INVESTIGATION OF ERGONOMICS RISKS RELATED FACTORS AFFECTED TO RE BAR WORKERS IN CONSTRUCTION SITES

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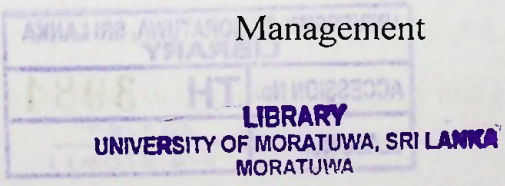
Degree of Master of Science in Occupational Safety and Health Management



Department Of Building Economics

University of Moratuwa
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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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06 . 06 . 2019

Dr. Sachie Gunatilake Date

Dissertation Supervisor

ABSTRACT

INVESTIGATION OF ERGONOMICS RISKS RELATED FACTORS AFFECTED TO RE BAR WORKERS IN CONSTRUCTION SITES

When thinking about Sri Lankan workers, professionals in OHSE, other involving parties are not interested in Ergonomics due to various reasons such as non-availability of data, ergonomics risk are not available in short term, workers do not think that they will face such illness as muscular skeletal disorders in their work life, consideration on manufacturing industries who have foreign base in Sri Lankans and apparel trade have followed ergonomics to some extent. In construction industry no strong evidence have been found and it is necessary to propose a framework to enhance health and safety conditions in construction industry in Sri Lanka.

This study is aiming to identify the Ergonomics risk factors faced by reinforcement workers in construction industry. The descriptive study was carried out through a preliminary survey, questionnaire survey and case study of selected workers. Data was analyse by using Percentage on work patterns, frequencies, averages of selected criteria and risk factor assessment tools. Mean and Mode also adapted to the analysis.

Almost eighteen criteria were selected for analyses the collected data along with the posture analyses modal. As per the analysis tools posture scores are under very high & high levels, As per the other criteria's work patterns was not in satisfactory levels according social criteria. On recommendations, In general labor handing on reinforcement work has to do in more organized manner to overcome ergonomics complications at construction sites.

Keywords: Ergonomic Risk Factors , Construction Sites , Posture Analysis , RULA Analysis ,REBA Analysis ,Re bar workers .

Dedication ……..

This Dissertation

Is Lovingly Dedicated to

My beloved Father, Mother, Wife & Friends

For their loving Support & Guidance

ACKNOWLEDGEMENT

This dissertation is not just a single effort of mine but this is a result of an immense effort and support given by lots of others. Therefore, I would like to extend my sincere thanks for the others who spent their valuable time with courtesy.

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LIST OF ABBREVIATIONS

Abbreviation	Description
BBs	Bar benders
BBHs	Bar bender Helpers
BLS	Buru of Labour Statistic
CTD	Cumulative trauma disorders
EERFM	Effective of Ergonomics Risk Factors Management
EHS	Environment Health & Safety
ERF	Ergonomics Risk Factors
ERFA	Ergonomics Risk Factors Assessment
ILO	International Labour Organization
MSDs	Muscular Skeletal Disorders
NIOSH	National Institute of Occupational Health & Safety
OCRA	Occupational Repetitive Action Index
OHSE	Occupational Health Safety & Environment
PATH	Posture Activity Tools Handling
RULA	Rapid Upper Limb Assessment
REBA	Rapid Entire Body Assessment
RWs	Reinforce Workers
WRMSD	Work Related Muscular Skeletal Disorders

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CHAPTER ONE

INTRODUCTION

1.1 Background

In general a word, ergonomics is the study of understanding how fit human work patterns are to work tasks which the worker carries on work place. According to Greek and Latin scholars ergonomics is the relationship between humans and their job background .Te-Hsin & Kliner B.H (2001). The experts in the globe mentioned that ergonomics is a set of adaptations such as engineering, anatomy, physiological, psychological interactions with the physical environment. According to the OSHA 1994, ergonomics is rather than forcing the worker to the job is the art or science of designing the work to fit the task Tyarri F & Smith L.J (1997)

When considering ergonomics risk factors or ergonomics related accidents, they can be considered either long term or short term. Most critical ergonomics risks are long term while short term accidents can be cured.

