A

DISSERTATION REPORT

ON

Comparison of Different Ergonomic Risk Assessment Tools in a Repetitive High Risk Metal Works Industry

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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IN
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BY

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(2013PIE5359)

UNDER THE GUIDANCE OF
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CERTIFICATE

This is to certify that the dissertation entitled **"Comparison of Different Ergonomic Risk Assessment Tools in a Repetitive High Risk Metal Works Industry"** being submitted by **Mohit Mendiratta (2013PIE5359)** is a bonafide work carried out by him under my supervision and guidance, and hence approved for submission to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.) in Industrial Engineering**. The matter embodied in this dissertation report has not been submitted anywhere else for award of any other degree or diploma.

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **"Comparison of Different Ergonomic Risk Assessment Tools in a Repetitive High Risk Metal Works Industry"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my own work carried out by me during a period of one year from July 2014 to June 2015 under the guidance and supervision of **Prof. Awadhesh Bhardwaj** of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for award of any other degree or diploma.

Mohit Mendiratta
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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Prof. Awadhesh Bhardwaj
Supervisor

Place: Jaipur
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ABSTRACT

This study presents a comparison between five different methods for determining risk factors for work-related musculoskeletal disorders in a high risk metal work industry. The Quick Exposure Check (QEC), Strain Index (SI), the OCRA checklist, Rapid Upper Limb Assessment (RULA) & the Rapid Entire Body Assessment (REBA) methods were all used to assess 66 workstations in metal works industry. Prevalence of work related musculoskeletal disorder (WMSDs) was evaluated from Standardized Nordic Questionnaire. The results of all different risk assessment method are compared using three risk categories (Low, Moderate, and High). Data were gathered using video and measurements taken at the workstations. A questionnaire was also administered to employees participating in the study along with the checklist of OCRA and QEC. The findings reveal that the various methods differ in their analyses of the same workstation. Strain Index was the most conservative, identifying over 36% of the work-stations as high risk. RULA identifies over 33% of workstation as safe, most by any method. Correlation was highest between RULA & REBA, and between OCRA checklist & QEC it is due to the similarity of these methods. The lowest correlation was found between QEC & Strain Index due to major differences of type of factors used and mode of calculation of risk output. RULA & REBA showed similar results for the number of workstations classified as high risk. RULA & REBA was found to be in perfect agreement of over 89% & did not find any workstation as two level discrepancies between them whereas QEC & SI was in just 43% of perfect agreement. Out of all the methods used Strain Index was found to be the most suitable method which approximately predicts for work-related musculoskeletal disorders in workers of metal work industry.

Key words: Ergonomics, Occupational Repetitive Actions (OCRA) checklist, Strain Index, Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), Quick Exposure Check (QEC).

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ABBREVIATIONS

QEC	Quick Exposure Check
RULA	Rapid Upper Limb Assessment
REBA	Rapid Entire Body Assessment
FIOH	Finnish Institute of Occupation Health
OCRA	Occupational Repetitive Actions
HAL	Hand Activity Level
WMSD	Work Related Musculoskeletal Disorder
OWAS	Ovako Working posture Analysis System
SI	Strain Index
DUE	Distal Upper Extremity
CTS	Carpal Tunnel Syndrome
NPF	Normalised Peak Force
ATA	Actual Technical Actions
RTA	Reference Technical Actions
CTEs	Certified Professional Ergonomists
VADE	Virtual Assembly Tool
NIOSH	National Institute for Occupational Safety and Health
OSH	Occupational Safety and Health
EN 1005 -3	European Standards, Safety of Machinery-Human Physical Performance Part 3

CHAPTER 1- INTRODUCTION

1.1 Background and Motivation

Work Related Musculoskeletal disorders (WMSDs) in the workplace have a huge impact, emerging as a growing problem in our modern societies (Yelin et al., 1990). They represent the second largest cause of short-term or temporary work disability after the common cold. Work-related musculoskeletal disorders (WMSDs) are responsible for injury in many working populations and are known as a vital occupational problem with increasing compensation and health costs, reduced productivity, and poorer quality of life (Karwowoski & Marras, 2003). Almost all work requires the use of the arms and hands. Therefore, most WMSD affect the hands, wrists, neck, elbows and shoulders. Work using the legs can lead to WMSD of the legs, ankles, hips, & feet. Some back problems also result from repetitive activities. Work-related musculoskeletal disorders (WMSDs) are a group of painful disorders of tendons, muscles, and nerves. Carpal tunnel syndrome, tendonitis, thoracic outlet syndrome, and tension neck syndrome are examples. WMSDs are reported to cause lost work time or absenteeism, transfer to another job, increase work restriction (Yelin et al., 1990) or disability than any other group of diseases with a significant economic toll on the individual, the society and organization as a whole. Findings of scientific research have identified psychosocial/organizational, physical, and individual occupational "risk factors" for the development of WMSDs. These studies have measured the stages of a diversity of factors across a range of occupations at different levels of risk, and examined their relations with the incidence (or prevalence) of MSDs for the populations concerned (Campo et al., 2008).

Moreover, WMSD is the most costly form of work disability. It was assessed that the cost of WMSD was nearly 215 billion dollars in 1995 in the United States; 26 billion Canadian dollars in 1998 in Canada, and 38 billion Euros in 2002 in Germany. India has been fighting with orthodox public health problems such as communicable diseases, high rate of population, malnutrition, growth, and insufficient medical care, apart from the occupational health problems. MSD is one of the major occupational health problems in India and estimates have shown that MSD adds to about 40% of all costs toward the treatment of work-related injuries. Decrease of certain types of movements and improvements in posture can result in reduced rates of WMSDs and in prolonged work lives. It is expected that this could be largely implemented to help reduction in Construction related Work-related Musculoskeletal Disorders (Yelin et al., 1990).

There are several tools which can be used to find the ergonomic risk of a particular job. Some tool takes more time than other, some disturbs the worker working and in some tool just videography the task can able to assess the risk. There are several tools in which prior training is necessary to apply the tools whereas others can be applied without prior training. So proper knowledge of the tool led us to find which tool can be applied in a particular task.

In order to get proper analysis of a specific task one may use more than one tool to analyse the task. This gives the proper information about the task whether it is at risk or no risk state. However confusion may arise if two tools give different results. In our study we have taken five different tools i.e. Strain Index, Rapid Upper Limb Assessment, Rapid Entire Body Assessment, Quick Exposure Check, and Occupation Repetitive Actions checklist and applied in same situation of metal work industry to gain a better understanding of how tool relate to one another and to find the best method in a metal work industry. Understanding of this also helps us to analyse jobs by not using two tools that will gives same outcomes.

1.2 Risk Assessment Methods

- QEC: The Quick Exposure Check (QEC) (David et al., 2003, 2008; Li & Buckle, 1999) is posture-based. Combining the observer's assessment with the worker's reactions to closed questions, it permits MSD risk factors to the back, arms, neck and upper extremities at a workstation to be assessed. In addition to an overall score for the entire body (QEC General), this method provides a risk index for each directed area (back, shoulder-arm, wrist-hand and neck). The assessment takes posture, movement, effort, frequency, and shift length into account along with psychosocial risk factors and exposure to vibration.
- FIOH: The Ergonomic Workplace Analysis method, established by the Finnish Institute of Occupational Health (FIOH) (Ahonen et al., 1989) offers a wide-ranging ergonomic analysis on 14 subject items: (1) Attention required, (2) Decision making, (3) Lifting, (4) Task restrictions (5) Accident risk, (6) Task content, (7) Working posture and movements (multiple body areas), (8) Personal contact and communication, (9) Physical workload, (10) Workstation

design, (11) Repetitiveness, (12) Noise, (13) Thermal environment and (14) Lighting. The observer (expert) allocates each item a grade on a scale of either four or five levels. Each level matches to a detailed condition designated by the method (i.e., a score of 5 shows a situation posing a risk to the worker's health, while a score of 1 shows acceptable and safe conditions). The workers estimate the same features of the workstation on a four-level scale (very good, good, poor and very poor). In this study, a total probable score out of 10 was established for each item by joining the worker's and the observer's assessments.

- Strain Index (SI): (Moore & Garg, 1995) quantifies exposure to MSD risk factors for the hands and wrists. It offers an index that takes into account the level of perceived exertion, number of efforts, duration of effort as a percentage of cycle time, hand and wrist posture, work speed and shift length. Measurements of duration and frequency were attained from the time-motion study. The force required (perceived exertion) to do the job was evaluated by the workers using a perceived exertion scale (Borg, 1998).
- HAL: The Hand Activity Level (HAL) threshold limit values method calculates the risk to the hands and wrists. The calculation is based on the hand activity level and takes into account the repetition and duration of effort along with the Normalized Peak Force (NPF) of the hand, which is the relative level of effort on a 0 to 10 scale analogous to 0 to 100% of the applicable population reference strength. Task hand peak force was assessed using a perceived exertion Borg scale (Borg, 1998) and was normalized using the 5th percentile industrial female worker strength. The number of efforts per second and their duration as a percentage of cycle time were attained from the time-motion study
- OCRA: The OCRA index and OCRA checklist (Colombini, 1998; Occhipinti, 1998) is based on the ratio between Actual Technical Actions (ATA), obtained by evaluating the task, and Reference Technical Actions (RTA). The RTA value is attained by taking into account the frequency and repetitiveness of movements, type of posture, use of force, recovery period distribution and additional factors such as localized tissue compression and vibration. The OCRA method provides two separate indices (shoulder and elbow/wrist/hand) for each of the right and left sides of the body. The OCRA checklist has series

of questionnaire to be asked from worker on different issues to find the overall score and thereby risk.

- RULA: The Rapid Upper Limb Assessment method (RULA) (McAtamney & Corlett, 1993) delivers an overall score that takes into account postural loading on the whole body with particular attention to the trunk, neck, shoulders, arms and wrists. The overall score also considers the time the posture is held, the force used and the repetitiveness of the movement.
- REBA: The Rapid Entire Body Assessment method (REBA) (Hignett & McAtamney, 2000) method delivers an overall score that takes all the body parts into account (trunk, neck, legs, shoulders, arms and wrists). The overall score takes into consideration the similar additional factors as RULA as well as the quality of the hand-coupling.
- EN 1005-3: The European Standard, Safety of machinery Human physical performance Part 3: Recommended force limits for machinery operation is a general-purpose method that helps designers evaluate the risk related to force application during work. The acceptable force is obtained by applying numerous multipliers, i.e., duration, speed and frequency of actions, to a basic capability, which is denoted by the maximum capability of the 15th percentile worker. The EN 1005-3 standard was applied to the shoulder joint for the purpose of this study. The 3D SSPP software (version 5 and 6) from the University of Michigan Center for Ergonomics was used to obtain the population capability distribution parameters that in turn were used to obtain the basic value for the shoulder (i.e., the 15th percentile maximum moment for the target worker population; see EN 1005-3). The decreased value was obtained by following the calculation steps using the standard’s proposed coefficients.

1.3 Selection of an Analysis Tool

A survey of Certified Professional Ergonomists (CPEs) was conducted by (Dempsey et al., 2005) to collect information on the forms of basic tools, direct and observational measurement techniques, and software used by practitioners. The inspiration for the survey was to better understand what types of tools and methods practitioners use, their views of these tools, and to possibly gain an understanding of the constraints or preferences that influence this selection. Reasons for using or not using a selection of tools were also surveyed. Of 578 surveys that were delivered to CPEs and Associate Ergonomics Professionals, 308 were reverted for a response rate of 53%. The respondents tended to be inclined towards physical ergonomics, as the survey mainly focused on this area of ergonomics. A high percentage of respondents reported using tape measures, video cameras, stopwatches and digital cameras. The most commonly used observational methods were those involving manual materials handling, whereas the most commonly used direct measurement tools were pinch and grip dynamometers and push/pull gauges. The frequency and type of software, checklists, and anthropometric data used are there (Dempsey et al., 2005).

1.4 Purpose of the Present Study

The purpose of the present study was to apply five ergonomic risk assessment tool i.e. RULA, REBA ,Strain Index, QEC, OCRA checklist in the metal work industry.

- Check the validation of the methods applied by using Chi Square test of independence.
- Compare the methods by using Kappa analysis and find the pairwise level of agreement between tools.
- Determine the reason for the level of agreement between the tools.
- Finding of most suitable method for the metal works industry out of the tools applied.

CHAPTER 2 - LITERATURE REVIEW

The ergonomic risk is always the concern of the industry due to worker safety as well as due to higher worker compensation cost. For this ergonomic risk must be assessed so that the high risk job can be identified and removed. This can be done by many methods but here we are taking the method such as OCRA checklist, Quick Exposure Check (QEC), Strain Index, RULA and REBA. All these methods are compared and the best method is identified for that specified task. The matter content available on this topic is found to be highly scattered in literature. An attempt has been made in this chapter to present the matter content in a systematic manner under different sections as given below.

2.1 Strain Index

The Strain Index (SI) is one method for assessing the risk of developing work-related distal upper extremity disorders (Moore & Garg, 1995). The SI analyst chooses the most appropriate task-variable score using a combination of direct time-motion measurement techniques combined with professional judgment. The SI does not predict the risk of developing a specific DUE (Distal Upper Extremity) disorder, but rather the summary score the magnitude of work-related exposure to general DUE MSDs (musculoskeletal disorders) risk factors. The validity of the method has done by many authors (Moore et al., 2001; Drinkaus et al., 2005). Some author shows the external validity and predictive validity of Strain Index (Rucker & Moore, 2002; Knox & Moore, 2001). It shows moderate to good inter rater agreement (Spielholz et al., 2008). This method has been extensively used by researchers and industrial practitioners. The SI method was originally designed for ‘‘mono-task’’ jobs (Moore & Garg, 1995). A mono-task job is firmly defined by the SI authors as a single-force exertion job. The SI method includes measuring or estimating six different exposure parameters (Moore & Garg, 1995): intensity of exertion, duration of exertion, efforts per minute, hand/wrist posture, speed of work (an estimate of perceived pace of the task) and duration per day of the job. Multipliers with different weights are developed for each of the exposure parameters (Moore & Garg, 1995). The final SI score is a product of the six multipliers.

The SI is an observational measure that measures exposure to physical risk factors related with the development of distal upper extremity (DUE) MSDs. Earlier to the development of the SI, neither ergonomists nor epidemiologists had access to a standardized, objective, and comprehensive DUE risk assessment method or tool (Moore & Garg, 1995). The DUE refers to muscle-tendon units and nerves of the elbow, forearm, wrist, and hand. Distal upper extremity disorders contain carpal tunnel syndrome (CTS), changes of synovitis, tendinitis, tenosynovitis, and bursitis (Tanaka et al. 2001). Epidemiologists can use SI score and task-variable scores to methodically find out job tasks that expose workers to physical risk factors. The SI was designed with the needs of professional ergonomists and OHS practitioners in mind (Stephens et al., 2006). With some confidence, ergonomic practitioners may use simpler methods, depending on their specificity requirement in job evaluations and available resources. Some SI computation methods may tend to over-estimate job risk levels, while others may tend to under-estimate job risk levels, due to dissimilar ways used in obtaining the various SI parameters and computations (Bao et al., 2009). SI were found to predict risk of CTS (carpal tunnel syndrome) when adjusted for relevant covariates (Garg et al., 2012).

2.2 Occupational Repetitive Actions (OCRA) Checklist

The OCRA Index was made to be used by occupational health and safety specialists, ergonomists, time and methods analysts, and production engineers (Colombini, 1998; Occhipinti, 1998). The Index is a very thorough assessment which needs slow-motion video analysis and in-depth time-motion study, and the evaluation of a single job may require 45 minutes or more (Occhipinti & Colombini, 2005). In 2000 introduction of the OCRA Checklist as a simplified version of the OCRA Index was done. The OCRA checklist, based on the OCRA index method, is generally recommended for the primarily screening of some workstations in a company featuring repetitive tasks, whereas the complete OCRA index is useful for the (re)design or in-depth analysis of workstations and tasks, OCRA checklist practises simpler tool based on same general framework of OCRA index (Occhipinti & Colombini, 2006). In developing the OCRA Checklist, reduced or eliminated some of the direct measurement and time-study requirements of the OCRA Index (Colombini et al., 2011). Since its release, many European job analysts have adopted the OCRA Checklist (Colombini et al. 2011; Occhipinti & Colombini, 2005).

