prevalence of MSDs among the workers in garment units and tailoring firms. The findings of the initial observation and worker complaints relating to posture, MSD, heat stress, time pressure, and health & hygiene are tabulated in Table 1. The information provided by the workers and initial observation and interview forms the basis of present study. The prevalence of postural stress and MSD risks are reported to be high. Time pressure happens to be moderate to sometimes high as the orders have to be delivered on due dates. The workers also complain about the high noise and absence of health and safety provisions.

Table 1. Worker Complaint on Ergonomic issues

Occupation	**A***	**B***	**C***	**D***	**E***	**F***	**G***
Garment Manufacturing & Tailoring units	High	High	Low	Moderate	Moderate to High	High	Moderate

***A**-MSD Problems, **B**-Postural Discomfort, **C**-Heat Stress, **D**- Health and Hygiene, **E**-Time Pressure, **F**-Noise, **G**- Any other (dust, vibration)*

3.1.1 Demographic data

The study was conducted in 5 garment manufacturing units located in North Karnataka. A random sample of 40 workers, including 20 males and 20 females from 5 garment manufacturing units formed the study sample. The average age, height, weight and experience are shown in Table 2 below.

Table 2. Demographic Data of Workers

Subject /Occupation	No. of workers	Mean age, Year (SD)*	Mean height, cm. (SD)*	Mean weight, Kg. (SD)*	Mean experience, Year (SD)*
Garment making	40	33.94 (8.36)	161.84 (6.27)	58.17 (5.91)	11.79 (6.68)

The mean experience of the workers is 11.79 year with (standard deviation of 6.68 year), the mean age of workers is 33.94 year (standard deviation of 8.36 year). It is to be noted that the workers are quite experience. Information about the personal habits of the workers like smoking, alcoholism, and tobacco intakes was collected. Information regarding availability of the welfare facilities, medical benefits and the use of personal protective devices was also collected

3.1.2 Problem areas identified

During the observation and discussions with the workers, several occupational health and ergonomics deficiencies in the work environment, furniture and equipment used that affects the health and safety of workers are revealed. After detailed analysis, some of the problems encountered in garment manufacturing are presented in Table 3.

Table 3. Problem areas identified in work environment

Place/ Area	Problem identified	Supportive findings
Cutting table	Height of the table too high	Postural discomfort and pain in neck, shoulders and hands
Sorting table	Work height too high	
Ironing table	Work height too low	
Sewing operation-stool	Improper seat, Height too high	
Inadequate illumination	Low level of lighting	Complaints of visual strain and blurred vision
Excessive noise	Noise level exceeds 90 dB(A)	Worker's complaints regarding high noise
Dust	In cutting sections	Respiratory problems
Hot and humid workplace	Humidity 26 to 57%	Risk factors

Some of the findings relating to the design of various furniture like cutting table, ironing table, seating during stitching operation and ironing table are presented in Table 3, which indicates that a high amount of mismatch between the anthropometry of human body and furniture design. It is one of the causes of discomfort and prevalence of MSDs as it leads to working in awkward postures.

3.1.3 Body Discomfort Survey

The outcome of the Body Discomfort Survey and Questionnaire are shown in Figure 3, as can be seen a majority of workers reported a high percentage of pain and discomfort in lower back, shoulders, neck and upper back (65%, 60%, 57.5% and 55% respectively). Moderate pain was reported in elbows, wrist/hand and ankles/feet. A major contributor of pain and discomfort is working in unnatural postures, repetitive tasks and poorly designed work stations. Similar values of pain and discomfort are reported in literature (Panhale et.al. 2020Upasana and Vinay 2016, Mukunda et.al.2014).