According to Ayat , Al swaity Adnan, Enshassi, (2005) forceful exertions cause ergonomics problems which include the quantity labor lifting, how pushing, pulling or using excessive force is used to perform tasks. These tasks which require forceful exertion place higher loads on the muscles, tendons, ligaments and joints. Force requirement may increase with:1.Increase weight of load handled or lifted load , 2. Increase bulkiness of the load handled or lifted during work . 3. Use of awkward posture at work . 4. The speed of movement work or object . 5. Increased slipperiness of the objects handled (requiring increased grip force) during work . 6. The presence of vibrations Ayat Al swaity, Adnan Enshassi.(2005).

Considering on world data on ergonomics Occupation Safety Health & Administration (OSHA) mentioned that musculoskeletal injuries resulting from poor workplace ergonomics account for 34% of all lost workday injuries and illnesses. Carpal tunnel syndrome accounts for 15% of all workplace injuries. 42% of carpal tunnel cases result in more than 30 days away from work.

According to the Bureau of Labor Statistics' most recent data, these types of injuries accounted for 380,600, or one-third, of days-away-from-work cases. Industries with

a framework to enhance health and safety conditions in construction industry in Sri Lanka according to Jayawardane, Gunawardena, (1998.). Also in the past half-decade, many foreign workmen were engaged in construction activities in large scale in construction industry and it has been identified that they're more efficient and effective in working compared to Sri Lankan work force. Moreover, there is a reasonable belief that reasons for efficiency of these foreign workers is their ergonomics based work patterns such as following basics of ergonomics during their work time. It was also noted that in construction industry, specially the high-rise building major work portions are reinforce work and concreting work. In an average one flow slab of $2000m^2$ building, around 25 tons of reinforce is been used and very complicated reinforcement arrangement has to completed by workers. So amidst the several work tasks, rebar workers (RWs) are facing many difficulties during their work. In considering all the factors, it can be stated that sufficient studies have not been conducted so far in Sri Lanka relevant to this topic and that is the key reason for this study.

1.3 Aims of the Study

The aim of this study is to investigate the ergonomics risk factors related to rebar workers in construction projects.

1.4 Objectives of the Study

Following objectives will be taken as the guidelines to achieve the aims of the study

1. Identify and review the key ergonomics risks faced by workers and their impacts to the workmen.
2. Identify and review the available ergonomics risks factor analysis (**ERFA**) tools and impact of the ergonomics tools in application.
3. Investigate the one Posture related ERF in building construction projects using suitable ergonomic risk factor analysis tools & other suitable Analysis methods .

1.5 Research Methodology

Studying on ergonomics risk on health and safety conditions of workmen in construction industry is an important current requirement. Sufficient studies have not been conducted so far in Sri Lanka relevant to this topic.

Following methodology will be used during this study.

1. Based on the literature survey, ergonomics risk factors are analyzed. For analysis the data scholar articles are referred .
2. For analysis of ERFA tools literature review base analysis were done . For that base on the scholar articles ERFA tools are listed out and benefits , Impacts , disadvantages are analyzed.
3. For investigate the risks filed study is conducted filed study was planned to conduct as a case study, cases will be selected from the field of building construction.
4. For the case selection which was based on work patterns, the work tasks was taken for consideration and in addition to risk analysis tools (RAT), field observation, taking photo evidence may also be considered .Raw data also collected on primary interviews during data collection.

1.6 Scope & Limitation of the research

The scope of the research is limited to building construction sites in Sri Lanka and high rise buildings are considered for the research. Also only CS2 (most top category) construction companies in the country were selected for studying. **In that category the sample is limited to reinforce work gangs.**

1.7 Structure of the Thesis

The thesis will consist of following chapters .

