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Ergonomic Assessment in the Apparel Industry Using Rapid Entire Body Assessment (REBA) Among Workers in India in Finishing Department

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ABSTRACT

This study aimed to assess ergonomic risks in the garment industry's finishing department using rapid entire body assessment (REBA) among ready-made garment workers in India. This study evaluates ergonomic risks associated with work-related musculoskeletal issues (WMSDs), mainly on the lower back, neck, and limbs, and explores the impact of body mass index (BMI) on posture. A convenience sampling study included 35 employees (male, 23; female, 12; age, >18 years) at a garment unit in Kolkata, India. Data were collected through observation, video, and photo analysis using Kinovea software. The respondents had a mean age of 40.14 years (SD = 8.96) and mean BMI of 24.73 kg/m2 (SD = 2.96). The study revealed a statistically significant relationship between BMI and head and neck flexion angles across operations (p-values: ironing - head: 0.007, neck: 0.01; quality checking - head: 0.004, neck: 0.004; packing - head: 0.001, neck: 0.006; thread trimming - head: 0.001, neck: 0.01; stain removal - head: 0.001, neck: 0.02). The study revealed a high prevalence of musculoskeletal disorders among Indian garment finishing operators due to awkward postures and prolonged standing, evident in the medium to high-risk REBA scores. The Application lies in understanding the relationship between BMI, head/neck flexion angles, and occurrence of musculoskeletal problems which helps to design better workplace environments for garment finishing workers in India.

Keywords: Risk assessment, Anthropometry, Job risk assessment, Musculoskeletal disorders, Quality Control, Work measurement, Industrial/workplace ergonomics, REBA (Rapid Entire Body Assessment), BMI

1. Introduction

The productivity of the manually driven apparel industry depends heavily on the efficient utilization of human resources. While operational management solutions that extend the use of human resources may initially appear to increase productivity, they can negatively impact workers' health if ergonomic considerations are overlooked (Purushothaman Ravichandran et al., 2016b). Improving worker utilization potentially helps businesses in revamping productivity in the short term, however, it could also result in serious health problems over the long run. Due to occupational health rules, these issues not only cause substantial medical costs for the business but also necessitate continuous payments to employees (Litchfield et al., 2016).

In the garment manufacturing industries, sewing machinists suffer from several health problems, like musculoskeletal disorders of the neck and shoulders which have been attributed to poor working postures as well as to the repetitive hand and arm movements (Chopde & Deshmukh, 2018). The repetitive motions involved in the garment industry in the cutting, sewing and finishing department with inadequate ergonomic conditions, can lead to work-related musculoskeletal disorders (S. Shah et al., 2020). In industry, special attention should be paid to the common postures like Standing, Sitting, Reaching, and Moving (Openshaw & Taylor, 2006) . Improper working postures constitute one of the primary risk factors for work-related musculoskeletal disorders, from minor back pain to severe disability (Kaya, 2023). In the clothing industry, serious accidents are relatively rare compared to other industries (Calvin & Joseph, 2006). However, the main health risks for clothing workers are not immediate, life-threatening hazards. Instead, they arise from more subtle hazards that accumulate over time (Saravanan, 2011.), (Polat & Kalayci, 2016). Initially, these hazards may cause minor pains, but they can develop into debilitating disorders that affect workers' daily lives (Saravanan, 2011). Ergonomics plays a vital role in preventing such problems by addressing risk factors like vibration, repetition, working environment, force, and posture before the onset of disorders. Consequently, there has been a significant increase in ergonomics risk assessment studies within the garment industry in recent years (Gade et al., 2015).

Sewing machine operators, for instance, face a significantly higher risk of muscle pain and injury compared to workers in other occupations (Kanniappan & Palani, 2020), (Okareh et al., 2021) Studies have shown that the frequency of persistent neck and shoulder injuries increases with years of employment in this role (Jana, 2015).

According to the International Ergonomics Association (International Ergonomics Association, 2022), "Ergonomics (human factors) is a scientific discipline concerned with understanding interactions among human-beings and other elements of a system and a profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance" The Greek words Ergos, which means "work," and nomos, which means "law," are the origin of the phrase ergonomics. British scientists who were concerned with the effective use of sophisticated military technology first used this term during World War II (Upreti et al., 2018).

In general, people think working in the apparel sector is safe. Clothing manufacturing facilities see comparatively few serious incidents when compared to other industries, immediate, potentially lethal threats do not present the greatest health risks. Conversely, less obvious dangers that have a cumulative effect over time provide the risks that garment workers must deal with. The workday often comprises extended hours with one midday meal break. Rarely are these workers given suitable workstations, and the lack of strong social infrastructure increases the likelihood of discomfort and disease (Ali & Baset, 2022). But these dangers are rarely looked into at work (Gade et al., 2015). Workplace safety issues have been linked to serious public health issues, including Work Related Musculoskeletal Diseases (WRMSDs).

There is mounting evidence that work-related factors contribute to upper limb chronic musculoskeletal problems Repetitive, forceful, or posture-required jobs have been linked to work-related musculoskeletal diseases (WRMSD) (Sealetsa & Thatcher, 2011). In the garment industry there are different sectors or units like cutting, sewing, finishing, Packing etc. In each sector there are different highly repetitive motions, and awkward work postures which cause this type of musculoskeletal disorder (Aribowo et al., 2020). In this paper, we will examine the ergonomic risk assessment of repetitive

motion in the finishing department, and the diseases related to this problem (Ali & Baset, 2022).

The operator's comfort and quality have a significant impact on output and product standards. As a result, it must evaluate the relationships between workspace and body dimensions that lead to changes in body posture. This leads to two conclusions: first, the working environment constrains the operator's posture, and second, the operator adapts to the workspace, which causes musculoskeletal complaints. Therefore, it is important to work to reduce operator complaints by redesigning the workstation to accommodate the operator's posture and consider their perceptions (A. Eladly & Gholmy, 2019). This research caters to areas in the finishing departments to study their ergonomics risk using REBA methods.