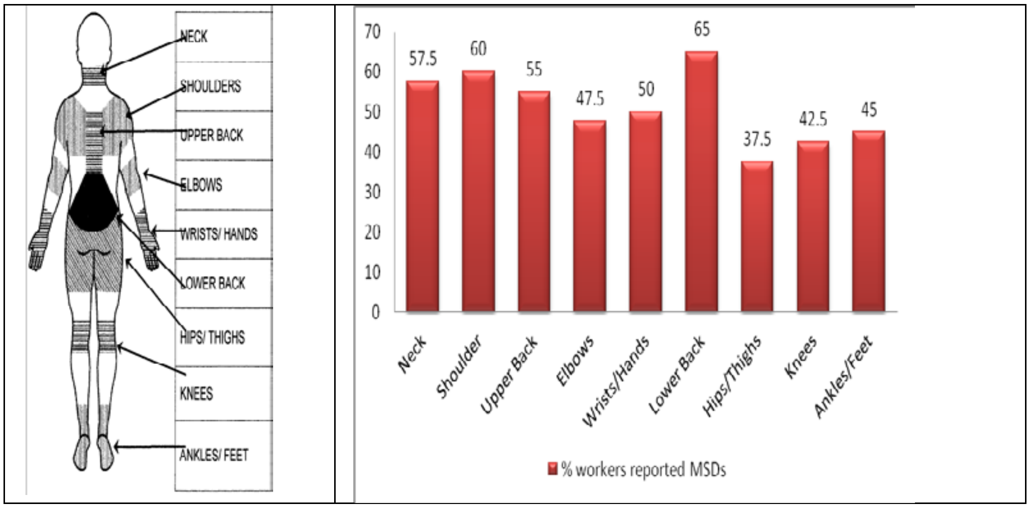


Figure 3. Reported frequency of musculoskeletal discomfort symptoms among workers in (%)

3.2 Rapid Upper Limb Assessment (RULA)

As reported earlier, RULA assessment tool is used to determine the risks in the working postures. About 40 postures from different sections like cutting, stitching, overlock, button hole, ironing and packing were taken. The photographs captured using a high quality camera are analysed. The photographs are printed and a 'Goniometer' is used to mark and measure the body part angles such as lower arm, wrist, upper arm, elbow, neck and trunk. The RULA assessment and scoring sheet proposed by (McAtamney & Corlett 1993) is employed to find out the risk score and subsequently the action to be taken. The findings of the analysis are shown in Table 4 and Figure 5. As can be seen about 47.50% of the postures analysed show a RULA score of 7 indicating high risk. Such postures are to be investigated further and change is required immediately. The Figure 4 shows the actual photos with markings to determine the body parts away from neutral axis.

Figure 4. Actual working postures with body angles marked for RULA analysis

Table 4. Distribution of RULA Score among Garment workers

RULA Score	**Risk level**	**Action**	**No. of workers**	**% of workers**
1-2	Negligible	Acceptable	0	0
3-4	Low	Investigate and change may be needed	07	17.50
5-6	Medium	Investigate, change soon	14	35.00
7	High	Investigate, change immediately	19	47.50
		Total	40	100

It can also be seen that the sewing machine operators in stitching section show high risks (about 50%) and the about 41% have medium risks. Similar results can be seen in other sections of garment industry. The high risk levels demonstrate that poorly designed workplace and workstations lead to awkward postures which cause muscular risks and discomfort among the workers.

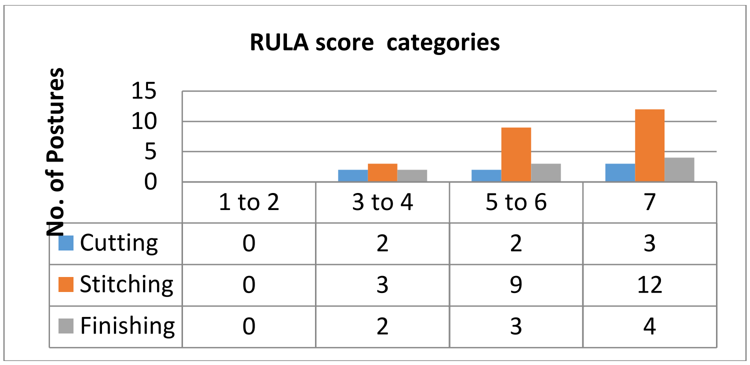


Figure 5. Process wise RULA scores and risk categories of postures

3.3 RULA analysis of Posture using CATIA

CATIA software offers solutions for ergonomic problems. The software has different modules like Human Measurement Editor, Human Builder, Human Activity Analysis and Human Posture Analysis [20]. Using the different modules it is possible to build an exact replica of human manikin with anthropometry dimensions and required body size. The modules facilitates manikin generation, gender and percentiles, how to manipulate with the manikin, animation etc. Human activity analysis allows interaction of human with the objects surrounding the workplace as well as lifting, pushing, pulling etc. and evaluates all postures. RULA is one of tool which is supported by this module. The first step in CATIA is to propose a manual workstation i.e. a 3D model is created as per known procedures. The second step is creating and describing a virtual human, indicating the type, gender and percentile. The RULA in CATIA involves detailed analysis of every posture of the manikin, the number of movements, static muscle work and duration of work. All these are combined into a final score from1 to 7 indicating the risks, and also given in color codes. The color codes in RULA analysis as indicated by CATIA are given in Figure 6. Green color indicates acceptable risk, yellow color low risk, orange color medium risk and red color high risk.