Chapter I	Introduction
Chapter II	Literature review
Chapter III	Methodology
Chapter IV	Findings and Analysis
Chapter V	Conclusion and Recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter literature related to the ERFA and its tools will be described. It also finds out the impacts on ergonomics risks on workers. Parallel to that, ergonomics risk factor reduction methods are also discussed.

2.2 Evaluation of the ergonomics related subject matters

Ergonomics mainly contain several risk factors and anthropometry in construction industry. Before identifying risk factors of ergonomics, it is vital to state out the main definitions regarding ergonomics. According to literature evaluating the concept of ergonomics, it is identified as an element which evaluates the demands of a specific task with reference to the capacity of workers to perform the task over a certain time period.

To develop a particular job design, demands of the task would ideally be held within the capacity of a fixed percentage of the working population.Fernandez & Marley., (1998).

According to (Fernandez and Goodman 1988)Application of ergonomic principles in work place can have myriad advantages which include increment of productivity and health and safety of the workforce, reduce number of compensation claims by workers, compliance with government regulations such as Occupational Safety and Health Administration (OSHA) standards, improvement of workers' job satisfaction, reduction of time loss, improvement of workers' work quality and morale and minimization of workers' absenteeism from work.

According to Helander (1997) chronological development of Ergonomics can be shown as follows)

- The decade of military ergonomics – 1950's
- The decade of industrial ergonomics – 1960's
- The decade of consumer ergonomics – 1970's

- The decade of HCI and software ergonomics – 1980's
- The decade of cognitive and organizational ergonomics – 1990's
- The decade of global communication and eco-ergonomics – 2000's

According to - Helander., (1997a & 1997b). Brown (1987), ergonomics should be adaptable to the shifting safety requirements of the society)

Brown (1987) was also confirmed the same. With the papers published in ergonomics in the period 1975 – 1980 he looked back its developments leading the field whereas prior to this period the journal was concerned with the 'traditional ergonomics topics of work and health, job design, manual labour handling and fatigue.

Ergonomics pertaining to workers' mental health still needs to progress, and so far, stress and stain identified in the domain of ergonomics were mainly resulting from physical not psychological aspects pertaining to health.)

2.3 Definitions of Ergonomics

According to Greek literature, the term ergonomics is derived from the Greek word Ergo meaning "work" and Nomo's meaning "natural laws of" or "study of." The profession has two major branches with considerable overlap. A. Mittal, Sharma & K. Mittal., (2013).

According OSHA (1994) ergonomic is the science of "designing the job to fit the worker, rather than forcing the worker to fit the job." Thus, ergonomic is going to commence a process to eliminate all the obstacles to enhancing quality, productivity and human performance by fitting the environment and work processes to the people Ahankoob1 & Charehzehi (2013).

It is Mentioned that the ergonomics can be defined simply as the study of work. Ergonomics is the science of designing the job to fit the worker, other than physically forcing the worker's body to fit the job Al Swaity & Enshassi (2005). Health related literature states that ergonomics is defined as the study of the entire design of a work place, equipment, machine, tool, product, environment and system which takes into consideration human being's physical, physiological, bio-mechanical and

psychological capabilities and optimizes the effectiveness and productivity of work systems while assuring the safety, health, and well-being of the workers (Fernandez & Marley 1998). In general, the goal of ergonomics is to fit the task to the individual, not the individual to the task.

2.4 Ergonomics Risk Factors in Construction Industry

According to Al Swaity and Enshassi (2005),exerting oneself too much may contribute to risk factors associated with ergonomics.)

2.4.1. Forceful exertions – Includes the quantity of labour lifting, it includes methods of pushing, pulling or any excessive force is used to perform tasks. These tasks which required forceful exertion place higher loads on the muscles, tendons, ligaments and joints.

- Force requirement may increase with:
- Increase of weight of load handled or lifted at work
- Increase of bulkiness of the load handled or lifted at work
- Use of awkward posture during work
- The speed of the movement at work
- Increased slipperiness of the object handled Increased (requiring increased grip force)
- The presence of vibrations Al Swaity & Enshassi (2005).