The OCRA checklist method is an observational assessment of physical exposure risks to the hand, wrist, arm, elbow, and shoulder (Colombini, 1998). The OCRA Checklist was designed to be completed using pen and paper at the worksite, taking ten to fifteen minutes to evaluate one job with a 30 second work-cycle time (Occhipinti & Colombini, 2005). In developing the OCRA Checklist some of the direct measurement and time-study requirements of the OCRA Index reduced or eliminated .Those reduced scoring items were replaced with exposure scoring schemes based on expert estimation using detailed verbal descriptors (Colombini et al. 2010). The OCRA Checklist summarizes exposure in terms of six task-variable scores (i) frequency of technical actions, (ii) force, (iii) awkward postures and movements, (iv) additional factors,(v) task duration (vi) lack of sufficient recovery, (Colombini, 1998; Occhipinti, 1998). The additional risk factors variable includes exposure to vibration, precision movements, glove use, mechanical compression, and cold stress (Occhipinti & Colombini, 2005). Task-variable scores are primarily determined by measuring the percentage of time a worker is exposed to a multiplicity of physical parameters. Increasing percentages of exposure to these factors correspond to increasing task-variable scores along a continuous scale. The sum of the frequency, force, posture, and additional factors scores is weighted by the scores for the lack of sufficient recovery and task duration variables, producing the OCRA Checklist summary exposure score. No studies of the inter- rater or intra-rater reliability of the Checklist or the Index have been performed and author admit that the lack of reliability data is a limitation of the OCRA methods (Occhipinti & Colombini, 2005)

2.3 Rapid Upper Limb Assessment (RULA)

RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a rapid assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body (McAtamney & Corlett, 1993). RULA can be used as a useful assessment tool for the evaluation of musculoskeletal loading which is known to contribute to work-related musculoskeletal disorders. RULA also can be used as a screening tool or incorporated into a wider ergonomic assessment of epidemiological, physical, mental, environmental and organizational factors (Kim et al., 1999). RULA methods of postural analysis closely correlate with the awkward postures adopted by the workers. According to RULA method the postures adopted by workers in small scale industries have been categorizes as having high to very high risk level. Proper training of workers and awareness may reduce the risk of musculoskeletal disorders (Singh & Kocher, 2012). RULA method proved to be a suitable tool for the quick evaluation of the loading of neck and trunk (Massaccesi et al., 2003).

The integration of the Rapid Upper Limb Assessment (RULA) algorithm, , with a virtual assembly tool (VADE), to ease the identification of potential upper limb injuries for this a pilot study clearly shows the validity and utility of this method in identifying and decreasing manual assembly process related musculoskeletal stresses (Shaikh et al., 2003). Modified RULA presents two posture risk quantification methods: first, an event-based method where the most common and the worst postures are assessed in a task; second, a time-based method where posture distributions are calculated from random samples of observed postures in the task (Bao et al., 2007). RULA has been used to evaluate children's computer-related posture, but the reliability of RULA on a paediatric population has not been established, study was to investigate the inter-rater and intra-rater reliability of the use of RULA with children (Dockrell et al., 2012). RULA proved generally to be a suitable method for evaluating children's posture (Breen et al., 2007).

2.4 Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) has been developed to fill a perceived need for a practitioner's field tool, precisely designed to be sensitive to the type of unpredictable working postures found in health care and other service industries (Hignett & McAtamney, 2000). REBA is a Rapid Entire Body Assessment tool which is being developed to investigate dynamic activities where there is a risk of work related musculoskeletal disorders. It is to be used to investigate tasks for which RULA (Rapid Upper Limb Assessment) was not designed. RULA is a survey method which was developed to be used in ergonomics investigations of inactive tasks where work-related upper limb and neck disorders are reported (McAtamney, 2002). REBA uses the RULA posture scoring criteria as a basis and is being designed to additionally record risks associated with the knee positions, the loads or forces being exerted, the coupling and whole body activities (McAtamney & Hignett, 1995).

Data are collected about the body posture, forces used, type of movement or action, repetition, and coupling. A final REBA score is generated to give an indication of the level of risk and exigency with which action should be taken. REBA may be more useful if specific ergonomic or biomechanical changes are being implemented to reduce risk of work-related injury particularly if an objective numeric score is required for re-assessment following modifications, to determine their effectiveness. REBA directs the user toward implementing controls, which are thorough, multi-factorial and useful to control hazards relating to several other areas, including task, load, environment, people and management factors (Coyle, 2005). REBA was used as a code with other ergonomic methodology (Ashby et al., 2004).

In the spectrum of postural analysis tools, REBA lies between the detailed event-driven systems and time-driven tools. REBA was designed to be used as an event-driven tool due the complexity of data collection. However it has lately been computerized by (Janik et al., 2002) for field use on a Palm PC and it can now be used as a time-driven tool. The initial development was based on the ranges of limb positions using concepts from RULA (rapid upper limb assessment), OWAS (Ovako Working posture Analysis System) and NIOSH (National Institute for Occupational Safety and Health). The baseline posture is the functional anatomically neutral posture. As the posture moves away from the neutral position, the risk scores increases. Tables are available to convert the 144 posture combinations into a single score that represents the level of musculoskeletal risk. These scores are then banded into three action levels that advise on the exigency of avoiding or reducing the risk of the assessed posture.

2.5 Quick Exposure Check (QEC)

The Quick Exposure Checklist (QEC) quickly measures the exposure to risks for work-related musculoskeletal disorders (WMSDs) (Li & Buckle, 1999). QEC is based on the practitioners needs and research on key WMSD risk factors . The tool is based on epidemiological evidence and investigations of OSH (Occupational Safety and Health) practitioner's aptitudes for undertaking assessments (David et al., 2008). The development of the tool involved a novel participatory approach and had input from approximately 160 health and safety practitioners. The development of action level was achieved by assessing a number of industrial tasks at the same time using the QEC and RULA and compare assessment score for both methods. The action level of QEC were then extracted from the corresponding RULA score (Brown & Li, 2003). The method has been published and is easily available in electronic form (David et al., 2003).

The QEC allows the four main body areas to be assessed and includes practitioners and workers in the assessment. Trials have determined its usability, intra- and inter-observer reliability, and validity which show it is valid to a wide range of working activities. The tool focuses mostly on physical workplace factors, but also includes the evaluation of psychosocial factors (David et al., 2008). About 150 practitioners have tested QEC and modified and validated it using both simulated and real tasks. QEC has a high level of sensitivity and usability and largely acceptable inter- and intra-observer reliability. Field studies confirm that QEC is applicable for a wide range of tasks. With a short training period and some practice, assessment can normally be completed quickly for each task. The construction validity of the QEC is reported in (Li & Buckle, 1999). The tool is found to have a high sensitivity (the ability to identify a change in exposure before and after an ergonomic intervention), a good intra-observer reliability, and a practically acceptable inter-observer reliability (Li & Buckle, 1999). There is a significant association between age, Body Mass Index and QEC risk level of musculoskeletal disorders occurrence (Abedini et al., 2012). Results of the QEC scores were found to be excessive for the shoulder/arm, wrist/hand and neck, whereas the scores for the back were found to be high for static use and moderate for moving (Bulduk et al., 2014).

2.6 Comparison of Different Ergonomic Risk Assessment Techniques

There are many ergonomic risk assessment techniques using now a days the most important of them are Quick Exposure Check (QEC), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Hand Activity level (HAL), Strain Index, occupation repetitive actions index (OCRA index), Occupation repetitive action checklist (OCRA checklist), Finnish Institute of Occupational Health (FIOH), The European Standard, Safety of machinery-Human physical performance Part 3 (EN 1005-3). There are many ergonomic risk assessment comparison has been done to solve the question of which ergonomic risk technique is to be used for the given task.

Comparison of ergonomic risk assessment output of RULA and Strain Index in automotive assembly plant shows that little agreement between the two hence cannot be interchangeably used (Drinkaus et al., 2003). Comparison of three observational techniques for assessing postural loads in industry shows that the inter-method reliability for postural load category between OWAS and RULA was just 29.2%, and the reliability between RULA and REBA was 48.2%. These results showed that compared to RULA, OWAS, and REBA generally underestimated postural loads for the analysed postures, irrespective of industry, work type, and whether or not the body postures were in a balanced state (Kee & Karwowski, 2007). Comparisons of ergonomic risk assessments in a repetitive high-risk sawmill occupation of Saw-filer states that all risk assessment methodologies examined i.e. RULA, REBA, ACGIH TLV, Strain Index and OCRA (with the exception of the ACGIH TLV calculated with %MVC) agreed a level of risk was associated with performance of the saw-filer job (Jones & Kumar, 2007). Comparing the results of eight methods used to evaluate risk factors associated with musculoskeletal disorders states that the FIOH, RULA and REBA methods did not identify any workstations as low risk. The QEC method proved to be the less severe in assessing overall risk, classifying 35% of the workstations as high risk compare to RULA with 76 % (Chiasson et al., 2012). Comparison of Ergonomic Risk Assessment Output in Four Sawmill Jobs for the methods examined, the RULA and SI were best (correct classification rates of 99 and 97% respectively). The quantitative ACGIH-TLV for mono-task hand work and Borg scale were worst (misclassification rates of 86 and 28% respectively (Jones & Kumar, 2010). Comparison of Ergonomic Risk Assessment Outputs from Rapid Entire Body Assessment and Quick Exposure Check in an Engine Oil Company revealed that substantial correlations between final score of REBA and QEC. There is possibility for researchers to apply interchangeably both methods, for postural risk assessment in appropriate working environments (Motamedzade et al., 2011).

CHAPTER-3 RESEARCH METHODOLOGY

3.1 Course of Action

- Selection of the metal work industry is done where the study has to be performed.
- Standard Nordic questionnaire was filled by every worker to find is there any pain in the body of the worker or not.
- Video recording of the entire task is done.
- Analysis of the video is done
- Filling of the OCRA checklist by the worker with the observer assistance and calculation of score was done for every task.
- Filling the Quick Exposure Check by the worker with the observer assistance and calculation of score was done for every task.
- The posture selected for the analysis of the RULA and REBA was most awkward at the workstation.
- Scoring for the RULA and REBA sheet is done for every task with the help of video analysis.
- Filling of Strain Index score sheet was done by the analysis of video.
- Convert the score of all tasks by every method into the category of “low” “medium” and “high” risk.
- The Chi Square test is performed in order to determine association between the risk levels of all the five methods and the reported pain by the workers. This will give the validity of each method in the metal work industry.
- After the validity of each method is done the comparison to be made between methods and level of agreement is found between them by the Kappa coefficient analysis.
- Determining the reason for level of agreement between tools.

3.2 Ergonomic Risk Assessment Tools Used

3.2.1 Strain Index

The Strain Index (SI) is a method of evaluating jobs to determine if they expose workers to increased risk of developing musculoskeletal disorders of the distal upper extremity (DUE) (Moore & Garg,1995). The DUE is defined as the elbow, forearm, wrist, and hand. The Strain Index was resultant from physiological, biomechanical, and epidemiological principles. According to work physiology, intensity of exertion (as a percentage of task-specific maximal effort), duration of exertion, and duration of recovery time amid exertions are the critical parameters for forecasting the onset and magnitude of localized muscle fatigue. According to biomechanics, the tensile load of a muscle–tendon unit is the addition of contractile force from the muscle component and elastic force related elongation (stretching). In addition, when loaded tendons cross joints and change direction, there are localized compressive forces that are proportional to the tensile load and the degree of deviation (joint posture) at that location. Epidemiological studies demonstrate that the magnitude, duration, and frequency of forces related to hand activity are associated with DUE morbidity.

Using these principles, one can suggest an index based on two measurements derived from a single cycle of work — total exertion time divided by recovery time. Total exertion time is the addition of the durations of the individual exertions applied by a hand within one job cycle (there may be one or many). Recovery time is cycle time subtract to exertion time. As exertion time increases (by increasing duration or frequency), recovery time decreases and the index value increases. As exertion time decreases, recovery time increases and the index value reduces. Since the physical stress on the body also depends on the magnitudes of these exertions, more forceful exertions represent greater stress than less forceful exertions. Therefore, the exertion periods in the numerator are “weighted” by their respective intensities.

The Strain Index uses six task variables to describe hand exertions: intensity of exertion, duration of exertion, exertions per minute, hand/wrist posture, speed of work (how fast), and duration per day. Intensity, duration, and posture were discussed above. Exertions per minute accounts for effects related to frequency. Speed of work accounts for reduced recovery efficiency when exertions are highly dynamic.

Duration of task per day combines these stresses across varying durations of task performance. The Strain Index contains the direct measurement of duration of exertion, efforts per minute, and duration per day and the estimation or direct measurement of intensity of exertion, hand/wrist posture, and speed of work. The values of these task variables represent descriptions of exposure (external physical stress). Translation of this information into dose and dosage (internal physical strain) is done by a set of linking functions that specify multiplier values for the values of the task variables. The Strain Index score is the product of these six multipliers.

3.2.1.1 Procedure for Strain Index

To analyse a job with the Strain Index, it is important to observe or videotape a representative sample of the job (Moore & Garg, 1995). The higher score should be used to characterize the job as a whole.

In terms of procedure, there are five steps1) Collect data on the six task variables. 2) Assign ordinal ratings using the ratings table. 3) Determine multiplier values using the multiplier table 4) Calculate the SI score (the product of the six multiplier values). 5) Interpret the result.

Durations of individual exertions and the overall cycle time can be measured manually with a stopwatch. The duration-of-exertion task variable represents the percent exertion time per job cycle and is calculated by dividing the total exertion time by the cycle time and multiplying by 100. Counts of exertions can be made manually, and the efforts-per-minute task variable is calculated by dividing the number of exertions per job cycle by the total cycle time (minutes). Data on duration of task per day can be measured, but it is usually ascertained by interviewing workers and supervisors. Ratings corresponding to these data are allocated using the ratings table.

Data collection for intensity of exertion, hand/wrist posture, and speed of work is usually done qualitatively using the ratings Table directly. Multiplier values for each task variable are determined using the multiplier Table shown in Table 1. The Strain Index score is the product of the six multipliers. Interpretation of the Strain Index score will be done in the last step. The entire task variable and variable multiplier for that task variable is shown in Table 1.

Table 1 - Strain Index score sheet

STRAIN INDEX SCORE SHEET			
Task variable	**Exposure Level**	**Exposure and Calculation guidelines**	**Variable multiplier**
Intensity of exertion	Light	Barely noticeable or relaxed effort	1
	Somewhat hard	Noticeable or definite effort	3
	Hard	Obvious effort, unchanged facial expression	6
	Very hard	Substantial effort, changes expression	9
	Nearly maximum	Uses shoulder or trunk for force	13
Duration of exertion (% of cycle)	< 10%	% duration of exertion = 100x Duration of all exertion (secs) / Total observation time (secs)	0.5
	10-29%		1
	30-49%		1.5
	50-79%		2
	>80%		3
Efforts per minute	<4	Efforts per minutes = No. of exertion / Total observation time (mins)	0.5
	4-8		1
	9-14		1.5
	15-19		2
	>20		3
Hand/wrist posture	Very good	Perfectly neutral= Ext 0-10^{0}	1
	Good	Near neutral= Ext 11-25^{0}	1
	Fair	Non- neutral= Ext 26-40^{0}	1.5
	Bad	Marked deviation= Ext 41-55^{0}	2
	Very bad	Near extreme = Ext >55^{0}	3
Speed of work	Very slow	Extreme relaxed pace	1
	Slow	Taking one's own time	1
	Fair	Normal speed of motion	1
	Fast	Rushed, but able to keep up	1.5
	Very fast	Rushed but barely/unable to keep up	2
Duration of task per day (hours)	<1		0.25
	1-2		0.5
	2-4		0.75
	4-8		1
	>8		1.5

Strain Index score = Product of all variable multipliers

The Strain Index action level consist of that if Strain Index score is less than 3 then the task is considered to be safe and if Strain Index score is coming out to be greater than 7 then task is considered to be at high risk. If the score lies in between the two then the risk of medium level. The whole action level is shown in Table 2.

Table 2 - Strain Index action level

Strain Index Action Level		
Strain Index Score Range	Description	Strain Index risk level
SI<3	Job is said to be approximately safe	low
3<SI<7	Job is said to be at moderate risk	Medium
SI>7	Job is at High Risk	High

3.2.2 Rapid Upper Limb Assessment (RULA)

Rapid upper-limb assessment (RULA) (McAtamney & Corlett, 1993) provides a simply calculated rating of musculoskeletal loads in tasks where people have a risk of neck and upper-limb loading. The tool provides a single score as a “snapshot” of the task, which is a rating of the posture, force, and movement required. The risk is calculated into a score of 1 (low) to 7 (high). These scores are clubbed into three action levels that provide an indication of the time frame in which it is practical to expect risk control to be initiated. RULA is used to assess the posture, force, and movement associated with sedentary tasks. Such tasks include screen-based or computer tasks, manufacturing, or retail tasks where the worker is seated or standing without moving about.

RULA was developed to require minimal training. (Dismukes, 1996) reported that people untrained in ergonomics could accurately evaluate upper-limb disorders using RULA. However, it is strongly advised that users have training so that they use the tool correctly. It is advised that new users practice using photographs and videotape of postures prior to using the tool in an assessment. One difficulty with any observation tool is deciding the angle of joint range, predominantly if the angle of vision is not in line with the side and back of the body. Where the user is unable to decide on the posture score, it is recommended that the higher of the two scores be chosen.