2. Literature review

India is the world's second-largest producer of textiles and garments. It is also the fifth-largest exporter of textiles spanning apparel, home and technical products. The textile and apparel industry contributes 2.3% to the country's GDP, 13% to industrial production and 12% to exports. Around 45 million people are working in the textile business, including 3.5 million people who work on handlooms (India Brand Equity Foundation, 2023). It is very important to examine the ergonomics hazards to which production-related employees are exposed, as well as the movements, improper postures, pains, and activities that are most responsible for absence from work. Most of these units have dangerous and unhealthy working conditions. Poorly constructed workstations, incorrect furniture, inadequate protection from hazardous chemicals, inadequate safety protocols in case of fire emergencies, a lack of personal protective equipment, and inadequate ventilation are a few examples (Soni & Jana, 2020). The risk of occupational diseases increases for those who work in such unsanitary or subpar conditions(Parimalam et al., 2006). Operators who have been impacted by these injuries have experienced more than just physical, mental, professional, and familial maladjustment. It is a partial loss of ability to work or even complete while the operator is at the peak of their productivity and professional expertise (Melo Junior, 2012). It has examined the impact of iron weight on muscular fatigue and body pain experienced during standing ironing and using a lightweight iron (0.77 kg) resulted in significantly less muscular fatigue and body pain compared to heavier irons (Aujla et al., 2008).

Work-related diseases and injuries were responsible for the deaths of 1.9 million people in 2016, according to the first joint estimates from the World Health Organization (WHO) and International Labor Organization (ILO)(WHO/ILO: Almost 2 million People Die from Work-Related Causes Each Year, 2021).

So, much research has been conducted in order to figure out ergonomics risk and reduction of risk by introducing various types of tools and techniques. In the garment manufacturing process includes various tasks, with workers in the checking section experiencing discomfort. To address this, a height-adjustable table with a tilting surface was designed based on ergonomic considerations, activity type, time, and productivity (Ganguli et al., 2009).

When performing repetitive ironing tasks, neck pain is more common (89.33%) than wrist/hand pain (81.33%) and shoulder pain (73%) combined. Both male and female employees frequently experience the symptoms of MSD. Some research in ergonomics focuses on human comfort because it improves relationships between people, machines, and workplaces. (Anand & Kumar, 2019).

Musculoskeletal problems are a typical occupational issue for Indian employees. In a study provides an evaluation of workers' work postures while performing various tasks in the apparel industry. Because of the

general lack of awareness of ergonomics, most workers have uncomfortable postures. Therefore, there is a moderate to high risk of musculoskeletal disorders among the workforces (Yasotha et al., 2018).

A trustworthy direct observational ergonomics risk assessment technique that the risk connected to the workers' chosen working postures was determined using the Rapid Entire Body Assessment (REBA) (Joshi & Deshpande, 2019).

In a study,180 postures were chosen, and the REBA method was used to analyze the data. More than 30% of postures revealed a high level of MSD risk, necessitating an immediate assessment for improvement, leading to the conclusion that overall working strategies were poorly developed. Major risk factors were connected to postural movements of the wrist, lower arm, and neck. The study's findings advance knowledge of cutting and sewing conditions in the apparel manufacturing industries, and they may be used to build ergonomic interventions that will lessen musculoskeletal complaints and enhance job quality, both of which will lead to increased work productivity (Ahmad et al., 2021).

Heavy workloads over extended periods of time, garment workers often experience musculoskeletal problems (Ashiq et al., 2021).

The sewing operators' anthropometric data, which should be considered in the case of ergonomically re-designing the sewing workstation, were somewhat correlated with the sewing operators' sitting posture angles on the kinematic stage (Eladly & El Gholmy, 2019).

In a study from the anthropometric measurement and type of sewing machine, sewing operators' sitting posture angles in the kinematic stage were affected. When ergonomically redesigning the sewing machine workstation, it's crucial to consider these two factors. Additionally, a notable correlation has been observed between the inclination angles of the workstation and the operator's BMI (Eladly, 2020).

In a study, some adjustments were applied by machine tilting in the workstation and a significant reduction in ergonomics problems were attained, proportion of Sewing Operator Related Defective Products (SORDP) was reduced by 56% in Line 1 and by 52% in Line 2. It was concluded that ergonomics interventions served to improve quality via reduction of operator errors in machine sewing task (Erdinc & Vayvay, 2008).

A Standard Nordic Musculoskeletal Questionnaire was used to collect detailed information on musculoskeletal symptoms, sociodemographic data, and factors associated with the problems through face-to-face interview. A total of 422 sewing machine operators included in the study 370 (87.7%) were females and 306 (72.5%) were in the age group of <30 years. The prevalence of self-reported work-related elbow and wrist musculoskeletal disorders was 40% and 37.7%, respectively (Kebede Deyyas & Tafese, 2014).

Another experimental study to determine the risk scores for the jobs performed by the operators in the maintenance and repair unit, REBA and RULA approaches were applied. As a result of the studies, it was decided to apply the mechanical parts in place in a way that minimizes the risk levels as improvement suggestions for clamping, milling, and turning operations that require urgent intervention (Muhacir et al., 2023) .

This study sheds light on the prevalent issue of neck pain among sewing machine operators, attributing it to prolonged forward-inclined positions leading to Forward Head Posture (FHP). With a substantial 64.67% prevalence of FHP among operators and 77.45% among those experiencing neck pain, the research underscores the significant impact of poor posture. Notably, a noteworthy but modest negative correlation between Craniovertebral angle (CVA) and

neck pain intensity (p=0.036, r= -0.208) suggests a connection between posture and pain. These insights emphasize the need for ergonomic interventions to address musculoskeletal issues in this occupational group (Wagachchi et al., 2020).

In Tirupur, it has been found that 77.6% experienced musculoskeletal problems, with the neck (32.1%), knee (28.7%), and low back (26.6%) being the most affected areas. This study was conducted on 380 garment industry workers. More than half reported moderate pain, and 54.2% sought healthcare, predominantly at government hospitals. Shockingly, only 8.7% of workers had acceptable posture. The findings underscore the urgent need to address health concerns among garment workers by reducing work strain and creating a supportive workplace environment for improved productivity (Purushothaman Ravichandran et al., 2016a).

In a study encompassing 200 workers across cutting, stitching, finishing, and packaging departments in Jaipur's apparel manufacturing industries, findings showed high-risk levels for musculoskeletal discomfort, especially in neck, trunk, and wrist areas. Recommendations include immediate ergonomic interventions, regular postural changes, and proper education to enhance worker health, efficiency, and overall industry productivity. The study underscores the urgent need for solutions to prevent injuries and improve the well-being of apparel manufacturing workers (Lodha & Kashyap, 2016).