Segment	**Score Range**	**Color associated to the score**					
		1	2	3	4	5	6
Upper arm	1 to 6						
Forearm	1 to 3						
Wrist	1 to 4						
Wrist twist	1 to 2						
Neck	1 to 6						
Trunk	1 to 6						

Figure 6. Color code in CATIA-V5 and RULA Score

In Figure 7 some sample body parts modelled in CATIA indicating the range of motion to determine the safe working postures are shown. CATIA indicates the safe range of motion for different body parts such as head, neck, lower arm, upper arm, elbow, lumbar region and eye travel. Based on the angles made, the risks are determined. In order to reduce the risks, the ergonomist should design the workstation which allows for normal working postures, so that the RULA scores are minimum for each body part, thus reducing the final RULA score.

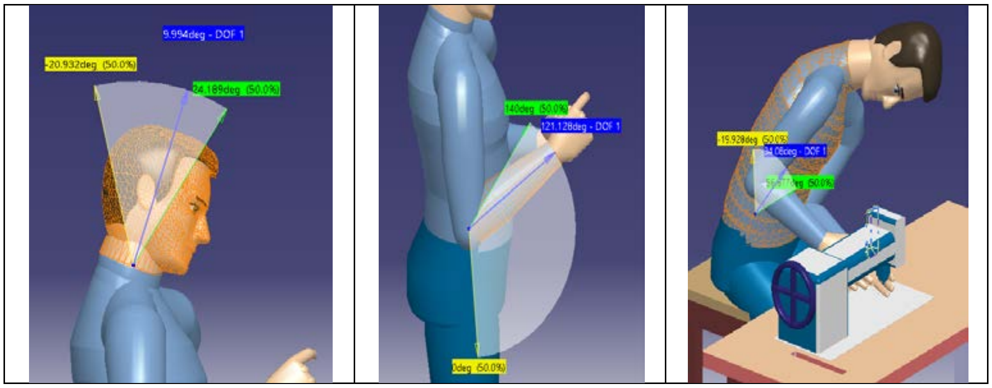
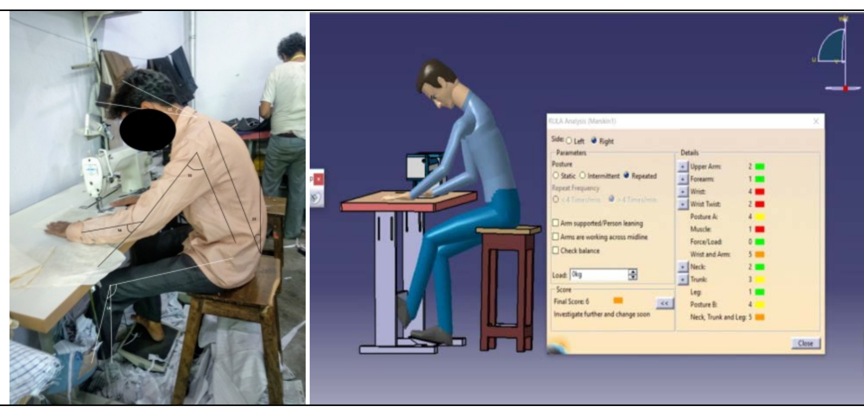


Figure 7. Showing the development of manikin and range of motion of head, lower arm and elbow in CATIA