RULA evaluates a working posture and the associated level of risk in a short time frame and with no need for devices beyond pen and paper. RULA was not designed to provide detailed postural information, such as the finger position, which might be pertinent to the overall risk to the worker. It may be necessary for RULA to be used with other assessment tools as part of a wider or more detailed ergonomic investigation. When using RULA, the assessors can benefit from establishing the following information when making recommendations for change (McAtamney & Corlett, 1992) knowledge of the products, processes, tasks, earlier musculoskeletal injuries, training, workplace layout and dimensions, and pertinent environmental risks or constraints.

RULA can be used to evaluate a particular task or posture for a single user or group of users (Herbert et al., 1996). It may be necessary to evaluate a number of different postures during a work cycle to establish a profile of the musculoskeletal loading. In such cases, it is useful to videotape or photograph workers from both sides and from the back while they are doing the tasks. RULA is useful in comparing existing and proposed workstation designs as part of a justification or suggestion for ergonomic changes. The RULA scores provide any non-ergonomist or stakeholder with evidence that proposed modifications can reduce musculoskeletal loading.

3.2.2.1 Procedure for RULA

The procedure for using RULA is explained in three steps:

STEP 1- The posture or postures for assessment are selected. A RULA evaluation represents a moment in the work cycle, and it is important to perceive the postures adopted during the full work cycle or a significant working period previous to selecting the postures for evaluation. Depending upon the type of study, the selection could be the longest held posture or what appear to be the worst postures adopted. It also can be useful to estimate the proportion of time spent in the numerous postures being assessed (McAtamney & Corlett, 1992).

STEP-2- The postures are scored using the scoring sheet, body-part diagrams, and tables. Decide whether the left, right, or both upper arms are at risk and need to be assessed. Then score the posture of each body part. (McAtamney & Corlett, 1993), Use the RULA assessment diagrams to score the posture for each body part, along with the forces/loads and the muscle use required for that particular posture. Follow the score sheet to calculate the posture scores for Groups A and B and use Table C to calculate the grand score

STEP-3- These scores are converted to one of the three action level. The grand score can be compared with the list of action levels. In most cases, to ensure that this in efficient and effective control of any risks identified, the actions lead to a more detailed investigation.

Figure 1 shows how to find the score of RULA in a systematic manner with the help of scoring sheet. Firstly combined score of Upper Arm, Lower Arm, Wrist, Wrist Twist by using Table A as shown in Figure 1 below. Then muscle score and force score is added to make score C. Score of Neck, Trunk, Legs is calculated from Table B to find score B. then score B is added with muscle score and force score is added to find score D. Then score C and score D is used to find grand score with the help of Table C. In Appendix IV given at the end shows complete worksheet of RULA.

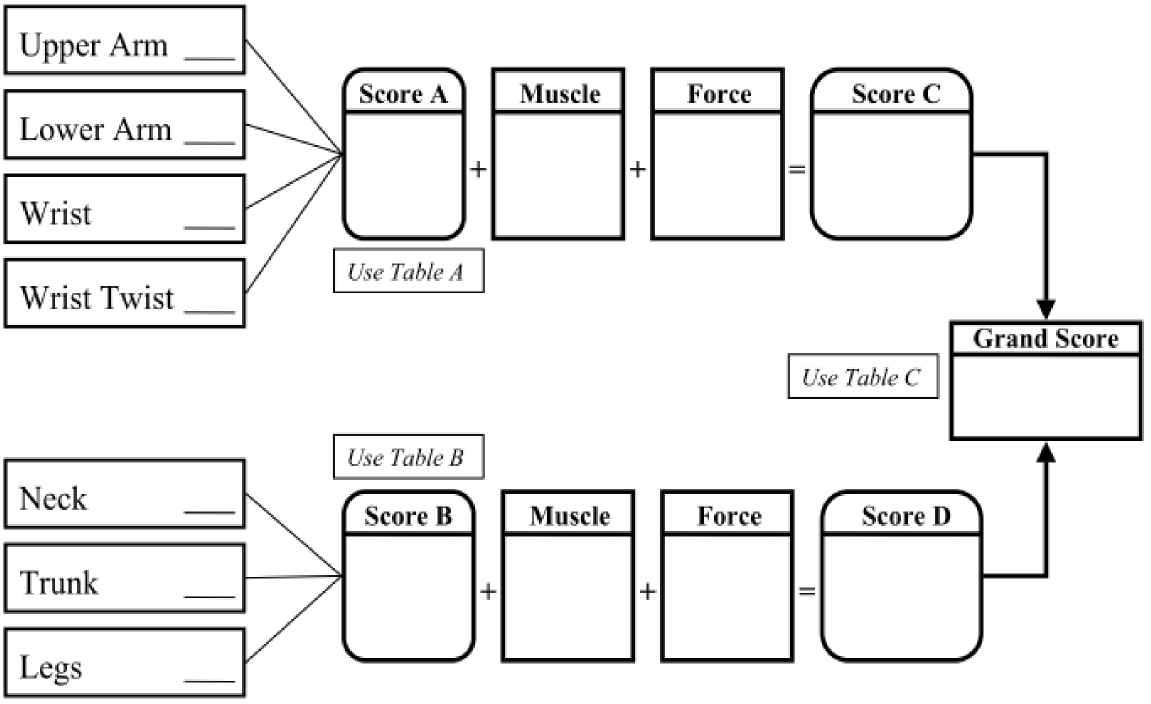


Figure 1 - RULA scoring sheet

Action level of RULA consists of three levels. Low level consists of score range 1-2. The medium level is having medium risk consists of RULA score 3-6. High RULA risk is when the RULA score is 7. All the risk and RULA score range is shown in the Table 3.

Table 3 - RULA action level

RULA Action Level		
RULA score range	Description	RULA risk level
1-2	Job is said to be approximately safe	Low
3-6	Job is said to be at moderate risk	Medium
7	Job is at High Risk	High

3.2.3 Rapid Entire Body Assessment

Rapid Entire Body Assessment (REBA) has been developed to fill a perceived requirement for a practitioner's field tool, explicitly designed to be sensitive to the type of unpredictable working postures found in health care and other service industries. (Hignett & McAtamney, 2000). REBA is a Rapid Entire Body Assessment tool which is being made to examine dynamic work where there is a risk of work related musculoskeletal disorders. It is to be used to examine tasks for which RULA was not designed. RULA is a survey method which was established to be used in ergonomics investigations of sedentary workstation where work-related upper limb and neck disorders are stated (McAtamney, 2002). REBA uses the RULA posture scoring measures as a basis and is being made to additionally record risks associated with the knee positions, the loads or forces being applied, the coupling and whole body activities(McAtamney & Hignett, 1995). Data are obtain about the body posture, forces used, type of movement or action, repetition, and coupling. A final REBA score is produced to give a suggestion of the level of risk and urgency with which action should be taken.

In the range of postural analysis tools, REBA lies sandwiched between the detailed event-driven systems and time-driven tools. Examples of detailed event-driven tools contain a three-dimensional observation system or the NIOSH (National Institute for Occupational Safety and Health) equation which needs information about specific parameters to give high sensitivity. Time-driven field tools such as OWAS (Ovako working posture analysis system) provide high generality but low sensitivity. REBA was made to be used as an event-driven tool due the complication of data collection. However it has recently been computerized by (Janik et al., 2002) for field use on a Palm PC and it can now be cast-off as a time-driven tool. The primary development was based on the ranges of limb positions using concepts from RULA (McAtamney & Corlett, 1993), OWAS and NIOSH. The starting position of posture is the functional anatomically neutral posture. As the posture moves away from the neutral position, the risk scores increases. Tables are available to change the 144 posture arrangements into a single score that represents the level of musculoskeletal risk as shown in the Appendix V. These scores are then banded into three action levels that advise on the urgency of avoiding or reducing the risk of the assessed posture.

3.2.3.1 Procedure for REBA

REBA has six steps:

Step 1 Observe the task - Notice the task to formulate a general ergonomic workplace assessment, as well as the impact of the work layout and environment, use of equipment, and behaviour of the worker with respect to risk taking. If it could happen, record data using photographs or a video camera. However, as with any observational tool, multiple views are advised to control for parallax errors.

Step-2 Select the postures for assessment - Pick which postures to examine from the observations in step one. The following criteria can be used: Most often repeated posture; longest retained posture. Posture demanding the most muscular activity or the greatest forces; Posture known to cause distress; Extreme, unstable, or awkward posture, particularly where a force is exerted; Posture most likely to be enhanced by interventions, control measures, or other changes. The decision can be constructed on one or more of the above criteria. The criteria for deciding which postures to scrutinize should be reported with the results/recommendations.

Step 3 Score the postures - Use the scoring sheet (Figure 2) and body-part scores (Table 4) to score the posture. The initial scoring is by group: Group A: trunk, neck, legs and Group B: upper arms, lower arms, wrists .Group B postures are scored discretely for the left and right sides, as specified on the scoring sheet. The load/force score, the coupling score, and the activity score are assigned at this stage. The process of finding the score is obviously explained in the Appendix V.

Step 4 Process the scores. Use Table A of Figure 2 to generate a single score from the trunk, neck, and legs scores. This is noted in the box on the scoring sheet and added to the load/force score to provide score A. Similarly the upper arms, lower arms, and wrist scores are used to generate the single score using Table B of Figure 2. The score is then added to the coupling score to produce score B. Scores A and B are entered into Table C of Figure 2, and a single score is read off. This is score C.

Step 5 Establish the REBA score - The type of muscle activity being performed is then signified by an activity score clearly shown in the Appendix V, which is added to give the final REBA score.

Step 6 -Confirm the action level with respect to the urgency for control measures - The REBA score is then checked against the action levels (Table 4). These are bands of scores corresponding to increasing urgency for the need to make changes.

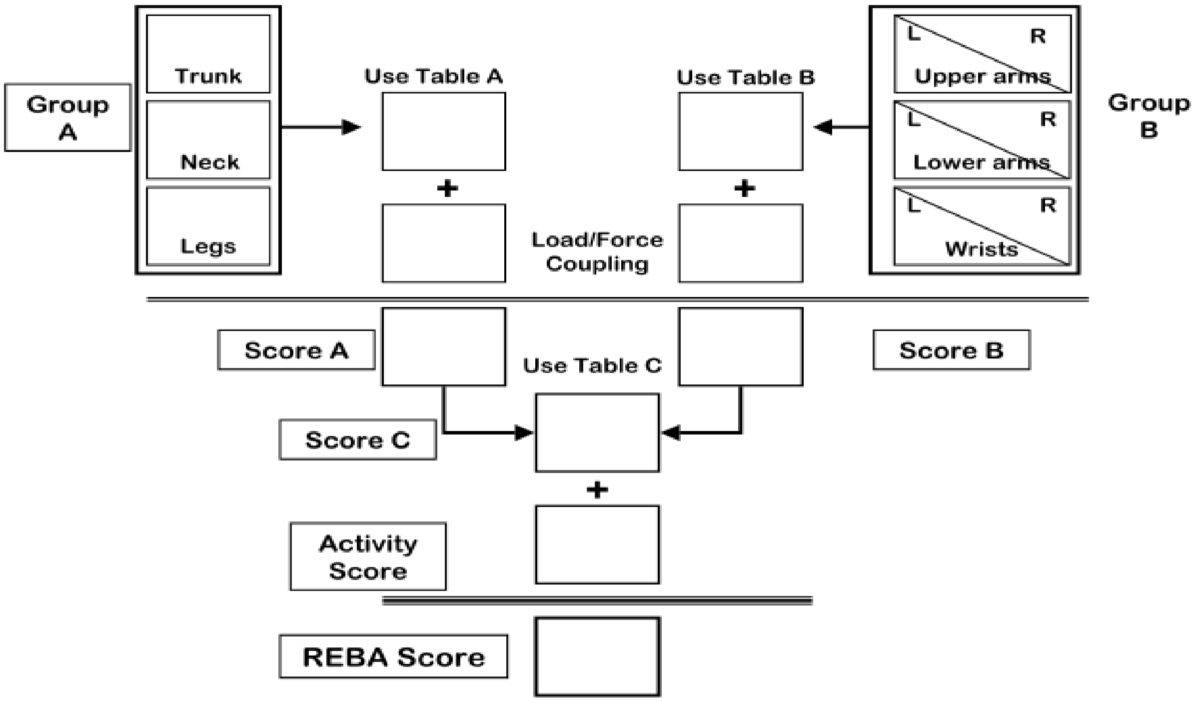


Figure 2 - REBA scoring sheet

The action level of REBA is shown in the Table 4. REBA score of 1 show that risk is low. A score of REBA in between 2-7 shows the medium risk of REBA. Score of 8-15 shows the risk of REBA is high.

Table 4 - REBA action level

REBA Action Level		
REBA score range	Description	REBA risk level
1	Job is said to be approximately safe	Low
2-7	Job is said to be at moderate risk	Medium
8-15	Job is at High Risk	High

3.2.4 Quick Exposure Check (QEC)

The quick exposure check (QEC) rapidly examines the exposure to risks for work-related musculoskeletal disorders (Li & Buckle, 1999). The QEC General index includes the indices for all parts of the body (back, hand/wrist, shoulder/arm, neck). The percentage score is evaluated by dividing the overall assessment score by the maximum overall score (X/X_{max}). The authors of this general index suggest four categories of risk (Brown & Li, 2003). To allow comparisons with other methods, action levels 2 and 3 were combined to form one category (moderate). The “high” and “very high” risk categories proposed by the authors (David et al., 2008) for the QEC Hand/wrist and QEC Shoulder/arm indices were merged into a single “high” category, creating three risk categories. When more than one worker could evaluate a given workstation, the assessments were averaged to provide a single index for each.

QEC is based on the practitioners’ requirements and research on major WMSD risk factors (Bernard, 1997). About 150 practitioners have verified QEC and modified and validated it using both simulated and real tasks. QEC has a high level of sensitivity and usability and mostly acceptable inter and intra observer reliability. Field studies confirm that QEC is relevant for a wide range of tasks. With a short training period and some practice, evaluation can normally be completed rapidly for each task. QEC gives an evaluation of a workplace and of equipment design, which eases redesign. QEC helps to prevent many kinds of WMSDs from developing and trains users about WMSD risks in their workplaces.

3.2.4.1 Procedure for QEC

QEC uses five steps:

Step 1: Self-Training - First-time QEC users must read the “QEC User Guide” as shown in next section to understand the terminology and assessment categories that are used in the checklist. Experienced users can skip step 1.

Step 2: Observer’s Assessment Checklist - The QEC user (the observer) uses the “Observer’s Assessment” checklist in (Appendix III) to conduct a risk assessment for a particular task. Most checklist assessment items are self-explanatory. New users can refer the “QEC User Guide”. At least one complete work cycle is observed before making the assessment. If a job consists of a variety of tasks, each task can be evaluated separately. Where a job cannot simply be broken down into tasks, the “worst” event within that job when a certain body part in question is most heavily loaded should be observed. The evaluation can be carried out by direct observation or by using video footage (if the information about the “Worker’s Assessment” can be obtained at another time; see step 3).

Step 3: Worker's Assessment Checklist- The worker being observed must complete the "Worker's Assessment" checklist as shown in (Appendix III).

Step 4: Calculation of Exposure Score- Use the "Table of Exposure Scores" (Appendix III) to calculate the exposure scores for each task assessed as follows:

- Circle all the letters corresponding to the reactions from the "Observer's Assessment" and the "Worker's Assessment."
- Mark the numbers at the intersection point of every pair of circled letters. For example, for the exposure to the back, number 8 should be selected as score 1, corresponding to the assessment items A2 and A3.
- Calculate a total score for each body part.

Step 5: Consideration of Actions - QEC rapidly identifies the exposure levels for the back, shoulder/arm, wrist/hand, and the neck, and the method assesses whether an ergonomic intervention can effectively reduce these exposure levels. Preliminary action levels for the QEC, based on QEC and RULA (McAtamney & Corlett, 1993) evaluations of a variety of tasks, have been suggested (Brown & Li, 2003). The exposure level E is calculated as percentage rates in between the actual total exposures score X and the maximum possible total X_{max}. For manual handling tasks, $X_{max\ MH}$ = 176; for other tasks, X_{max} = 162.

$$E (\%) = X/X_{max} \times 100\%$$

The action level of QEC consists that exposure level < 40 % is considered at low risk by QEC. Range of exposure level ≥40% to <70% is said to be at moderate risk. Exposure level of QEC is found to be greater than 70 % then job is said to be at higher risk. The risk level along with the range of exposure level is shown in Table 5.