A pilot cross-sectional study on garment industry workers identified significant ergonomic risks, with the lower back posing the highest danger. Female workers experienced more discomfort than males, and standing workers reported higher discomfort levels than those sitting. Surprisingly, the number of job years didn't correlate with discomfort. Objective assessments using RULA and REBA tools revealed no workers receiving acceptable scores, emphasizing the urgency of a comprehensive company-wide ergonomic assessment to address worker well-being promptly (Z. A. Shah et al., 2016).

Rapid Entire Body Assessment (REBA)

When examining ergonomic assessment techniques, studies in various fields using the REBA and RULA methods are popular and attract attention. The study first by Hignett and McAtaney includes ergonomic assessments of nurses' working environments (Hita Gutiérrez et al., 2020). The study's goal is to assess the risk level of the healthcare workers' uncertain work environment. The initial phase in developing the Rapid Entire Body Assessment (REBA), a postural analysis tool, designed for unpredictable working postures, particularly in healthcare and service industries, REBA incorporates dynamic and static postural factors, human–load interface, and a novel gravity-assisted upper limb concept. Although initial reliability in inter-observer coding is promising, further research is required to establish the tool's validity (Hignett & McAtamney, 2000). In REBA the whole-body parts are taken for the investigation process. The other importance of the REBA technique is to analyze the critical or awk-ward postures in different ways, especially in health care sectors based on awkward activities. The scores can be varied from task to task based on the human performance and risk factors involved in these specific job performances (Ramaganesh et al., 2021).

Research Gap

The issue of diversity in studies conducted in various countries by using REBA is mostly related to the lack of research concerning the Indian apparel industry, particularly in area of the finishing department. Different working conditions, practices, and ergonomic challenges can be quite different in a given region, and hence, findings from other regions may be of little use to the research in question if they are not directly applicable to the Indian context. Interest in the finishing department does not get enough attention, it is often possible to find research

on ergonomic assessments within the apparel industry, but the finishing department usually is left out of such research. The finishing department faces the specific ergonomic problems that require more extended research.

Significance of the research

It is significant for the garment industry since a majority of garment workers engage in repetitive tasks with uncomfortable body postures, ultimately resulting in work-related musculoskeletal disorders like back pain, neck pain, repetitive motion injuries, strain injuries, cumulative trauma disorders, and more (Ramdass, 2013). Ergonomic research can identify risk factors and provide solutions to reduce the risk of injury and improve health and well-being. This can help prevent accidents and injuries, reduce absenteeism, and improve employee morale. It can help with productivity by improving efficiency, which can lead to increased output, improved product quality and reduced costs. It will enhance the workers' comfort and job satisfaction as well. Many countries have labor laws and regulations that require employers to provide safe and healthy working conditions for their employees. This will help the garment manufacturers comply with these laws and regulations, avoiding penalties and legal issues.

Table 1. REBA score and action levels

Action level	REBA score	Risk level	Action (including further assessment)
0	1	Negligible	No action required
1	2-3	Low	Change may be needed
2	4-7	Medium	Further investigation, change soon
3	8-10	High	Investigate and implement change
4	11+	Very high	Implement change

Source: (Taghavi et al., 2017) & (Middlesworth, 2017)

Objectives of the research

- To evaluate the level of exposure to ergonomic risk factors among workers in the finishing department using REBA. To determine if there is any relationship between BMI with head and neck flexion angle.

3. Materials and Methods

In this section, the methodology followed to achieve the objective of the proposed research is discussed below which helps understand the ergonomic risk assessment in the finishing department at garment industry in India, Kolkata. Here workers are involved in various task such as Ironing packing labeling, and quality checking. A study of ergonomic risk assessment of repetitive motion in the finishing department using REBA software will include this following step:

Steps-1- Selection of work in the finishing department.

Steps-2- Observation of the selected work postures in the finishing department.

Steps-3- Data collection using video and images of various work posture of finishing worker.

Steps-4- Annotation of posture angle of worker using Kinovea software.

Steps-5- Data analysis using the REBA method.

Steps-6- REBA Scoring of postures of all finishing workers.

The study focuses on individuals working within the garment industry, particularly those involved in quality checking, ironing, packing, labeling, and stain removal. This Study focuses on the workers who have consistently carried out these tasks for an extended duration, working an average of 1 year and 6 days per week, for 8 hours each day.

To determine prevalence of WMSD, researcher use the Rapid Entire Body Assessment (REBA) method (Karuppiah et al., 2020) which assesses biomechanical and postural loads on the body using a systematic process by screening whole-body. Assessment worksheet for REBA is shown in Figure 1.