2.4.2 Working in Awkward Postures - Awkward posture (AWP) of the body is termed as outside the natural best location of each joint that can provide the stagnant and control Amstrong & Lifsitha (1987).

In the domain of construction, most of the labor associated with the commencing and concluding phases of tasks such as excavation, working underneath etc., may make the workers work in awkward positions.

2.4.3 Repetition - Performing similar movement Or motion of work in every few short times for more than two hours without any rest or stopping of work and break time is mentioned as a repetition work Amstrong & Lifsitha (1987). Working in bar-bending, re-bar stacking tightening, plastering of walls, block works etc. can be

identified as repetitive works. More than 60% of construction workers are being involved in such activities. Buchholz, Paquet, Punnet, Lee and Moir mention that the most repetitive work is observed in road construction activities.

2.4.4 Static Posture –In general mode the human body requires moving it sutable directions , Kroemer & Grandijinan. (1997). This means that a worker should not work in the same position for a long time without changing. Machine operators, crane operators are one of the categories affected in these types of ergonomics issues.

2.4.5 Vibration - Vibration - Vibration is illustrated as any movement of the body or a body part in one fixed point while using power tools or equipment and considerable thins that generated the vibration , Kensila & Prior. (1995). The activities might be different such as working with a machine or working with a tool. Tool vibration in building sector and water and telecommunication sector are prominent. Intensity of issues can change due to time, area, task etc.

2.4.6 Force - The Selected amount of physical effort which is required by the workers to do the various tasks or control and maintain operation and using of Utilizing the muscles much harder and speed than normal conditions tendons and joints. It is observed that the most of time the output of a task is less than the input of workmen due to various external factors.

2.4.7 Contact stress

Contact stress for ergonomics is mainly created by an exposure touch to any sharp or hard object putting localized or contact pressure on a part of the body.
Fraser-(1989)

2.4.8 Extreme Temperature and Weather Conditions - Extreme Temperature is one of the environmental features that can visible in hole world as a environment related factor , be divided to main segments such an extreme heat and extreme cold temperature stress . Extreme heat can be created reinforce fatigue and heat stress. At

the same time extreme cold can narrow or reduced the blood vessels and decline or cut off the sensitivity and harmonization full circulation of body parts. Hagg(2003).

2.5 Ergonomics Hazards Control

As per the studies of many researches it is important to make an effective ergonomic program by targeting the risk related factors appearing on tasks while meeting all the needs of workers. Ergonomic program is a systemic controlled process of anticipating, identifying or get aware on , designing planning , developing , constructing , analyzing. Hagg(2003).

2.5.1 Workstation Design and Choice of Tools

Hagberg et al.(1995) mentioned that even if definite limits are still do not exist in many cases related to ergonomics , related to ergonomics functions during work design . in most of work places appropriate tools and work stations are not used . instead of permanent solutions alternatives being used . those also ineffective to the work progress as we as worker perspective alternatives.

2.5.2 Product Design

During work in progress the design of a product is which is being used to work is essential for the working conditions and worker when producing it to work , it will positively influencing the load on the workers such as work stress , health stress as well as production costs outcomes and quality outcome.

2.5.3 Organizational Design

Work organization as per the ergonomics is an important part of the modern broad ergonomics concept it is being practiced in well organized organization in means of EHS . In particular, the opportunities strategies for job variation, rotation, job enrichment multi skilled workmen introduce to work and enlargement of great importance for prevention of muscular skeletal disorders(MSDs). in the work places .

2.5.4 Quality Aspects

It was mentioned that major point is to be that poor working conditions are related , leads to quality deficiencies and vice versa.. Noro and Imada (1991)

2.5.5 Participate Aspects

Noro and Imada (1991) agreed about the Correct , Full day and worker will get idea on what to do & what are the effects on work patterns & work related tasks .