Table 5 - QEC action level

QEC Action Level		
QEC range	Description	QEC risk level
<40%	Job is said to be approximately safe	Low
≥40%, QEC <70%	Job is said to be at moderate risk	Medium
≥ 70%	Job is at High Risk	High

3.2.4.2 A Guide to the Use of the Exposure Assessment Tool - QEC

This exposure tool consist of 9 steps has been designed to evaluate the change in exposure to musculoskeletal risks before and after an ergonomic intervention.

Step 1 - Exposure assessment for the back: Back posture (A1-A3) - The evaluation for the back posture should be made at the instant when the back is most heavily loaded. For example, when lifting a box, the back may be considered under highest loading at the instant when the person leans or reaches forward to pick up the load.

- The back can be considered as *"Almost neutral"* (Level A1) if the person is seen to work with his/her back flexion/extension, twisting, or side bending less than 20°, as shown in Figure 3.

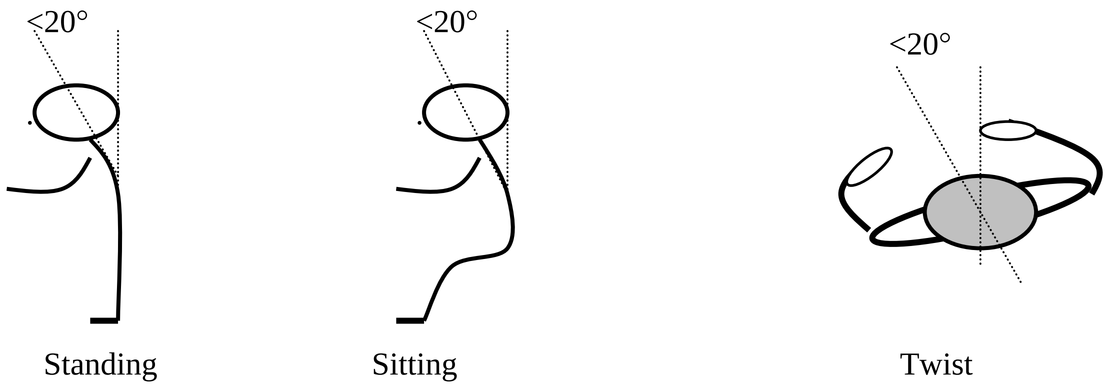


Figure 3 - Back is almost neutral

- The back can be considered as *"Moderately flexed or twisted"* (Level A2) if the person is seen to work with his/her back flexion/extension, twisting or side bending more than 20° but less than 60°, as shown in Figure - 4.

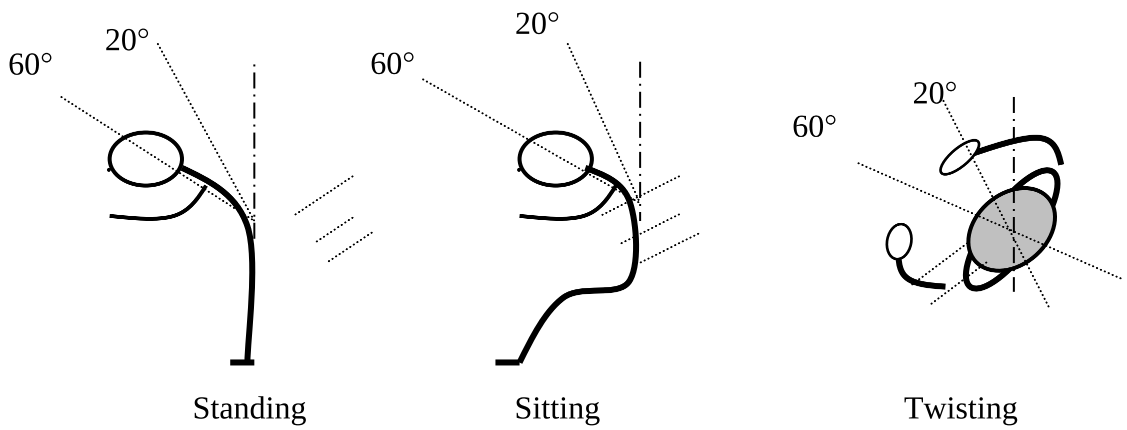


Figure 4- Back is flexed or twisted

➢ The back can be considered as *"Excessively flexed or twisted*" (Level A3) if the person is seen to work with his/her back flexion or twisting more than 60° (or close to 90°), as shown in Figure-5.

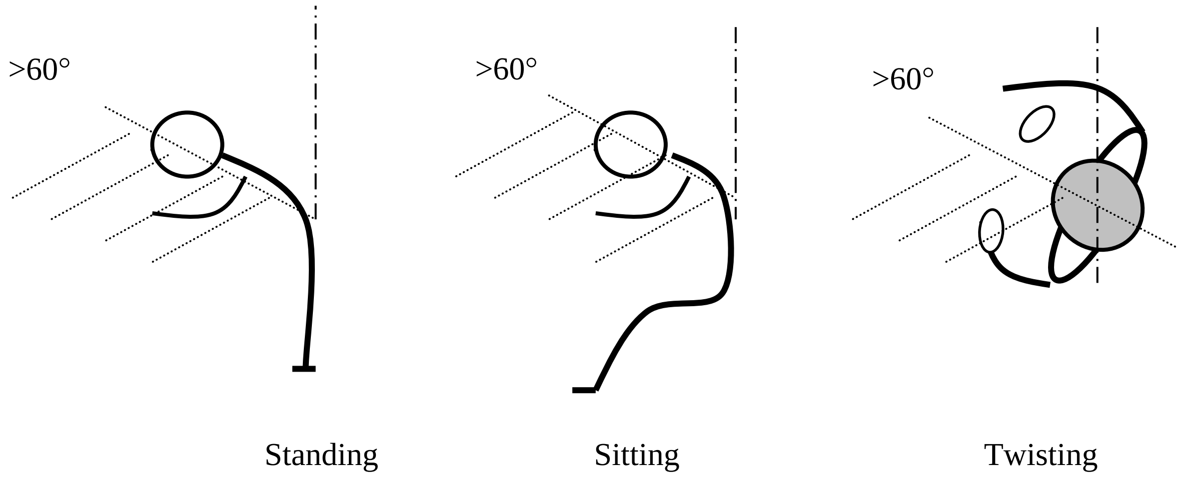


Figure 5 - Back is excessively flexed or twisted

Step 2 - Exposure assessment for the back: Back Movement (B1-B5)

➢ For manual material handling tasks, assess B1-B3. This refers to how frequently the person needs to bend, rotate his/her back when doing the task. Several back movements may happen within one task cycle.
➢ For tasks other then manual handling, such as sedentary work or repetitive tasks executed in standing or seated position, ignore B1-B3 and assess B4-B5.

Step 3 - Exposure assessment for the shoulder/arm: posture (C1-C3) – Evaluations should be made when the shoulder/arm is most heavily loaded during work, but not necessarily at the same time as the back is evaluated. For example, the load on the shoulder may not be at the highest level when the person bends down to pick up a box from the floor, but may become greater afterwards when the box is placed at a higher level.

Step 4 - Exposure assessment for the shoulder/arm: Movement (D1-D3) - The movement of the shoulder/arm is regarded as

➢ "Infrequent" if there is no regular motion pattern.
➢ "Frequent" if there is a regular motion pattern with some short pauses.
➢ "Very frequent" if there is a regular continuous motion pattern during work.

Step 5 - Exposure assessment for the wrist/hand: posture (E1-E2) – This is evaluated during the performance of the task at the point when the most awkward wrist posture is adopted, include wrist flexion/extension, side bending (ulnar/radial deviation) and rotation of the wrist around the axis of the forearm. The wrist is considered as "*almost straight*" (Level E1) if its movement is restricted within a small angular range (e.g. <15°) of the neutral wrist posture (Figure-6). Otherwise, if an obvious wrist angle can be observed during the performance of the task, the wrist is considered to be "*deviated or bent*" (Level E2, Figure-7).

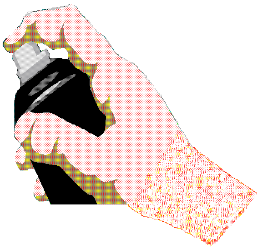


Figure 6 - Wrist is almost straight

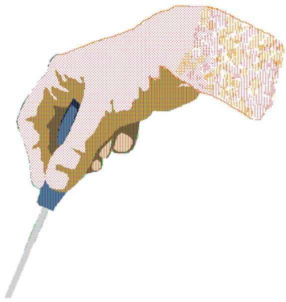


Figure 7 - Wrist is deviated or bent

Step 6 - Exposure assessment for the wrist/hand: movement (F1-F3) - This refers to the movement of the wrist/hand and forearm, apart from the movement of the fingers. One motion is counted every time when the same or similar motion pattern is repeated over a set period of time (e.g., 2 minutes).

Step 7 - Exposure assessment for the neck - The neck can be considered to be "*excessively bent or twisted"* if it is bent or twisted at an obvious angle (or more than 20°) related to the torso.

Step 8 - Worker's assessment of the same task - After the observer's assessment is made, ask the workers to reply the questions as shown in the Appendix III. Explain the meaning of the terms to him/her when required.

Step 9 - Calculation of the total exposure scores - The total exposure scores can be achieved by combining the assessments from the 'observer' (A-G) and the 'worker' (a-e) as shown in the Appendix III. Confirm that the correct combined scores have been determined before adding them into the total.

3.2.5 OCRA Checklist

The OCRA checklist method is an observational evaluation of physical exposure risks to the hand, wrist, arm, elbow, and shoulder (Colombini, 1998). The OCRA Checklist was designed to be completed using pen and paper at the worksite, taking ten to fifteen minutes to assess one job with a 30 second work-cycle time (Occhipinti & Colombini 2005). In developing the OCRA Checklist some of the direct measurement and time-study requirements of the OCRA Index reduced or eliminated .Those removed scoring items were replaced with exposure scoring schemes based on expert estimation using detailed verbal descriptors (Colombini et al. 2010). The OCRA Checklist summarizes exposure in terms of six task-variable scores (i) frequency of technical actions, (ii) awkward postures (iii) force, and movements, (iv) additional factors, (v) lack of sufficient recovery, and (vi) task duration (Colombini, 1998; Occhipinti, 1998). The additional risk factors variable contains exposure to vibration, precision movements, glove use, mechanical compression, and cold stress (Occhipinti & Colombini, 2005). Task-variable scores are mainly determined by measuring the percentage of time a worker is exposed to a multiplicity of physical parameters. Increasing percentages of exposure to these parameters correspond to increasing task-variable scores along a continuous scale. The sum of the frequency, force, posture, and additional factors scores is weighted by the scores for the lack of adequate recovery and task duration variables, producing the OCRA Checklist summary exposure score.

3.2.5.1 Procedure for OCRA Checklist

Raters administered the OCRA Checklist according to Occhipinti & Colombini‟s instructions (Occhipinti & Colombini 2001, Colombini et al., 2011). Checklist was initially developed in Italian, and various English translations were provided. The OCRA Checklist summary exposure score was automatically calculated as the raters recorded scores for the task- variables. The print version of the Checklist used in the present study is attached as Appendix II.

Raters used a stopwatch, verbal descriptors, and physical criteria to assess the percent time exposed to the pertinent OCRA parameters for the frequency, force, awkward posture and movements task variables. Raters determined scores for the task variables, which ranged from 0 up to 32 on a continuous scale. Raters used a counter and stopwatch to evaluate technical actions per minute, and used the verbal anchors of the Checklist to allocate dynamic technical action frequency scores. Technical action criteria were grounded on the definitions and example provide by the OCRA method developers (Colombini et al., 2002). Raters estimated force intensity using the Borg CR-10 scale (Borg, 1982) and verbal descriptors. Estimates for the additional factors and awkward postures task variables were evaluated using verbal descriptors. For greater clarification on the verbal descriptors linked with all of the task variables, refer to Appendix II.

The OCRA checklist action level is shown in Table 6. If checklist score is < 7.6 then task is considered at low risk. Score of 7.6 -14 represents moderate risk and a score of > 14.1 represents high risk.

Table 6 - OCRA checklist action level

OCRA Checklist Action Level		
OCRA Checklist score range	Description	OCRA Checklist risk level
<7.6	Job is said to be approximately safe	Low
7.6-14	Job is said to be at moderate risk	Medium
>14.1	Job is at High Risk	High

3.3 Standard Nordic Questionnaire

Standardised questionnaires for the investigation of musculoskeletal symptoms in an ergonomic or occupational health context are presented. It is shown in the Appendix I. The questions are forced choice variants and may be either self-administered or used in interviews. They focus on symptoms most often occur in an occupational setting. The reliability of the questionnaires has been shown to be acceptable. Specific characteristics of work strain are shown in the frequency of reactions to the questionnaires. (Kuorinka et al., 1987)

3.3.1 Structure of the Questionnaires

The questionnaires consist of structured, forced, binary or multiple choice variants and can be used as self-administered questionnaires or in interviews. There are two types of questionnaires: a general questionnaire, and specific ones focusing on the low back and neck/shoulders. The aim of the general questionnaire is simple surveying, while the specific ones permit a somewhat more thoughtful analysis.

The two main purposes of the questionnaires are to serve as instruments (1) in the screening of musculoskeletal disorders in an ergonomics framework, and (2) for occupational health care service. The questionnaires may provide means to assess the outcome of epidemiological studies on musculoskeletal disorders. The questionnaires are not meant to give a basis for clinical diagnosis. Screening of the musculoskeletal disorders may serve as a diagnostic tool for assessing the work environment, workstation and tool design. The incompatibility of the user and the task or the tool has been shown to relate to the musculoskeletal symptoms. The localisation of symptoms may expose the cause of loading. The occupational health service may use the questionnaire for many purposes e g, for diagnosis of the work strain, for follow-up of the effects of improvements of the work environment, and so on.

3.3.1.1 General Questionnaire

The general questionnaire was designed to answer the subsequent question: "Do musculoskeletal troubles happen in a given population, and if so, in what parts of the body are they restricted?" With this consideration in mind, a questionnaire was made in which the human body (viewed from the back) is divided into nine anatomical sections. These sections were carefully chosen on the basis of two criteria: regions where symptoms incline to accumulate, and regions which are different from each other both by the respondent and a health surveyor. The intended choice of the back feature of the body leaves gaps when disorders are situated in the frontal part of the shoulder or on the flexor side of the upper limbs. This choice has been made because many possible causes of pain in the front part of the body (abdominal and thoracical pains, etc.) might intermix with the musculoskeletal pain in the upper thorax. Primary observations seem to point out that this choice does not significantly modify the response rates. The verbal questions deal with each anatomical area in turn, and inquire whether the respondent has, or has had, troubles in the respective area during the preceding 12 months, whether this pain is disabling and whether it is on going.

3.3.1.2 Special Questionnaires for Low Back, Neck and Shoulder Symptoms

The two specific questionnaires focuses on anatomical areas in which the musculoskeletal symptoms are most common. These questionnaires investigate more deeply into the analysis of the respective symptoms and contain questions on the duration of the symptoms over past time i. e., entire life, last 12 months and previous 7 days. The main widening in these questionnaires is that they examine more thoroughly the severity of the symptoms in terms of their effect on activities at work and during leisure time, and in terms of total duration of symptoms and sick-leave during the previous 12 months.

3.3.2 Limitations of the Questionnaires

The general limitations of questionnaire techniques also apply to these standardised questionnaires. The experience of the person who fills out the questionnaire may affect the results. Recent and more serious musculoskeletal disorders are likely to to be remembered better than older and less serious ones. The environment and filling out situation at the time of the questioning may also influence the results. From an epidemiological viewpoint, it is obvious that this type of questionnaire is most pertinent for cross-sectional studies with all the connected limitations.

3.4 Data Collection

All the data that has been used here was collected in “XYZ” metal work industry that is located in Rewari district in Haryana. The main product of the company is copper sheet/circles/strips, brass sheet, wire netting, copper utensils etc. The main process there was cold rolling of sheet, hot rolling of sheet, bending of sheet, shearing of sheet, drawing of sheet etc. Prior to data collection, the analyst: (a) observed the subject for several cycles; (b) determined fundamental tasks of the job; and (c) confirmed with the worker that the selection of tasks was indicative of "normal operations."

The fundamental tasks of the job were identified using an expansive definition of a task. In order to perform data collection in an efficient manner, motions that were similar in level of exertion, speed or repetition, and risk to the affected body region as perceived by the analyst were combined into one task. Motions that were fundamentally different were assigned different task numbers.

The total no. of tasks found to be was 66. The entire worker was subjected to Nordic questionnaire to determine the occurrence of pain in the body. The entire task was first video recorded and keeping in mind the presence of ergonomist when using a video camera did not significantly change the way workers perform their job. The posture assessed for the study was most awkward position for the task which was used for the determination of score of RULA and REBA. Then RULA and REBA score for all the tasks was calculated by their respective sheets. Strain Index parameter was analysed by video and filling of appropriate parameter in the Strain Index sheet gives its score. OCRA checklist and QEC was filled by worker with the assistance of observer and score was calculated for all the tasks.