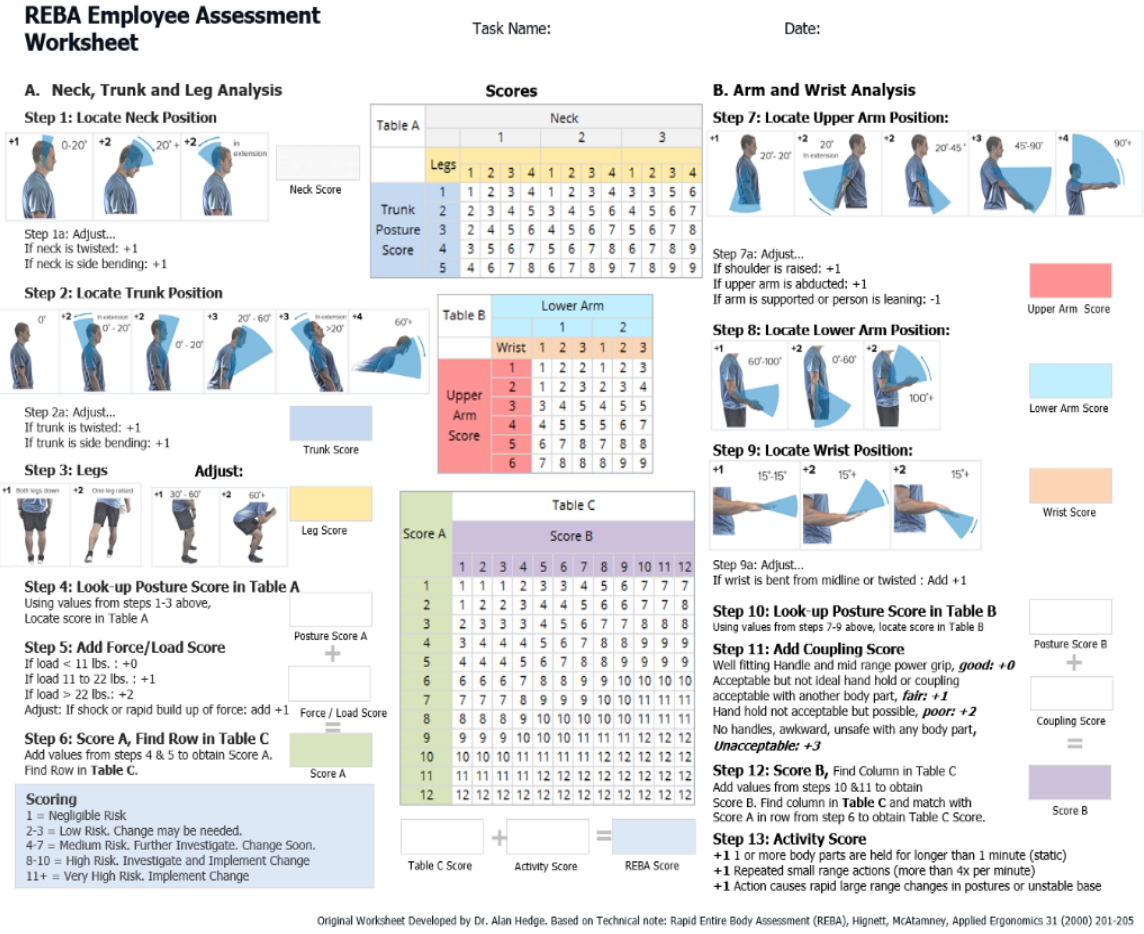

Figure 1. REBA employee assessment worksheet

4. Results, Analysis and Discussion

REBA analysis of Ironing

In the finishing department of garment industry there are various steps to follow. These include quality checking, ironing, and packaging. Each task has different levels of risk. In the garment industry, ironing is a necessary step using pressure and heat to remove creases from materials, which requires extended standing, repetitive action, and awkward postures, all of which contribute to musculoskeletal disorders (MSDs) in work. Ironing clothes is considered moderately heavy activity which demands lot of muscular effort (Sudhan, 2014).The workplace measurement of ironing table is given below.

- Length of the iron table: 60''

- Width of the iron table: 36''
- Hight of the iron table: 18"
- Workplace area: 60''X18''
- Iron's weight: 1.5kg (*Ironing Technology for Textile Care*, n.d.)

The study has been conducted at Regiment Garment Park Barasat in 2nd line of finishing. The Workplace environment of the company is given below.

- **Light**: 226-224 Lux
- **Humidity:** 73%
- **Temperature:** 32℃
- **Noise** :72-76.2 dB

Body flexion angles of the worker were estimated by using Kinovea software (see Figure 2) and the results have been analyzed for ironing operation (Figure 3 -a) using the REBA method are presented in the steps shown below. The total average cycle time of ironing a T-shirt is 36.45 sec and a total of 15 cycles have been overserved. Workers were working under the above working conditions.

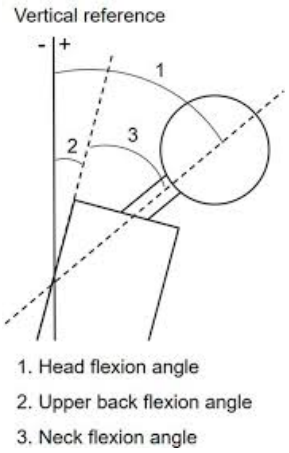

Figure 2. Measuring Upper Body Flexion Angle. Source: (Yoon et al., 2021)