2.5.6 Health Surveillance

Good health in the staff related to ergonomics is basic objective in ergonomics risk factor analysis . in various organizations how ever medical surveillances on ergonomics' has to be implemented more effectively in the organizations in means of effective health severance

2.5.7 Training and Information

When implementing, adaptation an ergonomics can be a Key issue to implementers . In many programs in more or less detailed by the implementers ,it is based on the objective of the plan aiming at various staff groups. In addition to that, according to Al Swaity and Enshassi (2005) there are many more types of ergonomics programs such as orientations, ergonomics training, monthly/yearly inspections, risks assessments ergonomics campaigns ergonomics programmed representatives, publicity campaigns and ergonomics topics of the month etc. Ergonomics program ought to contain basics of ergonomics principles, how to recognize by people symptoms and risks factors of MSDs etc.. while jobs development and . Lots of things can be done by the workers to reduce ergonomic hazards.

2.6 Impacts on Workmen

When looking closely, there are many construction workers who face these issues in various scales. Identification and awareness of these issues is a need to promote among the workmen and the management. The following list shows the basic and common well known symptoms of ergonomics but these examples are related to ergonomics in other industries as well. In general scenario, if anybody feels the below mentioned symptoms, the next step will be or very soon you might be caught in ergonomics illnesses such as pain or aches, numbness or tingling, stiffness, burning, swelling or weakness.

2.6.1 Physical Health Issues

Consideration in physical health issues in ergonomics mainly deals with the finger wrists, or other parts of body. Basically symptoms of these illnesses are common to workmen and the relationship with other ergonomics issues. Probably the most of times talked-about physical problems resulting from poor ergonomics due to musculoskeletal disorders (MSDs). MSDs can be the fastest-growing ero related occupational concerns at the movement . MSDs develop over long time durations with the worker as per the William, Wiehagen & Fred(2004). Probably the most talked physical problems resulting from poor ergonomics is musculoskeletal disorders (MSDs). MSDs can be the fastest growing occupational concerns which develop over long time durations William, Wiehagen & Fred(2004)

Following are the issues of Ergonomic disorders in general.

1. Tingling or numbness, particularly in the hands or fingers
2. Swelling, inflammation, or joint stiffness
3. Loss of muscle function or weakness
4. Discomfort or pain in the shoulders, neck, or upper or lower back
5. Extremities turning white or feeling unusually cold
6. General feeling of muscle tightness, cramping, or discomfort
7. Range of motion loss
8. Discomfort when making certain movements

In relation to the hands' fingers, one of the most common MSDs is "carpal tunnel syndrome". Cohen, Gjessing, Fine, Bernard & McGlothlin., (1997). In generally. An inflammation of a tendon due to overusing wrist or shoulder in ways that they're not mean to move.

Another type of common ergonomic problem which was identified relates to vibrations is "white finger. Repeated, long time prolonged exposure to vibration may cause Raynaud's syndrome or white finger". In Sri Lankan context, there is no such big reporting or evidence for Raynaud's syndrome, or white finger. But during the past recent years it is observed that some cases had been reported (W.F. Kinsella et al., 1995). Vibration-related injuries can be permanently crippling if they are not treated at early stages.

In many literature it is stated that "cumulative trauma disorders" (CTDs) are defined as physical injuries to workers , which develop due to repeated actions of biomechanical or physiological stress and it creating over a period of time on a specific body part.

Tendon Disorders: - Tendons are surrounded by sheaths of fibrous tissue that protect the tissue from friction during at work . (Anderson-1988).

Tenosynovitis: - Rowe-1985 illustrated that Tenosynovitis is fairly common in finger and wrist tendons or in other areas where the tendon excursion .

Ganelionic cyst: - Developed due to the swelling of a tendon sheath collected with synovial fluid in the mentioned areas . Ganglionic cyst is common, generally related to wrist usage during at work . Rowe and Birnbaum (1986) mentioned that,

Neurovascular disorders: - Those CTDs which involve both the nerve and the adjacent blood vessels are defines as Neurovascular disorders.

Thoracic outlet syndrome: - Anderson(1988). Differentiation or Compression of nerves and blood vessels as they pass through the neurovascular bundle between the neck and shoulder, termed as Thoracic Outlet Syndrome by the specialists . Which also known as cervico-brachial disorder or defect .