Figure 8 - Various processes in metal work industry

3.4.1 Assumptions During Data Collection

- The increase in the SI score due to the addition of one or more exertions is independent of the SI scores of any of the preceding forceful hand exertions.
- The workers replied in the Nordic questionnaire is absolutely true. No fake answers were given by workers in the questionnaire.
- The presence of observer when using a video camera did not significantly change the way worker performs their jobs.

- The worker performs at same performance level at all the time of a day/night (whether it is before tea/after tea, before lunch/after lunch etc.)
- The industry chosen for metal work industry represents the work of all metal work industry.
- There were no significant difference between the workers participated in the study to the workers who declined to participate.
- The day in which video recorded of the worker was an ordinary day and there was no significant difference between day of video recording and other days.
- Physical attribute of the worker has no effect on the workers performing the same task.
- The data given by worker to the observer for the filling of OCRA checklist and QEC was absolutely true.

CHAPTER-4 DATA ANALYSIS

4.1 Classification of Score into Risk Level

The score that we obtained by the different methods cannot be compared unless they are converted to the output which can be compared. The score of all the tools that were applied was classified into three categories of risk i.e. low, medium, high. The ambiguity of three, four and five level classification was converted to three level classifications by the author (Chiasson et al., 2012). All the score is converted to the three category risk level to compare output score of the five methods is shown in Table 7.

Table 7 - Risk categories used to compare output scores of the five methods for assessing MSD risk

Tool	Low risk	Medium risk	High risk
OCRA Checklist	<7.6	7.6 - 14	>14.1
RULA	1-2	3-6	7
REBA	1	2-7	8-15
Strain Index	0-3	3.1-7	>7.1
QEC	<40%	$\geq 40\%, < 70$	≥70%

4.2 Chi Square Test for Independence

The test is applicable when you have two categorical variables from a single population. It is used to determine whether there is a significant association between the two variables. The null hypothesis is that the variables are not associated: in other words, they are independent. The alternative hypothesis is that the variables are associated, or dependent. The main requirements of Chi Square test are:

- The sampling method is simple random sampling.
- The variables under study are each categorical.
- If sample data are displayed in a contingency table, the expected frequency count for each cell of the table is at least 5.

This approach consists of four steps: (1) State the hypotheses, (2) Formulate an analysis plan, (3) Analyse sample data, and (4) Interpret results.

Step 1 State the Hypotheses - Suppose that Variable A has *r* levels, and Variable B has *c* levels. The null hypothesis states that knowing the level of Variable A does not help you predict the level of Variable B. That is, the variables are independent.

H_0: Variable A and Variable B are independent.

H_a: Variable A and Variable B are not independent.

The alternative hypothesis is that knowing the level of Variable A *can* help you predict the level of Variable B.

Step 2 Formulate an Analysis Plan - The analysis plan describes how to use sample data to accept or reject the null hypothesis. The plan should stipulate the following elements.

- Significance level. Often, researchers choose significance levels equal to 0.01, 0.05, or 0.10; but any value between 0 and 1 can be used. Here analyst has taken significance level of 0.05.

- Test method. Use the Chi-Square test for independence to determine whether there is a significant relationship between two categorical variables. It can be done by SPSS statistics software or with the help of charts and formula used as given below.

Step 3 Analyse Sample Data - Using sample data, find the degrees of freedom, expected frequencies, test statistic, and the P-value associated with the test statistic.

- Degrees of freedom - The degrees of freedom (DF) is equal to:
    - DF = (r - 1) * (c - 1)
    - Where r is the number of levels for one categorical variable, and c is the number of levels for the other categorical variable.

- Expected frequencies - The expected frequency counts are computed separately for each level of one categorical variable at each level of the other categorical variable. Compute r * c expected frequencies, according to the following formula.
    - $E_{r,c} = (n_r * n_c) / n$

- where $E_{r,c}$ is the expected frequency count for level *r* of Variable A and level *c* of Variable B, n_r is the total number of sample observations at level r of Variable A, n_c is the total number of sample observations at level *c* of Variable B, and n is the total sample size.

➢ Test statistic - The test statistic is a chi-square random variable (X^2) defined by the following equation.
  - $X^2 = \Sigma [(O_{r,c} - E_{r,c})^2 / E_{r,c}]$
  - where $O_{r,c}$ is the observed frequency count at level *r* of Variable A and level *c* of Variable B, and $E_{r,c}$ is the expected frequency count at level *r* of Variable A and level *c* of Variable B.

➢ P-value - The P-value is the probability of observing a sample statistic as extreme as the test statistic. Since the test statistic is a chi-square, use the Chi-Square Distribution Calculator to assess the probability associated with the test statistic. Use the degrees of freedom computed above.

Step 4 Interpret Results - If the sample findings are unlikely, given the null hypothesis, the researcher rejects the null hypothesis. Typically, this includes comparing the P-value to the significance level, and rejecting the null hypothesis when the P-value is less than the significance level.

In this problem the association between risk level and the any reported pain in any part of body is determined using Chi Square test for independence. In order to carry out Chi Square test PASW statistics 18(SPSS software) is used. The level of significance is taken to be 0.05. The Null Hypothesis and Alternative Hypothesis taken in this case are:

H_o= *There is no association between the given method risk level and the pain reported by the workers.*

H_a = *There is association between the given method risk level and the pain reported by the worker.*

4.3 Assessment of the Validity of Strain Index in Metal Works

For assessing validity of Strain Index. The Strain Index is applied to the task of metal work industry and score is found for all the tasks and then score is converted to the risk level.

Table 8 - Case processing summary for Strain Index risk level and Nordic questionnaire analysis

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Strain Index risk level * Nordic Questionnaire analysis	66	100.0%	0	.0%	66	100.0%

Chi Square test for independence is then applied in order to determine the association between risk level and pain reported by the worker. The case processing summary as shown in Table 8 analysis shows all the 66 cases were valid.

Table 9 - Crosstabulation for Strain Index risk level and Nordic questionnaire analysis

Strain Index risk level * Nordic Questionnaire analysis Crosstabulation					
			Nordic Questionnaire analysis		Total
			No Pain	Pain	
Strain Index risk level	High	Count	1	23	24
		Expected Count	8.4	15.6	24.0
		Residual	-7.4	7.4	
		Std. Residual	-2.5	1.9	
	Low	Count	15	4	19
		Expected Count	6.6	12.4	19.0
		Residual	8.4	-8.4	
		Std. Residual	3.3	-2.4	
	Moderate	Count	7	16	23
		Expected Count	8.0	15.0	23.0
		Residual	-1.0	1.0	
		Std. Residual	-.4	.3	
Total		Count	23	43	66
		Expected Count	23.0	43.0	66.0

The Crosstabulation between Strain Index risk level and Nordic questionnaire is shown in the Table 9. Crosstabulation shows count and expected count for high low and moderate category. Moreover it gives residual which is the difference between count and expected count and standardised residual which is the conversion of residual into Z score. The significance of standardised residual is that it tells which cell is the significant contributor for giving the significant result.

In the Table 10 of Chi Square test results SPSS tells us that 0 cells have expected count less than 5 and the minimum expected count is 6.62. The sample size requirement for the chi-square test of independence is satisfied for Strain Index in metal works.

Table 10 - Result of Chi Square test of independence for Strain Index

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	26.423[a]	2	.000
Likelihood Ratio	29.201	2	.000
N of Valid Cases	66		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.62.			

The probability of the chi-square test statistic (Chi-square=26.423) was p=<0.001, which is less than the alpha level of significance of 0.05. The null hypothesis that there is no association between the given method risk level and the pain reported by the workers is rejected.

The alternate hypothesis that there is association between the given method risk level and the pain reported by the worker is supported by this analysis.

4.4 Assessment of the Validity of OCRA Checklist in Metal Works

To assess the validity of OCRA checklist. The OCRA checklist is applied to the task of metal work industry and score is found for all the tasks and then score is converted to the risk level. Chi Square test for independence is then applied in order to determine the association between risk level and pain reported by the worker. The case processing summary as shown in Table 11 for OCRA checklist risk level and Nordic questionnaire analysis shows all the 66 cases were valid. The Crosstabulation between OCRA checklist risk level and Nordic questionnaire is shown in the Table 12. Crosstabulation shows count and expected count for high low and moderate category.

Table 11 - Case processing summary for Strain Index risk level and Nordic questionnaire analysis

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
OCRA checklist risk level * Nordic Questionnaire analysis	66	100.0%	0	.0%	66	100.0%

Moreover it gives residual which is the difference between count and expected count and standardised residual which is the conversion of residual into Z score. The significance of standardised residual is that it tells which cell is the significant contributor for giving the significant result

Table 12 - Crosstabulation for Strain Index risk level and Nordic questionnaire analysis

OCRA checklist risk level * Nordic Questionnaire analysis Crosstabulation					
			Nordic Questionnaire analysis		Total
			No Pain	Pain	
OCRA checklist risk level	High	Count	2	18	20
		Expected Count	7.0	13.0	20.0
		Residual	-5.0	5.0	
		Std. Residual	-1.9	1.4	
	Low	Count	11	5	16
		Expected Count	5.6	10.4	16.0
		Residual	5.4	-5.4	
		Std. Residual	2.3	-1.7	
	Moderate	Count	10	20	30
		Expected Count	10.5	19.5	30.0
		Residual	-.5	.5	
		Std. Residual	-.1	.1	
Total		Count	23	43	66
		Expected Count	23.0	43.0	66.0

In the Table - 13 Chi Square test results SPSS tells us that 0 cells have expected count less than 5 and the minimum expected count is 5.58. The sample size requirement for the chi-square test of independence is satisfied for OCRA checklist in metal works. The probability of the Chi-square test statistic (Chi-square=13.569) was p=0.001, which is less than the alpha level of significance of 0.05. The null hypothesis that there is no association between the given method risk level and the pain reported by the workers is rejected

The alternate hypothesis that there is association between the given method risk level and the pain reported by the worker is supported by this analysis.

Table 13 - Result of Chi Square test of independence for OCRA checklist

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.569[a]	2	.001
Likelihood Ratio	14.270	2	.001
N of Valid Cases	66		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.58.			

4.5 Assessment of the Validity of QEC in Metal Works

To assess the validity of QEC. QEC is applied to the task of metal work industry and score is found for all the tasks and then score is converted to the risk level.

Table 14 - Case processing summary for Strain Index risk level and Nordic questionnaire analysis

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Quick Exposure Check risk level * Nordic Questionnaire analysis	66	100.0%	0	.0%	66	100.0%

Chi Square test for independence is then applied in order to determine the association between risk level and pain reported by the worker. The case processing summary as shown in Table 14 for QEC risk level and Nordic questionnaire analysis shows all the 66 cases were valid.

The Crosstabulation between QEC risk level and Nordic questionnaire is shown in the Table 15. Crosstabulation shows count and expected count for high low and moderate category. Count shows the no. of count that has come in reality in the study and expected count shows as if there is no difference between the groups, i.e. both groups have the same proportion as the total sample in each category of the test variable.

Moreover it gives residual which is the difference between count and expected count and standardised residual which is the conversion of residual into Z score. The significance of standardised residual is that it tells which cell is the significant contributor for giving the significant result.

Table 15 - Crosstabulation for QEC risk level and Nordic questionnaire analysis

Quick Exposure Check risk level * Nordic Questionnaire analysis Crosstabulation					
			Nordic Questionnaire analysis		Total
			No Pain	Pain	
Quick Exposure Check risk level	High	Count	2	15	17
		Expected Count	5.9	11.1	17.0
		Residual	-3.9	3.9	
		Std. Residual	-1.6	1.2	
	Low	Count	12	5	17
		Expected Count	5.9	11.1	17.0
		Residual	6.1	-6.1	
		Std. Residual	2.5	-1.8	
	Moderate	Count	9	23	32
		Expected Count	11.2	20.8	32.0
		Residual	-2.2	2.2	
		Std. Residual	-.6	.5	
Total		Count	23	43	66
		Expected Count	23.0	43.0	66.0

In the Table 16 Chi Square test results in SPSS tells us that 0 cells have expected count less than 5 and the minimum expected count is 5.92. The sample size requirement for the Chi-square test of independence is satisfied for QEC in metal works.

Table 16 - Result of Chi Square test of independence for QEC

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.191[a]	2	.001
Likelihood Ratio	14.402	2	.001
N of Valid Cases	66		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.92.			

The probability of the Chi-square test statistic (Chi-square=14.191) was p=0.001, which is less than the alpha level of significance of 0.05. The null hypothesis that there is no association between the given method risk level and the pain reported by the workers is rejected.

The alternate hypothesis that there is association between the given method risk level and the pain reported by the worker is supported by this analysis.

4.6 Assessment of the Validity of RULA in Metal Works

To assess the validity of RULA. RULA is applied to the task of metal work industry and score is found for all the tasks and then score is converted to the risk level. Chi Square test for independence is then applied in order to determine the association between risk level and pain reported by the worker. The case processing summary as shown in Table 17 for RULA risk level and Nordic questionnaire analysis shows all the 66 cases were valid

Table 17 - Case processing summary for RULA risk level and Nordic questionnaire analysis

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
RULA risk level * Nordic Questionnaire analysis	66	100.0%	0	.0%	66	100.0%

The Crosstabulation between RULA risk level and Nordic questionnaire is shown in the Table 18. Crosstabulation shows count and expected count for high low and moderate category.

Table 18 - Crosstabulation for RULA risk level and Nordic questionnaire analysis

RULA risk level * Nordic Questionnaire analysis Crosstabulation					
			Nordic Questionnaire analysis		Total
			No Pain	Pain	
RULA risk level	High	Count	2	20	22
		Expected Count	7.7	14.3	22.0
		Residual	-5.7	5.7	
		Std. Residual	-2.0	1.5	
	Low	Count	13	9	22
		Expected	7.7	14.3	22.0

		Count			
		Residual	5.3	-5.3	
		Std. Residual	1.9	-1.4	
	Moderate	Count	8	14	22
		Expected Count	7.7	14.3	22.0
		Residual	.3	-.3	
		Std. Residual	.1	-.1	
Total		Count	23	43	66
		Expected Count	23.0	43.0	66.0

In the Table 19 Chi Square test results SPSS tells us that 0 cells have expected count less than 5 and the minimum expected count is 7.67. The sample size requirement for the Chi-square test of independence is satisfied for RULA in metal works.

Table 19 - Result of Chi Square test of independence for RULA

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.146[a]	2	.002
Likelihood Ratio	13.326	2	.001
N of Valid Cases	66		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.67.			

The probability of the Chi-square test statistic (Chi-square=12.146) was p=0.002, which is less than the alpha level of significance of 0.05. The null hypothesis that there is no association between the given method risk level and the pain reported by the workers is rejected.

The alternate hypothesis that there is association between the given method risk level and the pain or ache that is reported by the worker is supported by this analysis.

4.7 Assessment of the Validity of REBA in Metal Works

To assess the validity of REBA. REBA is applied to the task of metal work industry and score is found for all the tasks and then score is converted to the risk level. Chi Square test for independence is then applied in order to determine the association between risk level and pain reported by the worker. The case processing summary as shown in Table 20 for REBA risk level and Nordic questionnaire analysis shows all the 66 cases were valid.

Table 20 - Case processing summary for REBA risk level and Nordic questionnaire analysis

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
REBA risk level * Nordic Questionnaire analysis	66	100.0%	0	.0%	66	100.0%

The Crosstabulation between REBA risk level and Nordic questionnaire is shown in the Table 21. Crosstabulation shows count and expected count for high low and moderate category

Table 21 - Crosstabulation for REBA risk level and Nordic questionnaire analysis

REBA risk level * Nordic Questionnaire analysis Crosstabulation					
			Nordic Questionnaire analysis		Total
			No Pain	Pain	
REBA risk level	High	Count	2	19	21
		Expected Count	7.3	13.7	21.0
		Residual	-5.3	5.3	
		Std. Residual	-2.0	1.4	
	Low	Count	11	9	20
		Expected Count	7.0	13.0	20.0
		Residual	4.0	-4.0	
		Std. Residual	1.5	-1.1	
	Moderate	Count	10	15	25
		Expected Count	8.7	16.3	25.0
		Residual	1.3	-1.3	
		Std. Residual	.4	-.3	
Total		Count	23	43	66
		Expected Count	23.0	43.0	66.0

In the Table 22 Chi Square test results SPSS tells us that 0 cells have expected count less than 5 and the minimum expected count is 6.97. The sample size requirement for the Chi-square test of independence is satisfied for REBA in metal works.