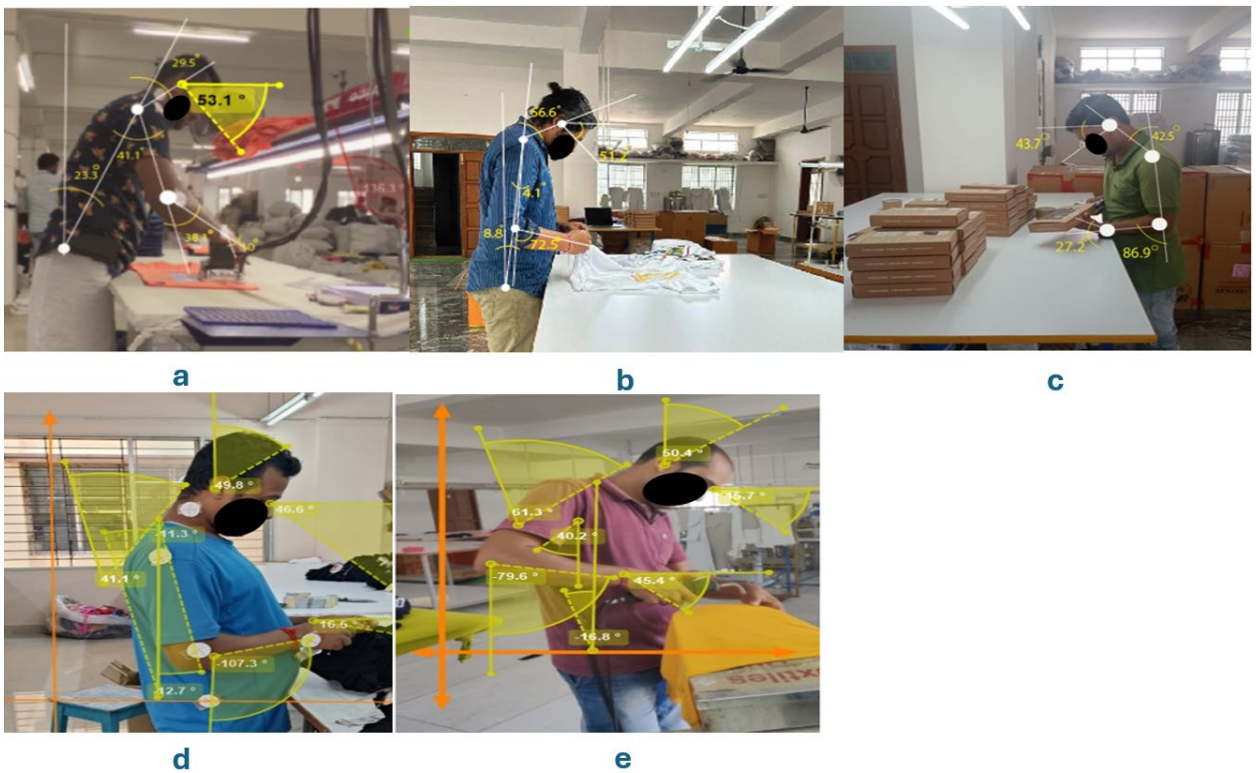

Figure 3. Different types of finishing Operation a- Ironing, b- Quality check, c-Packing, d- Thread trimming, e-Stain Removal (Posture angle analysis using Kinovea)

Step-by-step analysis of Ironing operation

- **Section A: Neck Trunk and Leg Analysis**

Step-1: Locate Neck Position

As per the above Figure 3-a, the neck flexion of the worker was 29.5° which is greater than 20°, because of bending from a straight line, the risk score of neck is +2.

Step-1a-Adjusted

The neck was "side bending" so, +1 is added. So, the total risk score is 2+1= 3.

Step-2: Trunk position.

The trunk position of the worker was 23.3° which falls within 20°-60°, and due to lack of turning, the risk score is considered as +3.

Step-3: Leg position.

The two legs were bearing the same weight both legs are down, so the point is +1.

Step-4: Look up posture Score in Table A (Figure 1 **-REBA chart)**

From the values of step 1-3 the posture score in Table A (Figure 1) is 5

Step-5: Load /force score.

The weight of the iron is less than 11lbs, so the risk score is +0.

Step-6: Score A

Adding values of step 4 and step 5, obtained Score A (Figure 1) is 5.

- **Section B: Arm and wrist analysis**

Step-7: Upper arm position.

The estimated angle of upper arm was 41° which is within the range of 20°-45°, so the risk score is +2.

Step-8: Lower arm position.

The approximate angle of lower arm is in 38°, so the risk score is +2.

Step-9: Wrist position.

Approximate angle of wrist was 10°, risk score is +1.

Step-9a: Adjusted

Wrist was twisted so according to REBA chart risk score is +1. Final score in step-9 is +2.

Step-10: Look up posture Score in Table B (Figure 1 **-REBA chart)**

From the values of step 7-9a the posture score in Table B (Figure 1) is 3

Step-11: Coupling Score

Iron handle is good to hold it, so coupling score is +0.

Step-12: Score B

The sum of scores from step 10 and step 11 results in an obtained Score B (Figure 1) of 3.

Step-13: Activity Score

Ironing is having small repetitive range actions more than 4x per minute, so the score is +1.

Analyzing the score values of A and B from the table C (Figure 1), it is observed that the table C score is 4, and an additional +1 is added for the activity. Therefore, the total REBA risk score is five. Referring to the risk level from Table 1, this signifies the need for further investigation, prompt changes, and indicates a medium risk level.

Table 2. Statistics and anthropometric data of the participations along with Head and Neck inclination angle

Finishing work	Sub	Gender	Age	SD Age	Experience (years)	Height	Weight	BMI	SD BMI	Head Inclination (Θ_H)	Neck Inclination (Θ_N)
Ironing	1	M	24	11.47	2	1.76	58	18.72	4.55	52.7	27.5
	2	M	50		25	1.73	78	26.06		53.1	29.5
	3	M	48		20	1.64	65	24.17		53.9	30.4
	4	M	42		17	1.67	72	25.82		55.1	34.8
	5	M	54		30	1.49	60	27.03		56.4	36.6
	6	M	35		8	1.55	76	31.63		57.8	38.7
	7	M	28		7	1.58	80	32.05		59.4	40.1
Quality Check	1	F	44	8.06	17	1.64	55	20.45	2.12	41.2	44.5
	2	M	48		23	1.76	68	21.95		45.2	49.9
	3	F	35		10	1.61	58	22.38		49.7	53.5
	4	M	29		4	1.79	74	23.10		51.2	56.6
	5	M	32		8	1.82	79	23.85		51.8	57.2
	6	F	50		22	1.61	64	24.69		53.4	58.8
	7	F	40		12	1.49	60	27.03		55.1	60.3
Packing	1	M	29	8.83	4	1.85	73	21.33	2.02	40.1	40.0
	2	F	28		3	1.61	58	22.38		40.2	39.9
	3	F	45		26	1.55	55	22.89		42.5	43.7
	4	M	37		13	1.79	77	24.03		43.4	44.2
	5	M	42		18	1.7	70	24.22		45.1	47.1
	6	F	52		25	1.58	66	26.44		45.6	46.2
	7	M	33		9	1.73	80	26.73		48.1	50.2
Thread Trimming	1	M	29	9.20	4	1.79	72	22.47	3.22	40.1	36.9
	2	F	32		8	1.82	75	22.64		39.2	37.6
	3	F	45		26	1.55	55	22.89		40.2	40.1
	4	F	54		30	1.58	66	26.44		45.9	43.2
	5	M	50		22	1.61	70	27.01		49.8	41.1
	6	F	40		12	1.49	60	27.03		49.1	43.3
	7	F	37		13	1.57	77	31.24		51.4	43.9
Stain Removal	1	M	29	9.30	4	1.79	72	22.47	1.78	46.3	52.5
	2	M	50		25	1.73	68	22.72		47.5	53.5
	3	M	37		13	1.79	77	24.03		49.5	55.5
	4	M	48		20	1.64	65	24.17		49.9	57.9
	5	M	42		18	1.7	70	24.22		50.0	61.3
	6	M	33		9	1.73	80	26.73		51.5	62.7
	7	M	54		30	1.49	60	27.03		51.8	59.8
Total Male	23	Consolidate Mean	40.14		15.34	1.66	68.2	24.73			
Total Female	12	SD	8.96		8.72	0.11	8.13	2.96			

REBA Score analysis of Quality Checking/Packing/ Thread Trimming/ Stain Removal operation: Accordingly, REBA score analysis also done in quality checking (Figure 3-b), packing (Figure 3-c), thread trimming (Figure 3-d), stain removal (Figure 3-e) and score analysis details are mentioned in Table 3, Table 4, Table 5, Table 6 respectively. Relationship with BMI vs Head Flexion Angle and Neck Flexion Angle are shown below.