2.7 Methods for calculating ergonomics risks

Problem solving is the fundamental part of the ergonomic analysis. There are many tools available to ergonomists to conduct analysis of the ergonomic risks which are faced in industries. Also they may help to change the risk and identify the root cause. Many tools are invented during researches and the tools for ergonomic will be developing continually over the years. As per the scholar articles there are several risk assessment tools noted.

Table 2.1: ERFA Techniques and its assessing functions

Techniques	**Main feature**	**Function**
OWAS	Time sampling for body posture & force	Whole body postures recording and analysis.
Check list	Assessment preparation of legs, trunks and neck for repetitive task work .	Check list for evaluating risk factors
RULA	Action levels Categorization body postures and force	Upper body and limb assessment.
NIOSH Equation for Lifting	Biomechanical load for manual handling Measurement of posture related	Identification of risk factors and assessment
PLIBEL	Check list , and the with questions in different body rejoins movement .	Identification of risk factor.
The Strain Index	Combined check for checking six exposure factors for work task	Risk assessment for distal upper extremity disorders

OCRA	Body postures being measured repetitive tasks regards postures and force.	Assessment postures and check various types of jobs
REBA	Categorization of body postures and force with action levels.	Entire Board assessment for dynamic tasks
FIOH Risk Factor Checklist	Repetitive tasks being Questions on physical load and posture .	Assessment of upper extremes
LUBA	joint angular deviation is check from neutral and protected discomfort	Upper body limbs being check regarding postural load factor
Upper Limb Disorder Guidance, HSG60	Checklist for ULD hazards	Assessment ULD of risk factors workplace

Table 2.1: Mentions main feature and functions of the selected ERFA tools & based on the selection appropriate one is selected for the case study . According to Davis (2005) following assessment tools were highlighted during his study. Once features were considered there are several importance's highlighted.

Based on that table 2.1: suitability of functions were checked , Some tools are suitable for upper limb disorder assessment , some are for work task assessment , work load assessment some used for Identification of risk factors etc. Moreover according to the comparison with listed tools finally Rapid upper limb Assessment (RULA) Strain index, Rapid Entire Body Assessment (REBA), Occupational Repetitive Action Index (OCRA) are mainly easy to use and operationally applicable in field. Further more selected four ERFA tools were kept for final selection .

In table 2.2 illustrates the working groups reported pains during their occupations this study was done by Keyserling , Bowuwer ,Silverstein (1992) for this study all the pains were listed with the area of the pain and the occupation also time period considered too it can be observed the occupation groups who are affected on ER . According to that construction workers were not highlighted in direct way but some occupations such as machine operators, carpenters were highlighted related to construction.

Table 2.2: Percentage of workers who reported pains in various areas of body

Occupation	Neck	Back	Hip	Knee	Ankle	Time	Reference
Bucher	27	55	9	26	20	3 Mon	Mangnusson 1987
Meters	20	34				1 day	Plunch 1989
Molders	10	26				1 day	Plunch 1989
Maintenance workers	11	20					Plunch 1989
Fisherman's	19	52	13	25	11	1 year	Tola 1988
Electronic Assembly	64	10	10	4		1 year	Weastgard 1984
Cable Makers	31	39	4			Year	Weastgard 1984
Machine operators	89					Year	Mangnusson 198
Carpenters	76					Year	Tola 1988
Office worker	62					Year	Tola 1988

Eggplant pikers	11	43				Year	Mangnu sson 198

Keyserling , Bowuwer ,Silverstcin , (1992)

According to table, it was noted that the highlighted pains are more available in occupations, therefore this might be taken for consideration on posture selection such as neck back, hip, knee related issues. This table can taken as a guide line for selecting of rebar workers during fulfillment of objective three.