Table 22 - Result of Chi Square test of independence for REBA

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.801[a]	2	.007
Likelihood Ratio	10.954	2	.004
N of Valid Cases	66		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.97.			

The probability of the Chi-square test statistic (Chi-square=9.801) was p=0.007, which is less than the alpha level of significance of 0.05. The null hypothesis that there is no association between the given method risk level and the pain reported by the workers is rejected.

The alternate hypothesis that there is association between the given method risk level and the pain reported by the worker is supported by this analysis.

4.8 Assessment of Level of Agreement between the Ergonomic Tool Used

Kappa is a widely used test of inter or intra-observer agreement (or reliability) which corrects for chance agreement. Simple percentage relationship can be used to find the agreement but despite the simplicity involved in its calculation, percentages can be misleading and does not reflect the true picture since it does not take into account the scores that the raters assign due to chance. Using percentages can result in two raters appearing to be highly reliable and completely in agreement, even if they have assigned their scores completely randomly and they actually do not agree at all. Cohen's Kappa overcomes this issue as it takes into account agreement occurring by chance The Kappa coefficient of agreement (Cohen, 1960) is measure of agreement that factors out of expected agreement. Kappa varies from + 1 to – 1.

Table 23 - Value of Kappa and its relationship

Value of Kappa	Relationship
<0	Less than chance agreement
.01 to 0.20	Slight agreement
.21 to 0.40	Fair agreement
.41 to 0.60	Moderate agreement
0.61 to 0.80	Substantial agreement
0.81 to 1	Almost perfect agreement

+ 1 means that the two observers are perfectly reliable. They classify everyone exactly the same way. 0 means there is no relationship at all between the two observer's classifications, above the agreement that would be expected by chance and - 1 means the two observers classify exactly the opposite of each other i.e. if one observer says yes, the other always says no. The value of Kappa is shown in the ranges and it is converted into moderate, slight, fair, substantial relationship also along with almost perfect agreement if the value is greater than 0. If the value of Kappa is less than 0 then the agreement is termed as less than chance agreement. The value of Kappa and its agreement is shown in the Table 23.

4.8.1 Level of Agreement between RULA and REBA Using Kappa Analysis.

In order to compare the agreement between RULA and REBA we first convert all the score of RULA and REBA into three level of risk i.e. "low", "medium", "high". Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two.Table 24 shows the count of RULA risk level of low, medium and high with the risk level of REBA in a Crosstabulation.

Table 24 - Crosstabulation for RULA risk level and REBA risk level

RULA risk level * REBA risk level Crosstabulation					
Count					
		REBA risk level			Total
		High	Low	Moderate	
RULA risk level	High	21	0	1	22
	Low	0	18	4	22
	Moderate	0	2	20	22
Total		21	20	25	66

The Kappa value for the level of agreement between RULA and REBA is coming out to be 0.841

Table 25 – Kappa value for the level of agreement between RULA and REBA

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.841	.057	9.685	.000
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

It is shown in Table 25 which represents there is almost perfect agreement between RULA and REBA. The p value is also coming out to be $p<0.05$ which signifies that the relationship between RULA and REBA is statistically significant.

The reason for the almost perfect level of agreement between RULA/REBA is because both the methods depend much on the angle measurement and method of achieving the score is quite similar. As the level of agreement between and REBA method is almost perfect agreement range hence it can be stated that both methods can be used interchangeably in metal works industry.

4.8.2 Level of Agreement between RULA & Strain Index Using Kappa Analysis

In order to compare the agreement between RULA and Strain Index we first convert all the score of RULA and Strain Index into three level of risk i.e. "low", "medium", "high". Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two. Table 26 shows the count of RULA risk level of low, medium and high with the risk level of Strain Index in a Crosstabulation.

Table 26 - Crosstabulation for RULA risk level and Strain Index risk level

RULA risk level * Strain Index risk level Crosstabulation					
Count					
		Strain Index risk level			Total
		High	Low	Moderate	
RULA risk level	High	14	1	7	22
	Low	4	13	5	22
	Moderate	6	5	11	22
Total		24	19	23	66

The Kappa value for the level of agreement between RULA and Strain Index is coming out to be 0.364 shown in Table 27 which represents that there is a fair agreement between RULA and Strain Index.

Table 27 - Kappa value for the level of agreement between RULA and Strain Index

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.364	.091	4.188	.000
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The p value is also coming out to be $p<0.05$ which signifies that the relationship between RULA and Strain Index is statistically significant. The reason for only a fair agreement between these two is that RULA is a method which is based much on angular measurement and less on force/load applied and zero dependence on duration whereas Strain Index is a method which depends much on speed, duration, intensity of work and depends on only posture of hand and wrist unlike RULA which depends on whole body position

4.8.3 Level of Agreement between RULA and OCRA Checklist Using Kappa Analysis.

In order to compare the agreement between RULA and OCRA checklist we first convert all the score of RULA and OCRA checklist into three level of risk i.e. "low", "medium", "high". Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two. Table 28 shows the count of RULA risk level of low, medium and high with the risk level of OCRA checklist in a Crosstabulation.

Table 28 - Crosstabulation for RULA risk level and OCRA checklist risk level

RULA risk level * OCRA checklist risk level Crosstabulation					
Count					
		OCRA checklist risk level			Total
		High	Low	Moderate	
RULA risk level	High	11	1	10	22
	Low	3	9	10	22
	Moderate	6	6	10	22
Total		20	16	30	66

The Kappa value for the level of agreement between RULA and OCRA checklist analysis is coming out to be 0.182 shown in Table 29 which represents there is a slight agreement between RULA and OCRA checklist analysis. The p value is also coming out to be $p<0.05$ which signifies that the relationship between RULA and OCRA checklist analysis is statistically significant. The reason for only a slight agreement between the RULA and OCRA checklist is because of that OCRA checklist totally dependent on the questions of checklist that depends on use of force, frequency, breaks between work, awkward position of arms only whereas RULA depends mostly on the angle measurement of whole body and less on force/load applied by worker and does not depend on frequency of use and breaks between works. Hence level of agreement between the two is less.

Table 29 - Kappa value for the level of agreement between RULA and OCRA checklist

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.182	.093	2.127	.033
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

4.8.4 Level of Agreement between RULA and QEC Using Kappa Analysis.

In order to compare the agreement between RULA and QEC we first convert all the score of RULA and QEC into three level of risk i.e. “low”, “medium”, “high”. Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two.

Table 30 - Crosstabulation for RULA risk level and QEC risk level

RULA risk level * Quick Exposure Check risk level Crosstabulation					
Count					
		Quick Exposure Check risk level			Total
		high	low	moderate	
RULA risk level	high	10	2	10	22
	low	3	9	10	22
	moderate	4	6	12	22
Total		17	17	32	66

Table 30 shows the count of RULA risk level of low, medium and high with the risk level of QEC in a Crosstabulation.

Table 31 - Kappa value for the level of agreement between RULA and OCRA checklist

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.205	.092	2.413	.016
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The Kappa value for the level of agreement between RULA and QEC analysis is coming out to be 0.205 shown in Table 31 which represents there is a fair agreement between RULA and QEC. The p value is also coming out to be $p<0.05$ which signifies that the relationship between RULA and QEC is statistically significant.

The reason for only a fair agreement between the RULA and QEC is because of that QEC totally dependent on the questions of workers assessment as well as observer assessment. Observer assessment totally based on the frequency and position of back, shoulder, arm and neck whereas RULA does not depend on frequency. In worker assessment of QEC depends on maximum weight handled, time spend per day on this task, maximum force level as well as question towards workers perspective whereas RULA does not take these factors into account hence there is only moderate level of agreement between the two.

4.8.5 Level of Agreement between REBA & Strain Index Using Kappa Analysis

In order to compare the agreement between REBA and Strain Index we first convert all the score of REBA and Strain Index into three level of risk i.e. “low”, “medium”, “high”. Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two.

Table 32 - Crosstabulation for REBA risk level and Strain Index risk level

REBA risk level * Strain Index risk level Crosstabulation					
Count					
		Strain Index risk level			Total
		High	Low	Moderate	
REBA risk level	High	14	1	6	21
	Low	4	10	6	20
	Moderate	6	8	11	25
Total		24	19	23	66

Table 32 shows the count of REBA risk level of low, medium and high with the risk level of Strain Index in a Crosstabulation.

The Kappa value for the level of agreement between REBA and Strain Index is coming out to be 0.294 shown in Table 33 which represents that there is a fair agreement between REBA and Strain Index. The p value is also coming out to be $p<0.05$ which signifies that the relationship between REBA and Strain Index is statistically significant.

Table 33 - Kappa value for the Level of agreement between REBA and Strain Index

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.294	.093	3.379	.001
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for only a fair agreement between these two is that REBA is a method which is based much on angular measurement and less on force/load applied and zero dependence on duration whereas Strain Index is a method which depends much on speed, duration, intensity of work and depends on only posture of hand and wrist unlike REBA which depends on whole body position.

4.8.6 Level of Agreement between REBA and OCRA Checklist Using Kappa Analysis.

In order to compare the agreement between REBA and OCRA checklist we first convert all the score of REBA and OCRA checklist into three level of risk i.e. "low", "medium", "high". Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two. Table 34 shows the count of REBA risk level of low, medium and high with the risk level of OCRA checklist in a Crosstabulation.

Table 34 - Crosstabulation for REBA risk level and OCRA checklist risk level

REBA risk level * OCRA checklist risk level Crosstabulation					
Count					
		OCRA checklist risk level			Total
		High	Low	Moderate	
REBA risk level	High	11	1	9	21
	Low	3	9	8	20
	Moderate	6	6	13	25
Total		20	16	30	66

The Kappa value for the level of agreement between REBA and OCRA checklist risk level as shown in Table 35 is coming out to be 0.240 which represents there is a fair agreement between REBA and OCRA checklist analysis. The p value is also coming out to be $p<0.05$ which signifies that the relationship between REBA and OCRA checklist analysis is statistically significant.

Table 35 - Kappa value for the Level of agreement between REBA and OCRA checklist

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.240	.095	2.763	.006
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for only a fair agreement between the REBA and OCRA checklist is because of that OCRA checklist totally dependent on the questions of checklist that depends on use of force, frequency, breaks between work, awkward position of arms only whereas REBA depends mostly on the angle measurement of whole body and less on force/load applied by worker and does not depend on frequency of use and breaks between works. Hence level of agreement between the two is low.

4.8.7 Level of Agreement between REBA and QEC Using Kappa Analysis.

In order to compare the agreement between REBA and QEC we first convert all the score of REBA and QEC into three level of risk i.e. "low", "medium", "high". Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two. Table 36 shows the count of REBA risk level of low, medium and high with the risk level of QEC in a Crosstabulation.

Table 36 - Crosstabulation for REBA risk level and QEC risk level

REBA risk level * Quick Exposure Check risk level Crosstabulation					
Count					
		Quick Exposure Check risk level			Total
		High	Low	Moderate	
REBA risk level	High	10	2	9	21
	Low	3	9	8	20
	Moderate	4	6	15	25
Total		17	17	32	66

The Kappa value for the level of agreement between REBA and QEC analysis is coming out to be 0.261 as shown in Table 37 which represents there is a fair agreement between REBA and QEC. The p value is also coming out to be $p<0.05$

which signifies that the relationship between REBA and QEC is statistically significant.

Table 37 - Kappa value for the Level of agreement between REBA and QEC

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.261	.094	3.024	.002
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for only a fair agreement between the REBA and QEC is because of that QEC totally dependent on the questions of workers assessment as well as observer assessment. Observer assessment totally based on the frequency and position of back, shoulder, arm and neck whereas REBA does not depend on frequency. In worker assessment of QEC depends on maximum weight handled, time spend per day on this task, maximum force level as well as question towards workers perspective whereas REBA does not take these factors into account hence there is only fair level of agreement between the two.

4.8.8 Level of Agreement between Strain Index and OCRA Checklist Using Kappa Analysis.

In order to compare the agreement between Strain Index and OCRA checklist we first convert all the score of Strain Index and OCRA checklist into three level of risk i.e. “low”, “medium”, “high”. Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two.

Table 38 - Crosstabulation for Strain Index risk level and OCRA checklist risk level

Strain Index risk level * OCRA checklist risk level Crosstabulation					
Count					
		OCRA checklist risk level			Total
		High	Low	Moderate	
Strain Index risk level	High	11	2	11	24
	Low	3	9	7	19
	Moderate	6	5	12	23
Total		20	16	30	66

Table 38 shows the count of OCRA checklist risk level of low, medium and high with the risk level of Strain Index in a Crosstabulation. The Kappa value for the level of agreement between Strain Index and OCRA checklist is coming out to be 0.221 as shown in Table 39 which represents that there is a fair agreement between Strain Index and OCRA checklist. The p value is also coming out to be $p<0.05$ which signifies that the relationship between Strain Index and OCRA checklist is statistically significant.

Table 39 - Kappa value for the Level of agreement between Strain Index and OCRA checklist

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.221	.094	2.565	.010
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for only a fair agreement between these two is that Strain Index is a method which depends much on speed, duration, intensity of work and depends on only posture of hand and wrist. OCRA checklist totally dependent on the questions of checklist that depends on use of force, frequency, awkward position of arms, breaks between work and additional factors such as precision, gloves used, vibrations etc. whereas Strain Index is independent of breaks between work and additional factors used in checklist. Hence there is only a fair agreement between OCRA checklist and Strain Index.

4.8.9 Level of Agreement between Strain Index and QEC Using Kappa Analysis

In order to compare the agreement between Strain Index and QEC we first convert all the score of Strain Index and QEC into three level of risk i.e. “low”, “medium”, “high”.

Table 40 - Crosstabulation for Strain Index risk level and OCRA checklist risk level

Strain Index risk level * Quick Exposure Check risk level Crosstabulation					
Count					
		Quick Exposure Check risk level			Total
		High	Low	Moderate	
Strain Index risk level	High	9	1	14	24
	Low	4	9	6	19
	Moderate	4	7	12	23
Total		17	17	32	66

Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two .Table 40 shows the count of QEC risk level of low, medium and high with the risk level of Strain Index in a Crosstabulation

The Kappa value for the level of agreement between Strain Index and QEC is coming out to be 0.178 as shown in Table 41 which represents that there is a slight agreement between Strain Index and QEC. The p value is also coming out to be $p<0.05$ which signifies that the relationship between Strain Index and QEC is statistically significant.

Table 41 - Kappa value for the Level of agreement between Strain Index and QEC

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.178	.093	2.084	.037
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for only a slight agreement between these two is that Strain Index is a method which depends much on speed, duration, intensity of work and depends on posture of hand and wrist only in contrast to QEC which depends on position of back, shoulder, arm and neck. QEC depends on the questions of workers assessment as well as observer assessment. Observer assessment totally based on the frequency and position of back, shoulder, arm and neck .workers assessment of QEC depends on maximum weight handled, time spend per day on this task, maximum force level as well as question towards workers perspective whereas Strain Index does not take worker perspective into account. Due to these differences in factors level of agreement between QEC and Strain Index is slight.

4.8.10 Level of Agreement between OCRA checklist & QEC using kappa analysis

In order to compare the agreement between OCRA checklist and QEC we first convert all the score of OCRA checklist and QEC into three level of risk i.e. “low”, “medium”, “high”. Then Kappa coefficient is applied in SPSS software to find the level of agreement between the two. Table 42 shows the count of QEC risk level of Low, medium and high with the risk level of OCRA checklist in a Crosstabulation. Level of agreement is found by Kappa.

Table 42 - Crosstabulation for OCRA checklist risk level and QEC risk level

OCRA checklist risk level * Quick Exposure Check risk level Crosstabulation					
Count					
		Quick Exposure Check risk level			Total
		High	Low	Moderate	
OCRA checklist risk level	High	14	2	4	20
	Low	0	12	4	16
	Moderate	3	3	24	30
Total		17	17	32	66

The Kappa value for the level of agreement between OCRA checklist and QEC is coming out to be 0.621 as shown in Table 43 which represents that there is a substantial agreement between OCRA checklist and QEC. The p value is also coming out to be $p<0.05$ which signifies that the relationship between OCRA checklist and QEC is statistically significant.

Table 43 - Kappa value for the Level of agreement between OCRA checklist and QEC

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.621	.083	7.048	.000
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

The reason for substantial agreement between these two is that both methods based basically on a checklist. Both methods depends much on frequency, position, force, additional factors such as vibrations, visual demand of the task etc. and hence gives similar results. As the level of agreement between both of them is substantial. Hence both methods can be used interchangeably in a metal work industry.