Table 3. REBA Score analysis of Quality Checking

Finishing work	SEC A (For REBA Table A) Figure-1					SEC B (For REBA Table B) Figure-1				
	Steps	**Body parts**	**Dynamic position in flexion angle/twisting/ bending/Standing**	**Reference**	**REBA Score**	**Steps**	**Body parts**	**Dynamic position in flexion angle/twisting/ bending/Standing**	**Reference**	**REBA Score**
Quality Check	1	Neck position	56.6°	(20°-60°)	+2	7	Upper arm	4.1°	(0°-20°)	+1
	1a	Adjusted	Neck is twisted	if bent or twisted add +1	+1	8	Lower arm	72.5°	(60°-100°)	+1
	Final Neck score in Step-1				+3	9	Wrist	0°	(0°-15°)	+1
	2	Trunk position	8.8°	(0°-20°)	+2	10	Look up posture Score in Table B (from Figure 1 -REBA chart)	Table B (from the figure 1)	From the values step-7 to step-9	1
	3	Leg position	Both legs down		+1	11	Coupling Score	-	-	0
	4	Look up posture Score in Table A (from Figure 1 - REBA chart)	Table A (from the figure 1)	From the values step-1 to step-3	4	12	Score B		Adding values of step 10 and step 11	1
	5	Load/force	No load	Load <11Ibs	0	13	Activity Score	small repetitive range actions more than 4x per minute		1

	6	Score A		Adding values of step 4 and step 5	4		SEC C (For REBA Table C) Figure-1	**3**
							REBA score (SEC C + Activity Score) and action levels (from Table 1)	4 and Rick level is "Medium", Require further investigation, change soon

Table 4. REBA Score analysis of Packing

Finishing work	**SEC A (For REBA Table A) Figure-1**					**SEC B (For REBA Table B) Figure-1**				
	Steps	**Body parts**	**Dynamic position in flexion angle/twisting/ bending/ Standing**	**Reference**	**REBA Score**	**Steps**	**Body parts**	**Dynamic position in flexion angle/twisting/bending/Standing**	**Reference**	**REBA Score**
Packing	1	Neck position	42.5°	(>20°)	+2	7	Upper arm	0°	(0°-20°)	+1
	1a	Adjusted	Neck is twisted	if bent or twisted add +1	+1	8	Lower arm	86.9°	(60-100°)	+1
	Final Neck score in Step-1				+3	9	Wrist	27.2°	(>15°)	+2
	2	Trunk	0°		+1	9a	Adjusted	Wrist is bent	if bent or twisted add +1	+1

	3	Leg	Both legs down		+1	Final Wrist score in Step-9				+3
	4	Look up posture Score in Table A (from Figure 1 - REBA chart)	Table A (from the figure 1)	From the values step-1 to step-3	3	10	Look up posture Score in Table B (from Figure 1 - REBA chart)	Table B (from the figure 1)	From the values step-7 to step-9	2
	5	Load/force score	2lbs	<11Ibs	0	11	Coupling	-	-	0
	6	Score A		Adding values of step 4 and step 5	3	12	Score B		Adding values of step 10 and step 11	2
						13	Activity Score	small repetitive range actions more than 4x per minute		1
							SEC C (For REBA Table C) Figure-1	3		
							REBA score (SEC C + Activity Score) and action levels (from Table 1)	4 and Rick level is "Medium", Require further investigation, change soon		

Table 5. REBA Score analysis of Thread Trimming

Finishing work	SEC A (For REBA Table A) Figure-1					SEC B (For REBA Table B) Figure-1				
	Steps	Body parts	Dynamic position in flexion angle/twisting/ bending/Standing	Reference	REBA Score	Steps	Body parts	Dynamic position in flexion angle/twisting/ bending/Standing	Reference	REBA Score
Thread Trimming	1	Neck position	39.62°	(>20°)	+2	7	Upper arm	11.3°	(0°-20°)	+1
	2	Trunk	12.7°		+2	8	Lower arm	103.6°	(>100 °)	+2
	3	Leg	Both legs down		+1	9	Wrist	16.5°	(>15°)	+2
	4	Look up posture Score in Table A (from Figure 1 -REBA chart)	Table A (from the figure-1)	From the values step-1 to step-3	3	9a	Adjusted	Wrist is bent	if bent or twisted add +1	+1
	5	Load/force score	1lbs	<11Ibs	0	Final Wrist score in Step-9				+3
	6	Score A		Adding values of step 4 and step 5	3	10	Look up posture Score in Table B (from Figure 1 -REBA chart)	Table B (from the figure 1)	From the values step-7 to step-9	3
						11	Coupling	-	-	0
						12	Score B		Adding values of step 10 and step 11	3

						13	Activity Score	small repetitive range actions more than 4x per minute		1
							SEC C (For REBA Table C) Figure-1	3		
							REBA score (SEC C + Activity Score) and action levels (from Table 1)	4 and Risk level is "Medium", Require further investigation, change soon		

Table 6. REBA Score analysis of Stain Removal

Finishing work	SEC A (For REBA Table A) Figure-1					SEC B (For REBA Table B) Figure-1				
	Steps	Body parts	Dynamic position in flexion angle/twisting/ bending/Standing	Reference	REBA Score	Steps	Body parts	Dynamic position in flexion angle/twisting/ bending/Standing	Reference	REBA Score
Stain Removal	1	Neck	50.4°	(>20°)	+2	7	Upper arm	40.2°	(20°-45°)	+2
	1a	Adjusted	Neck is bent	if bent or twisted add +1	+1	8	Lower arm	79.6°	(60-100°)	+1
	Final Neck score in Step-1				+3	9	Wrist	45.4°	(>15°)	+2
	2	Trunk	16.8°		+2	9a	Adjusted	Wrist is bent	if bent or twisted add +1	+1
	2a	Adjusted	Trunk is bent	if bent or twiste	+1	Final Wrist score in Step-9				+3

				d add +1						
Final Trunk score in Step-2					+3	10	Look up posture Score in Table B (from Figure 1 - REBA chart)	Table B (from the figure-1)	From the values step-7 to step-9	3
3	Leg	Both legs down			+1	11	Coupling	-	-	0
4	Look up posture Score in Table A (from Figure 1 - REBA chart)	Table A (from the figure-1)	From the values step-1 to step-3		5	12	Score B		Adding values of step 10 and step 11	3
5	Load/force score	1lbs	<11Ibs		0	13	Activity Score	Wrist is held more than one-minute due stain cleaning operation	1 or more body parts are held for longer 1 minute (static)	1
6	Score A		Adding values of step 4 and step 5		5		SEC C (For REBA Table C) Figure-1	4		
							REBA score (SEC C+ Activity Score) and action levels (from Table 1)	5 and Risk level is "Medium", Require further investigation, change soon		