In Figure 8 (a) and (b) actual working postures of the workers stitching garments are taken from two different units. As can be seen from the figure both the workers are subjected to awkward posture. The seating is not properly designed without any cushioning or lumbar support. Both the postures are evaluated for risk level using RULA analysis in CATIA. Figure 8 (a) gives a RULA grand score of 7, high risk which necessitates immediate change in posture to avoid further complications. The major criteria for both the postures are uncomfortable seating, high wooden stool, much bending in lumbar region and no back support. To overcome these issues, a human manikin is developed with the same body dimensions and modelled in CATIA. The model built shows a change in seating providing for a lumbar support and height of the stool according to the anthropometry to keep the posture in neutral position as close as possible. The modelled human manikin is evaluated using RULA analysis. It gives a final score of 4, indicating low risk. The small improvements observed in workplace and ergonomic interventions lead to reducing the risks of work-related musculoskeletal disorders.

a



b

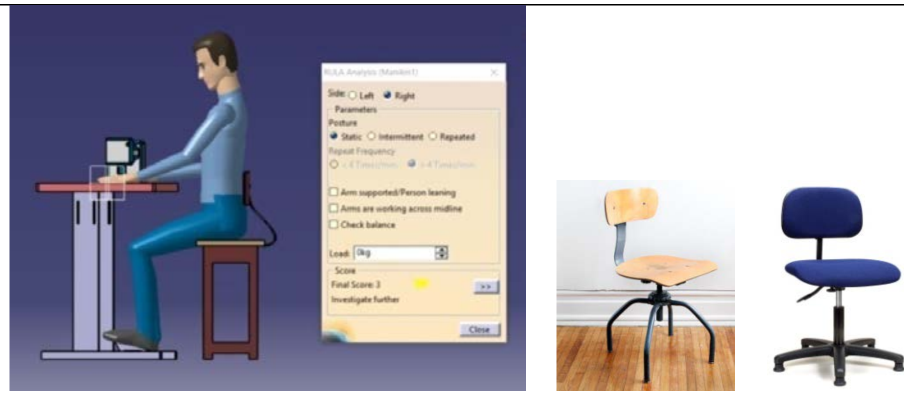


Figure 8. Actual Working Postures in stitching (a) & Digital Human Modeling in CATIA and RULA scores, and (b) showing suggested improvement

In the Table 5 the RULA scores for each body part and the final grand score for posture shown in Figure 8 (b). It is recommended to use an adjustable chair with a low back support. Some photos of chairs are shown in Figure 8(b) which can be procured. Also it is recommended to have an adjustable table so that the operator can have flexibility according to his/her anthropometry dimensions. With the ergonomic interventions recommended, the RULA posture score is reduced from a high risk of 7 to low risk of 4.

Table 5: Comparison between RULA scores for existing workstation and showing improvements in CATIA modeling & simulation

Work Station	Task/ Activity	Upper Arm	Lower Arm	Wrist	Wrist Twist	Table A	Neck	Trunk	Legs	Muscle Score	Force/ Load	Table B	Final Score
B	Stitching old	3	1	4	2	5	2	3	1	1	0		7
B	Stitching new	2	1	2	2	5	1	2	1	1	0		4

4.0 Work Environment

4.1 Illumination

The average lighting levels in the cutting and stitching sections were 275 and 325 lux respectively. This was found to be low when compared to the standard levels recommended by (Grandjean E. 1988), for fine work which are 500 to 700 lux respectively. The inappropriate selection of lighting and their arrangement failed to give the desired levels of illumination at the point of operation. Due to absence of task lighting the workers complained about the occurrence of accidents such as needle piercing because of the visual strain caused by inadequate illumination at the point of task.

4.2 Noise

The noise exposure levels measured were high and the workers exposure over long periods resulted in noise-induced hearing loss and other related health problems. The poor maintenance of the sewing machines further added to the high levels of noise. The level of noise ranged from 76 dB (A) to 103 dB (A) with a mean value of 92.3 dB (A). In India the current threshold limit for continuous noise exposure for eight hours is 90 dB (A). Hence, in the current study the noise levels were found to be exceeding beyond the recommended levels. Dust problems were reported from the cutting section by 25% of the workers. In the finishing section, due to use of the steam iron, the environment was hot and humid. The worker complaints regarding the high levels of noise were from the stitching section 70.83% and the cutting section were 57.14%, Table 6.