4.9 Most Suitable Method for Metal Works Industry within the Methods Used

For finding the most suitable method within the methods used analyst first convert all the three risk level category into two risk level category so that it can be compared with Nordic questionnaire analysis. For this analyst has merged medium level and high level risk into risk category whereas low risk category into no risk category and compared with Nordic questionnaire analysis which also has a two category of pain and no-pain. The Kappa coefficient analysis is used here which is better than simple percentage analysis and takes chance agreement too. Hence higher the value of Kappa higher is the level of agreement and the tool which gives highest level of agreement will turn out to be most suitable tool among them.

4.9.1 Level of Agreement between RULA and Nordic Questionnaire

The RULA analysis that has been merged its category of medium and high risk into risk category and low risk category into no risk category. This count for RULA risk and no risk with the questionnaire pain and no pain is shown in Table 44.

Table 44 - Crosstabulation for RULA analysis and Nordic Questionnaire analysis

RULA analysis * Nordic Questionnaire analysis Crosstabulation				
Count				
		Nordic Questionnaire analysis		Total
		No Pain	Pain	
RULA analysis	No risk	13	9	22
	Risk	10	34	44
Total		23	43	66

The Kappa value for the level of agreement between RULA and Nordic questionnaire as shown in Table 45 is coming out to be 0.360 which represents that there is a fair agreement between RULA and Nordic questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between RULA and Nordic questionnaire is statistically significant.

Table 45 – Kappa value for the level of agreement between RULA analysis and Nordic questionnaire analysis

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.360	.120	2.923	.003
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

4.9.2 Level of Agreement between REBA and Nordic Questionnaire

The REBA analysis that has been merged its category of medium and high risk into risk category and low risk category into no risk category. This count for REBA risk and no risk with the questionnaire pain and no pain is shown in Table 46

Table 46 - Crosstabulation for REBA analysis and Nordic Questionnaire analysis

REBA analysis * Nordic Questionnaire analysis Crosstabulation				
Count				
		Nordic Questionnaire analysis		Total
		No Pain	Pain	
REBA analysis	No risk	11	9	20
	Risk	12	34	46
Total		23	43	66

The Kappa value for the level of agreement between REBA and Nordic questionnaire as Table 47 is coming out to be 0.277 which represents that there is a fair agreement between REBA and Nordic questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between REBA and Nordic questionnaire is statistically significant.

Table 47 - Kappa value for the level of agreement between REBA analysis and Nordic questionnaire analysis

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.277	.124	2.265	.023
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

4.9.3 Level of Agreement between Strain Index and Nordic Questionnaire

The Strain Index analysis that has been merged its category of medium and high risk into risk category and low risk category into no risk category. This count for Strain Index risk and no risk with the questionnaire pain and no pain is shown in Table 48 by a crosstabulation between them.

Table 48 - Crosstabulation for Strain Index analysis and Nordic Questionnaire analysis

Strain Index analysis * Nordic Questionnaire analysis Crosstabulation				
Count				
		Nordic Questionnaire analysis		Total
		No pain	Pain	
Strain Index analysis	No risk	15	3	18
	Risk	8	40	48
Total		23	43	66

The Kappa value for the level of agreement between Strain Index and Nordic questionnaire as shown in Table 49 is coming out to be 0.613 which represents that there is a substantial agreement between Strain Index and Nordic questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between Strain Index and Nordic questionnaire is statistically significant.

Table 49 - Kappa value for the level of agreement between Strain Index analysis and Nordic questionnaire analysis

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.613	.104	5.062	.000
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

4.9.4 Level of Agreement between OCRA Checklist and Nordic Questionnaire

The OCRA checklist analysis that has been merged its category of medium and high risk into risk category and low risk category into no risk category. This count for OCRA checklist risk and no risk with the questionnaire pain and no pain is shown in Table 50.

Table 50 - Crosstabulation for OCRA checklist analysis and Nordic Questionnaire analysis

OCRA checklist analysis * Nordic Questionnaire analysis Crosstabulation				
Count				
		Nordic Questionnaire analysis		Total
		No pain	Pain	
OCRA checklist analysis	No risk	11	5	16
	Risk	12	38	50
Total		23	43	66

The Kappa value for the level of agreement between OCRA checklist and Nordic questionnaire as shown in Table 51 is coming out to be 0.390 which represents that there is a fair agreement between OCRA checklist and Nordic questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between OCRA checklist and Nordic questionnaire is statistically significant.

Table 51 - Kappa value for the level of agreement between OCRA checklist analysis and Nordic questionnaire analysis

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.390	.119	3.270	.001
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

4.9.5 Level of Agreement between QEC and Nordic Questionnaire

The QEC analysis that has been merged its category of medium and high risk into risk category and low risk category into no risk category. This count for QEC risk and no risk with the questionnaire pain and no pain is shown in Table 52.

Table 52 - Crosstabulation for QEC analysis and Nordic Questionnaire analysis

Quick Exposure Check analysis * Nordic Questionnaire analysis Crosstabulation				
Count				
		Nordic Questionnaire analysis		Total
		no pain	pain	
Quick Exposure Check analysis	no pain	9	5	14
	pain	14	38	52
Total		23	43	66

The Kappa value for the level of agreement between QEC and Nordic questionnaire as shown in Table 53 is coming out to be 0.303 which represents that there is a fair agreement between QEC and Nordic questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between QEC and Nordic questionnaire is statistically significant.

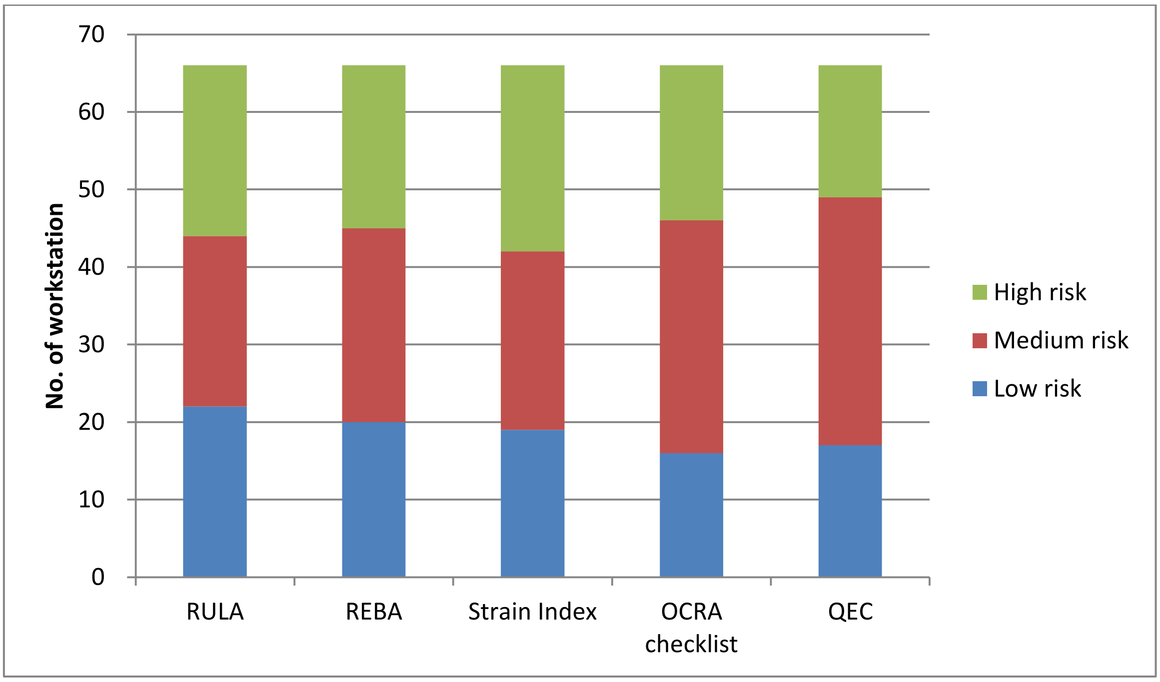
Table 53 - Kappa value for the level of agreement between QEC analysis and Nordic questionnaire analysis

Symmetric Measures					
		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.303	.121	2.604	.009
N of Valid Cases		66			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

CHAPTER-5 RESULT and DISCUSSION

The no. of workstation studied in a metal work industry was 66 and it was converted to three risk level by each tool. The tool as shown in Figure 9 shows the assessment of each tool i.e. the no. of workstations shown at what category of risk by the respective tool.

Figure 9 - Assessment of risk category of tools with no. of workstation



Strain Index describes maximum workstation as high risk whereas QEC shows least workstation as high risk. RULA describes maximum workstation as low risk or safe because RULA is a method has much dependency on posture of body and low dependency on the force applied and is independent of frequency but in the study of metal work industry as mass production comes into play so worker do work at a high frequency hence assessment tool must depends on frequency measure for the correct outcome. on the contrary OCRA checklist shows least no. of workstation to be safe

The percentage of discrepancy of one risk level means if one tool shows low risk other shows medium risk and if one shows medium risk other shows high risk. Percentage of discrepancy of two risk level means that if one show low other must show high risk. All the pairwise relations is shown below in the Table 54. In this pairwise comparison is shown along with no. of workstation having discrepancy of one risk level and two risk level in terms of no . of workstation as well as in percentage of workstation.

Table 54 - Pairwise comparison of tool with the kappa value

Pair wise tool comparison	No. of workstation having discrepancy of one risk level	No. of workstation having discrepancy of two risk level	Kappa value
RULA/REBA	7 (11%)	0 (0%)	0.841
RULA/Strain Index	22 (33%)	5 (8%)	0.364
RULA/OCRA checklist	27 (41%)	5 (8%)	0.182
RULA/QEC	31 (47%)	4 (6%)	0.205
REBA/Strain Index	26 (39%)	5 (8%)	0.294
REBA/OCRA checklist	29 (44%)	4 (6%)	0.240
REBA/QEC	28 (42%)	4 (6%)	0.261
Strain Index/OCRA checklist	27 (41%)	5 (8%)	0.221
Strain Index/QEC	31 (47%)	6 (9%)	0.178
OCRA checklist/QEC	13 (20%)	2 (3%)	0.621

The Kappa value is coming highest between RULA/REBA i.e. 0.841 because of very much similarity between the methods. both uses same kind of analysis of neck, trunk, leg in one table and arm and wrist analysis other table. and additional factor of force/muscle score is taken care in both methods but still in seven cases RULA and REBA does not match it is mostly of leg analysis. RULA only measures score is leg supported or not and does not emphasis on angle of leg whereas REBA gives importance of angle in leg and adds score in the leg too. That’s why RULA is mostly uses as an upper limb assessment tool whereas REBA is an entire body assessment tool. As the value of Kappa is 0.841 which shows nearly perfect agreement between the two. Hence these tools can be used interchangeably in metal works industry i.e. if one tool has applied no need to applied another tool as both will give synonymous results in metal work industry. The value of Kappa is coming out to be lowest in Strain Index and QEC and also discrepancy of one risk level and two risk level is coming out to be highest. It is because both tools are totally different because QEC is kind of checklist tool which depends much on workers perspective such as how stressful worker describe this work, is worker having difficulty keeping up with the work etc. moreover QEC takes into account the bending of neck, back, shoulder, arm, wrist etc. which is in contrast to Strain Index which do not depend on worker perspective and depends on angle of wrist only and its score depends much on frequency, speed, intensity, and duration of exertion. The Kappa value between OCRA checklist and QEC is coming out to be 0.621 which shows relation between both is substantial. Both have higher value of Kappa because of similarity between the tools. Both are used as a checklist tool .both methods depends much on frequency, position, force, additional factors such as vibrations, visual demand of the task etc. and takes workers perspective into account and hence gives similar results. As there is a substantial correlation between the two hence both methods can be used interchangeably in metal works industry.

For finding out the most suitable tool among the tool used for the study analyst first convert the three risk level into two risk level for the statistically comparison with workers outcome from questionnaire. Analyst merged the level of medium risk and high risk as one category of risk category and low risk into no risk category and compared with the questionnaire as shown in Table 55.

Table 55 - Pairwise comparison of tool analysis with Nordic questionnaire analysis

Pairwise comparison of tool and Nordic questionnaire analysis	Kappa value
RULA analysis/Nordic questionnaire analysis	0.360
REBA analysis/ Nordic questionnaire analysis	0.277
Strain Index analysis/ Nordic questionnaire analysis	0.613
OCRA checklist analysis/ Nordic questionnaire analysis	0.390
QEC analysis/ Nordic questionnaire analysis	0.303

The value of Kappa coming out to be maximum i.e. 0.613 in case of Strain Index with the questionnaire which represents that there is a substantial agreement between Strain Index and questionnaire. The p value is also coming out to be $p<0.05$ which signifies that the relationship between them is statistically significant. Strain Index is the method which best relates towards questionnaire. Hence it is the most suitable method among all of them.

CHAPTER -6 CONCLUSION

In the study for the prevalence of musculoskeletal disorder in metal works industry this is obtained through Nordic questionnaire i.e. related to feedback from worker about pain occur in the body of worker by doing their respective task and five ergonomic risk assessment tools i.e. RULA, REBA, OCRA checklist, Strain Index and QEC. The no. of tasks studied were sixty-six and the processes studied was mainly cold rolling of sheet, hot rolling of sheet, bending of sheet, shearing of sheet, drawing of sheet etc. the validity of each method is determined through Chi Square test for independence. All the five method are found to be statistically significant.

To compare outputs for all the tools the score is first converted to the three risk level category for every tool which can be compared. Then the outputs is compared by making 3x3 matrix. Results of the comparison leads us that RULA and REBA gives similar results. At 89.39 % both tools found to be in perfect agreement and can be used interchangeably. QEC and OCRA checklist are found to be having substantial level of agreement and hence giving nearly similar results and hence can be used interchangeably used. QEC and OCRA checklist found to be at 74.2 % at perfect agreement.

The main factors by which the tools gives different results is the design of the tools, factors taken by the tool, workers perception into account or not, different weightage given to the same factor, way of calculation of score and additional factors (vibration, visual demand of task, use of precision tools) used by tool or not.

The agreement of tool outputs is only one of the many considerations that an analyst faces. If an analyst uses two tools that give very different outputs, he or she may assume that one or both of the tools must be wrong. In truth, both may give valuable information as to what are the "problem" areas of the job and what aspects may be overlooked in an effort to improve the job and reduce its risk.

The most suitable method was found by merging the three risk level category into two risk level category. Merging of medium risk category and high risk category into risk category and low risk category into no risk category and statistically compared all the tools output to the feedback from worker which was done by questionnaire. The results shows us that Strain Index has highest level of agreement i.e. substantial level of agreement of Kappa value being 0.613 with the questionnaire. Hence turned out to be the most suitable method for the metal work industry.

6.1 Future Scope

Analyst has taken only five ergonomic tool there are many more ergonomic tool which an analyst can take such as Hand Activity Level (HAL) , Finnish institute of occupation health(FIOH), The European Standard, Safety of machinery-Human physical performance e Part 3(EN1005-3), OCRA index etc. and comparison can be made, moreover analyst has taken just one sector of metal work industry, much more sector can be taken such as food industry, automobile industry, construction work, aerospace industry etc. and comparison can be made within the sector as well as in between the sectors. Analyst has found the most suitable method with in the five ergonomic tools used but not by using all ergonomic tools. By using all the tools within the study analyst can find the best method for metal work industry. Analyst can find best method for other sectors also. Analyst has the opportunity to mix the methods and find a unique method which can fit in any sector and in any industry to give a suitable result.