Correlation between BMI with Head (Θ_H) and Neck (Θ_N) flexion angle

An experimental group, consisting of 7 ironing operators from the finishing department, all participating subjects are right-handed and familiar with the ironing task. For each operator the angle of head inclination as well as the neck inclination has been measured (Table 2). As shown in Figure 3 -a) the operator's (subject -2) head inclined at 53.1° angle and neck inclination angle is 29.5°and their relation with BMI is shown in Figure 4. As depicted in the figure below, a significant correlation is observed between BMI and head flexion angle. In below Figure 4, and Figure 5 the relationships for quality checking, packing, thread trimming, and stain removal operations are respectively illustrated. The multiple regression analysis demonstrates that both head and neck inclinations have significant relationships with BMI among workers in the garment industry in the finishing department. Considering both factors together provides a more comprehensive understanding of their influence on BMI levels. These findings highlight the importance of addressing ergonomic factors, such as head and neck inclinations of repetitive finishing operation, in promoting worker health and well-being. The overall model is statistically significant (p-value < 0.001), indicating that head and neck inclinations collectively contribute to predicting BMI among garment industry workers.

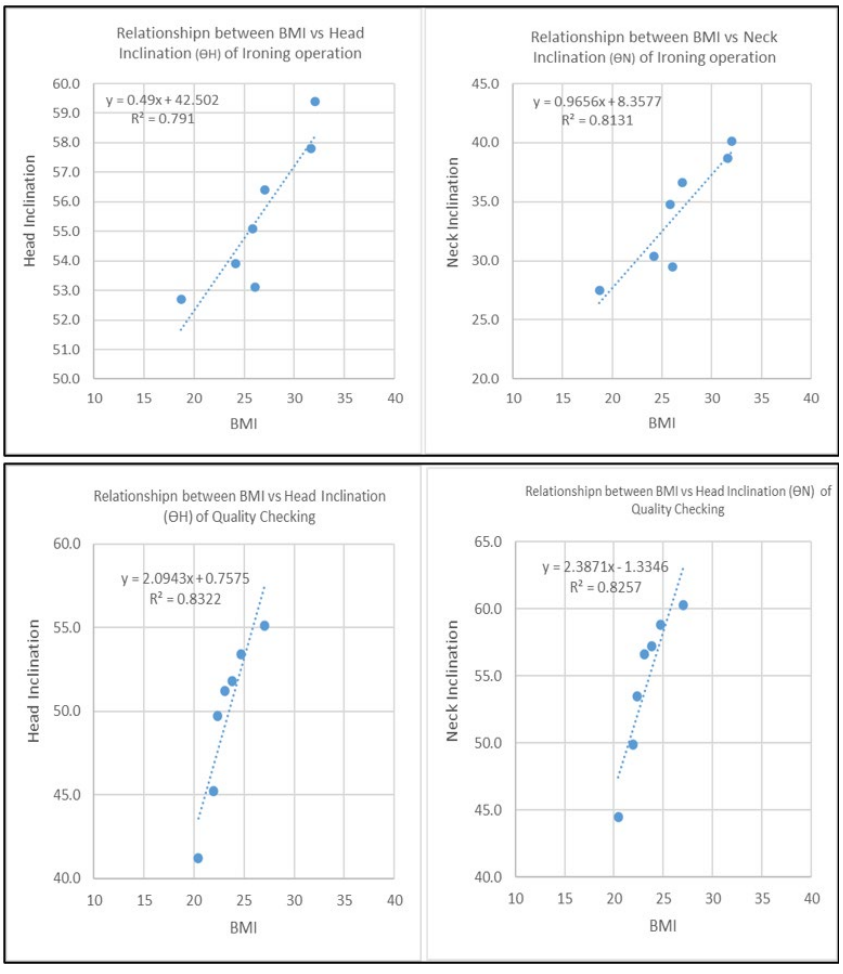

Figure 4. Relationship between BMI vs Head (ΘH) and Neck (ΘN) Inclination angle of Ironing & Quality check operation