Table 6. Work environment complaints in different sections

(n=number of respondents having complaints)

Physical working conditions	Cutting (n=7)		Stitching (n=24)		Finishing (n=9)	
Total number of workers	No.	%	No.	%	No.	%
Noise	4	57.14	17	70.83	4	44.44
Illumination	5	71.42	13	54.16	6	66.67
Temperature	3	42.80	15	62.50	3	33.33

4.3 Accidents and Injuries

The results also highlight that major injuries were reported in the cutting and stitching sections. The most common accidents from the cutting section were cuts and bruises while operating the cutting machine. The proper use of hand gloves in necessary to reduce such injuries and protect the fingers. In addition to the above, the continuous use of shears led to swelling of fingers. Most of the workers wrap the handles of the shears with a piece of cotton cloth to reduce the friction of the metallic handle on the muscles and the resultant pain. In the stitching section, most common injury was piercing of the needle, sometimes the broken needles may fly into the body or eyes. Injuries to both the middle finger and index finger were also reported. A number of cases of burning of fingers and arms were reported from the ironing section. The numbers of accidents reported during the year are shown in Table 7.

Table 7. Distribution of accidents faced under the various sections (n= Number of respondents)

	Cutting (n=7)		Stitching (n=24)		Finishing (n=9)	
Total number of workers	No.	%	No.	%	No.	%
Accidents reported	3	42.85	7	29.16	3	33.33

Other deficiencies observed in the garment industry were the absence of safety devices like fire extinguishers, alarms and emergency exits, and also the first aid box. The general health related problems of the workers in garment industry are presented in Table 8, which show that 29.73% of the workers have hearing problems, and 43.24 workers have visual problems in stitching section. The high prevalence of MSDs is seen as 59% of the workers report having discomfort and pain.

Table 8. Frequency of health related problems of the workers (n=Number of respondents)

Health problems	Cutting		Stitching		Finishing	
Total number of workers	No.	%	No.	%	No.	%
Hearing	5	13.51	11	29.73	0	0
Visual	3	8.10	16	43.24	13	35.13
Skin related	7	18.91	4	10.81	10	27.02
MSDs	11	29.73	22	59.45	13	35.13
Vibration related issues	1	2.50	7	18.91	0	0

4. Conclusion

The present study highlighted the ergonomic deficiencies and other work related discomfort, poor working conditions, environment and safety issues in unorganised garment units and tailoring firms. Most of the workers are stressed out and show signs of tiredness and fatigue. One cause may be the poor work station design where the workers adjust themselves according to the system resulting in working with unatural/awkward postures. Rapid Upper Limb Assessment scores indicated more than 45% of the postures in high risk category, which require further detailed investigation and change in the postures. Some of the working postures selected were modeled and simulated using CATIA software to indicate the kind of improvements possible through low cost ergonomic interventions. Ergonomic interventions are recommended in work station design, providing adjustability to the workers, thus reducing postural stress considerably. One of the immediate solution is changing the wooden stools used by stitching workers with a adjustable chair designed according to anthropometry which can reduce the number of complaints related to back pain and discomfort. The illumination and noise levels were found to be beyond the standard values, which can be improved. The workers's complaints regarding accidents can be addressed by giving proper training and ergonomic awareness. In general several improvements are possible through application of ergonomic principles which can reduce the risks due to awkward postures of the workers leading to a healthy workforce. The present study is the beginning of a long term plan of the authors to study the garment industries in the informal/unorganised sector and bring out the ergonomic deficiencies and suggest improvements.

References

M.Manzoor Hussain, Qutubuddin S.M, Katuru Phani Raja Kumar and Ch.Kesav Reddy- Digital Human Modeling in Ergonomic Risk Assessment of Working Postures using RULA- *Proceedings of the International Conference of Industrial Engineering and Operations Management Bangkok, Thailand,March 5-7, 2019*

Qutubuddin S.M., Hebbal S.S, ACS Kumar., Computer Assisted systems for Enhancing the Application of Ergonomics in Manufacturing Systems', *International Journal of Ergonomics (IJEG)* , Malaysia. Volume 2, No.1, pp. 1-11, April 2012

Jagadish R, Asif Ansari, Sameer Quraishi, Ayesha Sultana and Qutubuddin S.M - Ergonomic Risk Assessment of Working Postures in Small Scale Industries, *Grenze International Journal of Engineering and Technology, Special Issue*,(2018) 202-208

Vrushali Panhale, Prachita Walankar, Dhruvi Doshi, Drasti Desai- Evaluation of Musculoskeletal Pain and Posture in Embroidery Workers of Mumbai – A crosssectional study, *International Journal of Health Sciences and Research*, (2020) Vol.10 (1) ISSN: 2249:9571

O.J. Sealetsa and A. Thatcher - Ergonomics Issues Among Sewing Machine Operators in the Textile Manufacturing Industry In Botswana-*Work* 38 (2011)279-289, ISSN-1051-9815.