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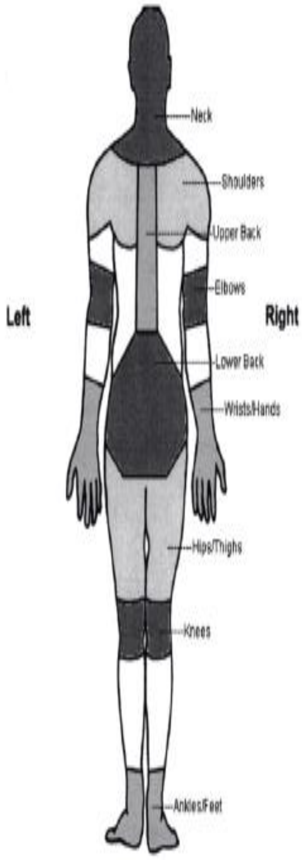
APPENDIX I - STANDARDIZED NORDIC QUESTIONNAIRE

Name__________________________________ Immediate Supervisor: ______________ Date: __/__/__

Job Title: ________________ Section: _____________ Gender: M F Age: _____ Height: ___ ft.___ in. Weight: _____

How long have you been doing this job? ____ years ____ months On average, how many hours do you work each week? ____



Back View

To be answered by everyone		To be answered by those who have had trouble			
Have you at any time during **the last 12 months** had trouble (ache, pain, discomfort, numbness) in:		Have you at any time during the **last 12 months been prevented from doing your normal work** (at home or away from home) because of the trouble?		Have you had trouble at any time during **the last 7 days?**	
Neck ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Shoulders ☐ No	☐ Yes, right shoulder ☐ Yes, left shoulder ☐ Yes, both shoulders	☐ No	☐ Yes	☐ No	☐ Yes
Elbows ☐ No	☐ Yes, right elbow ☐ Yes, left elbow ☐ Yes, both elbows	☐ No	☐ Yes	☐ No	☐ Yes
Wrists/Hands ☐ No	☐ Yes, right wrist/hand ☐ Yes, left wrist/hand ☐ Yes, both wrists/hands	☐ No	☐ Yes	☐ No	☐ Yes
Upper Back ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Lower Back (small of back) ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Hips/Thighs ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Knees ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Ankles/Feet ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes

***Based on the Nordic Questionnaire**

APPENDIX II - OCRA CHECKLIST

NAME ______________________________ AGE______ JOBTITLE_________________________

Q-1	**TYPE OF WORK INTERRUPTION (WITH PAUSES OR OTHER VISUAL CONTROL TASKS)**
SCORE	CHOOSE ONE OPTION FROM BELOW. It is possible to choose intermediate values.
0	There is an interruption of at least 5 minutes every hour in the repetitive work (also count the lunch break)
1	There are two interruptions in the morning and two in the afternoon (plus the lunch break). lasting at least 7–10 minutes on the 7–8 hour shift, or at least four interruptions per shift (plus the lunch break), or four 7–10 minute interruptions in the 6-hour shift
3	There are two pauses, lasting at least 7–10 minutes each in the 6-hour shift (without lunch break); or, three pauses, plus the lunch break, in a 7–8-hour shift.
4	There are two pauses, plus the lunch break, lasting at least 7–10 minutes each over a 7–8 hour shift (or three pauses without the lunch break), or one pause of at least 7–10 minutes over a 6-hour shift
6	There is a single pause, lasting at least 10 minutes, in a 7-hour shift without lunch break; or, in an 8-hour shift there only is a lunch break (the lunch break is not counted among the working hours
10	There are no real pauses except for a few minutes (less than 5) in a 7–8-hour shift
OVERALL SCORE -- OPTION CHOSEN	

Q-2	**ARM ACTIVITY and WORKING FREQUENCY WITH WHICH THE CYCLES ARE PERFORMED (IF NECESSARY, INTERMEDIATE SCORES CAN BE CHOSEN)**
SCORE	CHOOSE ONE OPTION FROM BELOW. It is possible to choose intermediate values.
0	Arm movements are slow, and frequent short interruptions are possible (20 actions per minute).
1	Arm movements are not too fast, are constant and regular. short interruptions are possible (30 actions per minute).
3	Arm movements are quite fast and regular (about 40), but short interruptions are possible
4	Arm movements are quite fast and regular, only occasional and irregular short pauses are possible (about 40 actions per minute
6	Arm movements are fast. only occasional and irregular short pauses are possible (about 50 actions per minute)
8	Arm movements are very fast. the lack of interruptions in pace makes it difficult to hold the pace, which is about 60 actions per minute
10	Very high frequencies, 70 actions per minute or more. absolutely no interruptions are possible
OVERALL SCORE -- OPTION CHOSEN	

Q-3	**PRESENCE OF WORKING ACTIVITIES INVOLVING THE REPEATED USE OF FORCE IN THE HANDS-ARMS (AT LEAST ONCE EVERY FEW CYCLES DURING ALL THE TASK ANALYZED).**
3(A)THIS WORKING TASK IMPLIES: ☐ The handling of objects weighing over 3 kg ☐ Gripping between forefinger and thumb and lifting objects weighing over 1 kg (in pinch) ☐ Using the weight of the body to obtain the necessary force to carry out a working action ☐ The hands are used as tools to hit or strike something	SCORE FOR 3(A) 1 - Once every few cycles 2 - Once every cycle 4 - About half of the cycle 8 - For over half of the CYCLE
3(B)THE WORKING ACTIVITY REQUIRES THE USE OF INTENSE FORCE FOR: ☐ Pulling or pushing levers ☐ Pushing buttons ☐ Closing or opening ☐ Pressing or handling components ☐ Using tools	SCORE FOR 3(B) 4 - 1/3 of the time 6 - About half of the time 8 - Over half of the time 16 - Nearly all the time
3(C)THE WORKING ACTIVITY REQUIRES THE USE OF MODERATE FORCE FOR: ☐ Pulling or pushing levers ☐ Pushing buttons ☐ Closing or opening ☐ Pressing or handling components ☐ Using tools	SCORE FOR 3(C) 2 - 1/3 of the time 4 - About half of the time 6 - Over half of the time 8 - Nearly all the time
OVERALL SCORE – 3(A)+3(B)+3(C)	

Q-4	**PRESENCE OF AWKWARD POSITIONS OF THE ARMS DURING THE REPETITIVE TASK**	
4(A)	1 - The arm/arms are not leaning on the workbench but are a little uplifted for a little over half the time 2 - The arms have nothing to lean on and are kept nearly at shoulder height for about 1/3of the time 4 - The arms are kept at about shoulder height, without support, for over half of the time 8 - The arms are kept at about shoulder height, without support, all the time	
4(B)	2 - The wrist must bend in an extreme position, or must keep awkward postures (such as wide flexions or extensions, or wide lateral deviations) for at least 1/3 of the time 4 - The wrist must bend in an extreme position, or must keep awkward postures (such as wide flexions or extensions, or wide lateral deviations) for over half of the time 8 - The wrist must bend in an extreme position all the time	
4(C)	2 - The elbow executes sudden movements (jerking movements, striking movements) for about 1/3 of the time 4 - The elbow executes sudden movements (jerking movements, striking movements) for over half of the time 8 - The elbow executes sudden movements (jerking movements, striking movements) nearly all the time	
4(D)	☐ Grip objects, parts, or tools with fingertips with constricted fingers (pinch) ☐ Grip objects, parts, or tools with fingertips with the hand nearly open (palmar grip) ☐ Keeping fingers hooked	SCORE FOR 4(D) 2 for about 1/3 of the time 4 for over half the time 8 all the time

4(E)	Add +3 if presence of identical movements of shoulder and/or elbow, and/or wrist, and/or hands, repeated for at least 2/3 of the time and also the cycle is shorter than 15 seconds otherwise add 0
OVERALL SCORE – HIGHEST OF [4(A), 4(B), 4(C), 4(D)]+4(E)	

Q-5	**PRESENCE OF ADDITIONAL RISK FACTORS:**
SCORE	RECORD THE HIGHEST SCORE ASSOCIATED WITH THE ADDITIONAL FACTORS IDENTIFIED
2	Gloves inadequate to the task are used for over half of the time (uncomfortable, too thick, wrong size, etc.)
2	Vibrating tools are used for over half of the time
2	The tools employed cause compressions of the skin (reddening, callosities, blisters, etc.)
2	precision tasks are carried out for over half of the time (tasks over areas smaller than 2 or 3 mm)
2	More than one additional factor is present at the same time and, overall, they occupy over half of the time
3	One or more additional factors are present, and they occupy the whole of the time
1	Working pace set by the machine, but there are "buffers" in which the working rhythm can either be slowed down or accelerated
2	Working pace completely determined by the machine
OVERALL SCORE – HIGHEST SCORE FROM ADDITIONAL RISK FACTOR	

OVERALL CHECKLIST SCORE = SCORE OF Q-1 + Q-2 + Q-3 + Q-4 + Q-5

APPENDIX III - QUICK EXPOSURE CHECK

Job title: ________________ Task: ________________ Worker's name: _______________

Part A: Observer's Assessment

Back

When performing the task. Is the back

A1: Almost neutral?

A2: Moderately flexed or twisted or side bent?

A3: Excessively flexed or twisted or side bent?

For manual handling tasks only: *Is the movement of the back*

B1: Infrequent? (Around 3 times per minute or less)

B2: Frequent? (Around 8 times per minute)

B3: Very frequent? (Around 12 times per minute or more)

Other tasks: *is the task performed in static posture most of the time? (Either seated or standing*)

B4: No

B5: Yes

Wrist/Hand

Is the task performed

E1: With almost a straight wrist?

E2: With a deviated or bent wrist position?

Is the task performed with similar repeated motion patterns

F1: 10 times per minute or less?

F2: 11 to 20 times per minute?

F3: More than 20 times per minute?

Shoulder/arm

Is the task performed

C1: At or below waist height?

C2: At about chest height?

C3: At or above shoulder height?

Is the arm movement repeated

Dl: Infrequently? (Some intermittent arm movement)

D2: Frequently? (Regular arm movement with some pauses)

D3: Very frequently? (Almost continuous arm movement)

Neck

When performing the task. is the head/neck bent or twisted excessively?

G1: No

G2: Yes, occasionally

G3: Yes, continuously

Part B: Workers assessment

- **What is the maximum weight handled in this task?**

a1: Light (5 kg or less)

a2: Moderate (6 to l0 kg)

a3: Heavy (11 to 20 kg)

a4: Very Heavy (More than 20 kg)

- **How much time on average do you spend per day doing this task?**

b1: less than 2 hours

b2: 2 to 4 hours

b3: more than 4 hours

- **When performing this task (single or double handed), what is maximum force level exerted by one hand?**

c1: Low (e.g. Less than 1 kg)

c2: Medium (e.g. 1 to 4 kg)

c3: High (More than 4 kg)

- **Do you experience any vibration during work?**

d1: Low (or no)

d2: Medium

d3: high

- **Is the visual demand of this task -**

e1: Low? (There is almost no need to view fine details)

e2: High? (There is a need to view some fine details)

- **Do you have difficulty keeping up with this work?**

f1: Never

f2: Sometimes

f3: Often

- **How stressful do you find this work?**

g1: Not at all

g2: Low

g3: Medium

g4: High

Table of Exposure Scores

Exposure to the **Back**

	A1	A2	A3	Score 1	B1	B2	B3	Score 2	b1	b2	b3	Score 3
a1	*2*	*4*	*6*		*2*	*4*	*6*		*2*	*4*	*6*	
a2	*4*	*6*	*8*		*4*	*6*	*8*		*4*	*6*	*8*	
a3	*6*	*8*	*10*		*6*	*8*	*10*		*6*	*8*	*10*	
a4	*8*	*10*	*12*		*8*	*10*	*12*		*8*	*10*	*12*	

				Score 4				B4	B5	Score 5	Total score for the back = Sum of scores 1 to 5
b1	*2*	*4*	*6*		*2*	*4*	*6*	*2*	*4*		
b2	*4*	*6*	*8*		*4*	*6*	*8*	*4*	*6*		
b3	*6*	*8*	*10*		*6*	*8*	*10*	*6*	*8*		

Exposure to the **Shoulder/arm**

	C1	C2	C3	Score 1	D1	D2	D3	Score 2	b1	b2	b3	Score 3
a1	*2*	*4*	*6*		*2*	*4*	*6*		*2*	*4*	*6*	
a2	*4*	*6*	*8*		*4*	*6*	*8*		*4*	*6*	*8*	
a3	*6*	*8*	*10*		*6*	*8*	*10*		*6*	*8*	*10*	
a4	*8*	*10*	*12*		*8*	*10*	*12*		*8*	*10*	*12*	

				Score 4				Score 5	Total score for shoulder/arm = Sum of scores 1 to 5
b1	*2*	*4*	*6*		*2*	*4*	*6*		
b2	*4*	*6*	*8*		*4*	*6*	*8*		
b3	*6*	*8*	*10*		*6*	*8*	*10*		

Exposure to the **Wrist/hand**

	F1	F2	F3	Score 1	E1	E2	Score 2	b1	b2	b3	Score 3
c1	*2*	*4*	*6*		*2*	*4*		*2*	*4*	*6*	
c2	*4*	*6*	*8*		*4*	*6*		*4*	*6*	*8*	
c3	*6*	*8*	*10*		*6*	*8*		*6*	*8*	*10*	

				Score 4			Score 5	Total score for the wrist/hand = Sum of scores 1 to 5
b1	*2*	*4*	*6*		*2*	*4*		
b2	*4*	*6*	*8*		*4*	*6*		
b3	*6*	*8*	*10*		*6*	*8*		

Exposure to the **Neck**

	G1	G2	G3	Score 1	e1	e2	Score 2	Total score for the neck
b1	*2*	*4*	*6*		*2*	*4*		= Scores 1+ 2
b2	*4*	*6*	*8*		*4*	*6*		
b3	*6*	*8*	*10*		*6*	*8*		

Worker's evaluations

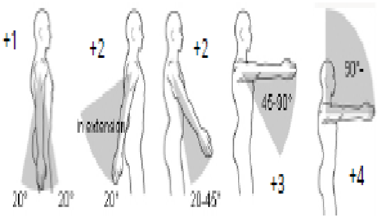
d1	d2	d3	f1	f2	f3	g1	g2	g3	g4	(Worker's evaluation) Total
1	*4*	*9*	*1*	*4*	*9*	*1*	*4*	*9*	*16*	

Back: ________ Shoulder/arm: __________ Wrist/hand :___________ Neck: _____________

APPENDIX IV - RULA WORKSHEET

A. Arm and Wrist Analysis

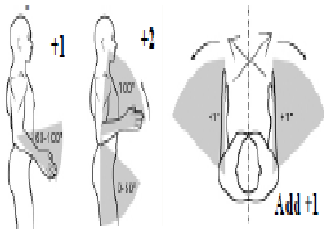
Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

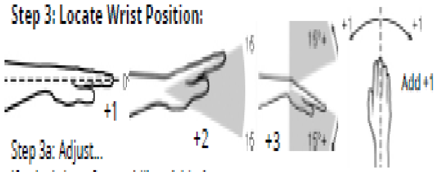
Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in **Table C.**

Wrist & Arm Score

Scores

Table A		Wrist Score							
		1		2		3		4	
Upper Arm	Lower Arm	Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

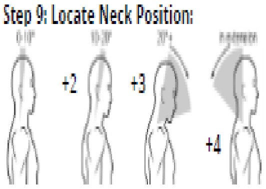
Table C		Neck, Trunk, Leg Score						
		1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

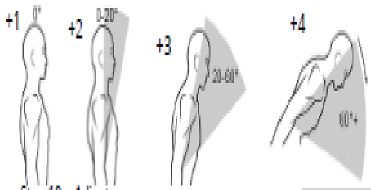
Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score											
	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

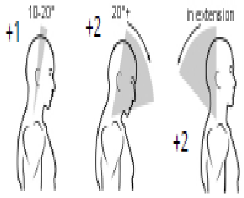
Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in **Table C.**

Neck, Trunk, Leg Score

APPENDIX V - REBA WORKSHEET

A. Neck, Trunk and Leg Analysis

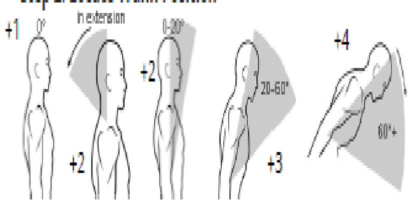
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

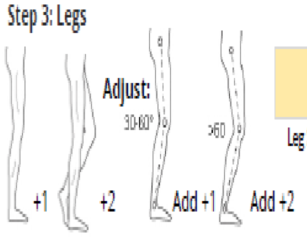
Step 2: Locate Trunk Position



Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A

Using values from steps 1-3 above,
Locate score in Table A

Posture Score A

+

Step 5: Add Force/Load Score

If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score

=

Step 6: Score A, Find Row in Table C

Add values from steps 4 & 5 to obtain Score A.
Find Row in Table C.

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A

		Neck 1				Neck 2				Neck 3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B

		Lower Arm 1			Lower Arm 2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

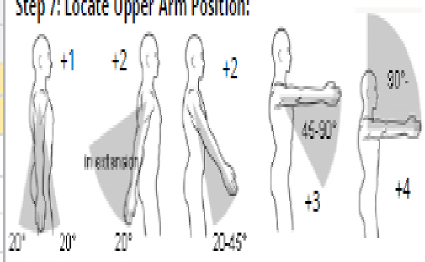
Table C

Score A	Score B 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

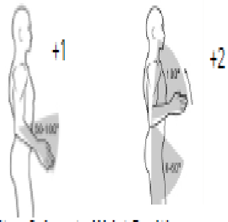
Step 7: Locate Upper Arm Position:



Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

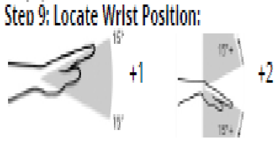
Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:



Wrist Score

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B

Using values from steps 7-9 above, locate score in Table B

Posture Score B

+

Step 11: Add Coupling Score

Well fitting Handle and mid rang power grip, ***good:* +0**
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair:* +1**
Hand hold not acceptable but possible, ***poor:* +2**
No handles, awkward, unsafe with any body part, ***Unacceptable:* +3**

Coupling Score

=

Step 12: Score B, Find Column in Table C

Add values from steps 10 & 11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score

+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base