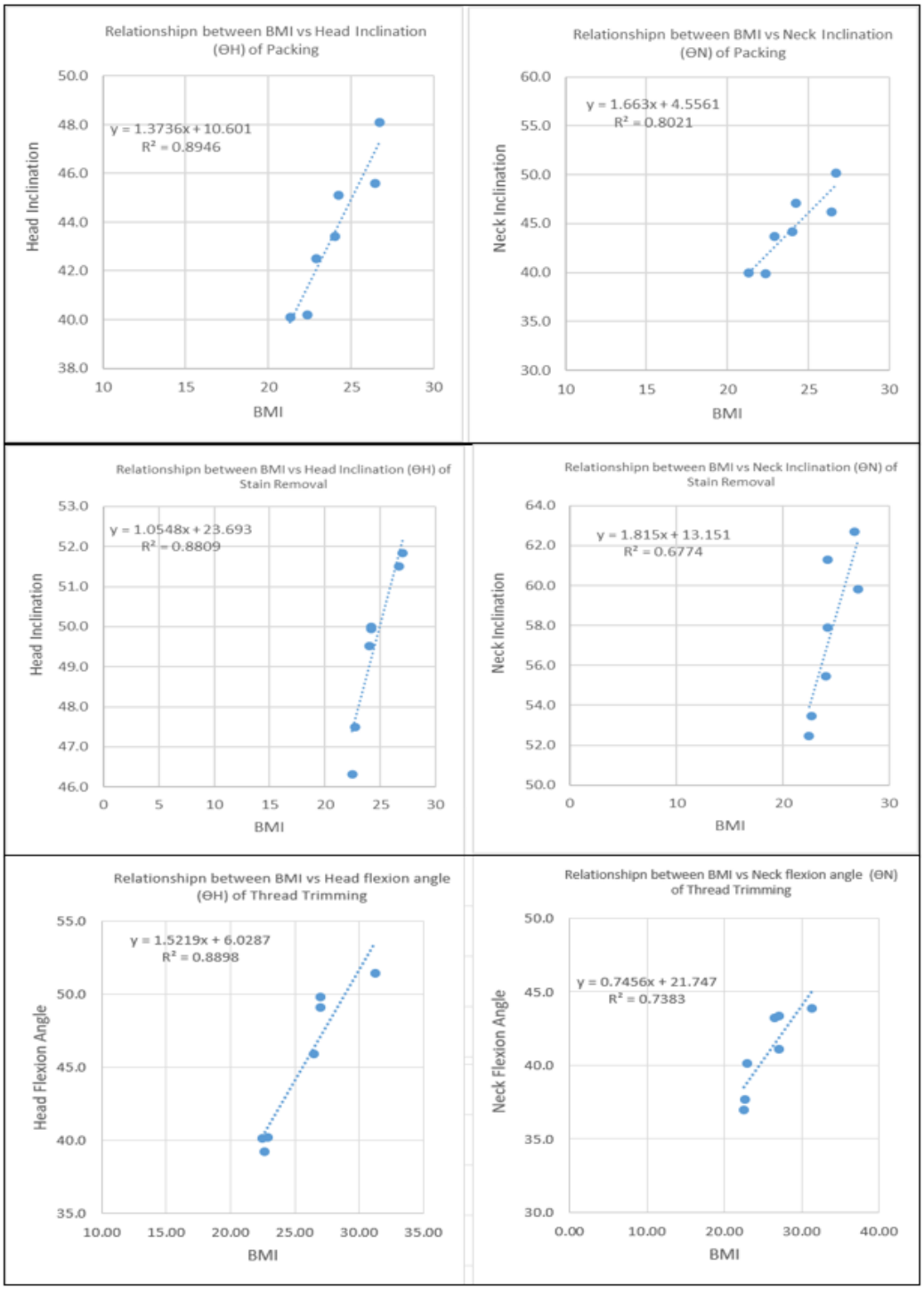

Figure 5. Relationship between BMI vs Head (ΘH) and Neck (ΘN) Inclination angle of Packing, Thread Trimming, & Stain Removal operation

Table 7. Regression Analysis

Regression Analysis									
		Head	Neck			Coefficients	Standard Error	t Stat	P-value
Ironing	Multiple R	0.8894	0.9017	Head	Intercept	42.5020	3.0222	14.0634	0.00001
	R Square	0.7910	0.8131		X Variable 1	0.4900	0.1126	4.3500	0.0074
	Adjusted R Square	0.7492	0.7758	Neck	Intercept	8.3577	5.5540	1.5048	0.1927
	Standard Error	1.2542	2.3048		X Variable 1	0.9656	0.2070	4.6644	0.0055
Quality Checking	Multiple R	0.9122	0.9087	Head	Intercept	0.7575	9.8550	0.0769	0.9417
	R Square	0.8322	0.8257		X Variable 1	2.0943	0.4206	4.9794	0.0042
	Adjusted R Square	0.7986	0.7908	Neck	Intercept	-1.3346	11.4931	-0.1161	0.9121
	Standard Error	2.1831	2.5460		X Variable 1	2.3871	0.4905	4.8665	0.0046
Packing	Multiple R	0.9458	0.8956	Head	Intercept	10.6012	5.0775	2.0879	0.0911
	R Square	0.8946	0.8021		X Variable 1	1.3736	0.2109	6.5131	0.0013
	Adjusted R Square	0.8735	0.7625	Neck	Intercept	4.5561	8.8942	0.5123	0.6303
	Standard Error	1.0427	1.8265		X Variable 1	1.6630	0.3694	4.5014	0.0064
Thread Trimming	Multiple R	0.9433	0.8592	Head	Intercept	6.0287	6.1898	0.9740	0.3748
	R Square	0.8898	0.7383		X Variable 1	1.5219	0.2395	6.3547	0.0014
	Adjusted R Square	0.8678	0.6860	Neck	Intercept	21.7471	5.1308	4.2386	0.0082
	Standard Error	1.8908	1.5673		X Variable 1	0.7456	0.1985	3.7559	0.0132
Stain Removal	Multiple R	0.9385	0.8230	Head	Intercept	23.6928	4.2567	5.5660	0.0026
	R Square	0.8809	0.6774		X Variable 1	1.0548	0.1735	6.0798	0.0017

	Adjusted R Square	0.8570	0.6128	Neck	Intercept	13.1514	13.7453	0.9568	0.3826
	Standard Error	0.7570	2.4444		X Variable 1	1.8150	0.5602	3.2400	0.0229

5. Conclusion

The experimental findings reveal a notable prevalence of musculoskeletal disorders among finishing operators in this study. Factors such as awkward standing postures, uncomfortable holding of pieces, and prolonged standing significantly contribute to an elevated risk for workers, especially in the context of India garment industry in finishing department. After REBA analysis of finishing workers in the garment industry indicates medium risk levels (scores of five, four, four, four, and five for ironing, quality checking, packing, thread trimming, and stain removal, respectively). This necessitates further investigation into prompt adjustments in setup or working postures. The study also establishes a substantial correlation (Figure 5 Relationship between BMI vs Head (ϴH) and Neck (ϴN) Inclination angle of Packing, Thread Trimming, & Stain Removal operation Table 7) between the independent variable BMI of finishing workers and dependent variables like head flexion angle and neck flexion angle. As BMI increases, so do the angles, resulting in elevated REBA scores and heightened musculoskeletal disorder risks. Industry experts should assist operators in improving work methods or posture angles during various finishing tasks in the garment industry, with a potential need to determine workstation inclination angles based on the operator's BMI. Improper repetitive task led to work related disease, PMTS software like timeSSD (Mondal & Jana, 2022), GSD can help to standardize the various micro motion performed in the industry then there is possibility to reduce the potential risk which can be future scope of the research.

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