P.Parimalam, N.Kamalamma, A.K.Ganguli -Ergonomic intervention to improve work environment in the garment manufacturing units - *IJOEM*-August (2006) volume 10 issue 2 page no 74 - 77

Upasana and Deepa Vinay- Ergonomic evaluation of work related musculoskeletal disorders among tailors, *International Journal of Home Science*, (2016), Vol.2(3) 283286 ISSN 2395-7476

Mukunda A et.al - Ergonomics Evaluation of the Work Station in a Garment Manufacturing Industry- an Exploratory Study - *International Journal of Mechanical and Production Engineering*, ISSN: 2320-2092, Volume 2 issue-4 April 2014.

Efua Vandyck, Seth Oppong, William Senayah and Elizabeth Ba-ama - A review of Ergonomically designed work seats; the situation of small- scale garment producers in Ghana - *International Journal Of Education Reserach And Reivew* (2013) Vol.2(5), pp. 017-022, ISSN : 2329-9843

Velittin Kalinkara, Nurten Cekal, Ilgaz Akdongan and Nesrin Kacar - Anthropometric Measurements Related To The Workplace Design For Female Workers Employed In The Textiles Sector In Denizli, Turkey - *Eurasian Journal Of Anthropology* – 2(2): 102-111, 2011

Qutubuddin S.M, Hebbal S.S, Kumar A.C.S- Significance of anthropometric data for the Manufacturing Organizations, *International Journal of Enginnering Reserach and Applications*. 2013; 5:111-126.

Aida sheta, G,Abou-Ali, Sherwit.H, EI-Gholmy and Amira. M. Eladly - Anthropometric body measurements and the ergonomics design of the sewing machine workstation, *Textile Bioengineering and Information Symposium At: University of Manchester*, Manchester, UK, 2019

Neha Gahlot, Manju Metha and Kiran Singh - Assessment Of Posture Discomfort Among Female Sewing Operators - *International Journal of Bio-Resource and Stress Management* 2016, 7(1): 115-118

Seyyed Ali Moussavi Najarkola and Ramazan Mirzaei - Evaluation Of Upper Limb Musculoskeletal Loads Due To Posture , Repetition And Force By Rapid Upper Limb Assessment In A Textile Factory - *Health Scope International Quarterly Journal* 2012; (1): 18-24

Olcay Polat and Can B.Kalayci - Ergonomics risk assement of worker in garment industry - Textile Science and economy VIII 8th *International Scientific- Professional Conference* May 16-19st , 2016 Zrenjanin, Serbia.

Shah ZA , Amjad A , Ashraf M, Mushtaq F and Sheikh IA – Prevalence of MSD problems in a Pakistani Garment Manufacturing Industry, *Malaysian Journal Of Public Health Medicine* 2016, volume 16(Suppl.1) : 75-79

Ozlem kaya-Design of Work Place and Ergonomics in Garment Enterprises - *Elsevier - Proceedia Manufacturing* 3 (2015) 6437 - 6443.

Lynn McAtamney and E Nigel Corlett., RULA: a survey method for the investigation of world-related upper limb disorders, *Applied Ergonomics*, 24(2), pp.91-99, 1993

Sougata Karmakar, Sanjog J and Thaneshwar Patel- Digital Human Modeling and Simulation in Product and Workplace design: Indian Scenario, *IJERA*, (2014) ISSN 2248-9622

Darliana Mohamad, Baba Md Deros, Ahmad Rasdan Ismail, Dian Darina Indah Daruis, Ezrin Hani Sukadarin – RULA Analysis of Work-Related Dosorder among Packaging Industry Worker Using Digital Human Modeling (DHM), *Advanced Engineering Forum*, (2013) vol.10 pp 9-15 ISSN 2234-991X

Stefan Vaclav, Katarina Senderska, Albert Mares- Design of Manual Assembly Workstations in CATIA, Technical article, Technical University of Kosice pp.41-49

Grandjean, E. 1988- Fitting *the Task to the Man: An Ergonomic Approach*, London: Taylor and Francis

Bibliographies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