Table 2.3 ERF Described by Authors in Selected Articles

	Weight & Load	Bukiness	Movemen nt	Grip force	Vibration	Repitisio n	Static Posture	Force	Tempert ure	Awkward Posture	Contact Stress	ToT Count
Swathi & Enshassi	√	√	√	√	√					√		6
Buncher & Paquel						√						1
Kroemer & Chandara m							√					1
Kensila & Piror					√				√			2
Franser											√	1
Keyserl & Brouwer							√					1
A.B. Wahab					√							1
Alirezer & Aref					√	√	√	√	√	√	√	7
D.Sang	√	√				√				√		4
J . Allard	√											1
Amstrong				√	√	√	√	√	√			6
Jhonatha n .L & Vendergri tt .					√			√		√		3
Caroline & Jamees .D	√					√	√			√		4
Williams & Marras			√									1
R.Buruett a & A.plooyb										√		1
Buruette & Daye			√									1
La Jolla & Gilman	√			√	√	√		√	√	√	√	8
Danuta &Roman - Lu								√		√		2
IOWA Universit y					√	√	√	√	√	√	√	7
OSHA Publicatio n 3456	√				√	√			√	√		5
Keyserlin g & Esteson				√				√	√			3
S.T Unton	√				√	√				√		4
	7	2	3	4	10	9	7	7	7	11	4	

Below table summarizes the scholars, articles mentioning ERF in their literature. It also mentions the frequency of considering ergonomic related factors on articles.

Table 2.4: Assessment factor summary of Posture, ERF and Studied Postures

Factor	Summary
More reviewed Posture	Awkward posture
More user support & Reliable ERF	RULA, REBA, OCRS & NIOSH
More affected body Parts	Neck Back, Hip, Knee

In this table it summarizes the results of the three tables which are attached. According to that more reviewed ERF by scholars is posture. Also the most user-supportive and reliable ERFs were RULA, REBA, OCRS & NIOSH lifting equation as highlighted previously . Therefore, following assessment will be considered for further study.

2.7.1 Identification of suitable EFRs

Strain index – J Stephen and Arun Gray highlight that Strain index was introduced for checking WRMSDs in upper regions mainly and others for calculation. Separate work sheet was developed and more than six ERF could be evaluated on this method. Following criteria were discussed during evaluation.

- Intensity of exertion
- Duration of Exertion
- Effort per minute
- Hand wrist posture
- Speed of work
- Duration of work

This is based on physiological, biomechanical and epidemiological principles. Consideration on advantages accounted for task duration and recovery time and daily

advantages are required. Individuals with training, videos and other media were required for analysis.

1. NIOSH Lifting Formula.

Ming-Lun Lu et al. (2015) stated that, these techniques have been used for calculating manual lifting operations during manual handling without sudden changes in acceleration that are performed from a starting position. This is based on physiological, biomechanical and epidemiological principles. This tool would help analyzing of lower back pains. For this a recommended weight limit and lifting index is required.

2. Rapid Upper Limb Assessment (RULA)

Static postures, rapid changing postures and unstable postures can also be a reliable qualitative assessment (Appendix).

4. Rapid Entire Body Assessment (REBA)

REBR is used to assess static postures and rapidly changing unstable postures, specially it can be used for assessing handling loads and heavy tools which is also a reliable qualitative assessment (Appendix).

5. Occupational Repetitive Action Index (OCRA)

As per the Daniela Colombina and Enrico Occhipinti, (2000) OCRA can be used for posture, force, duration and other main risk factors. OCRA is mainly used to help to develop standards to reduce risk during operation of machine and tools to designers. Also upper limb disorders will be addressed by OCRA.

2.7.2 Selection of ERF for the study

According to the literature reviews, ERF explained by the authors were short listed and the frequency of highlighting ERF in various aspects was observed. Aim of the objective is to note down the most suitable ERF and how the illustrating frequency is distributed among the authors with respect to their articles. In respect to the research this effort would help to choose the best ERFs which will be suitable for the study

Table 2.5: Adverse Health Effects Associated With Various Postures. Keyserling, Bowuwer, Silverstcin (1992)

Posture	Adverse Health Effect.	Mentioned in articles	Reference	Nos
Standing	Compression neuropathies	01	Feldmen 1983	01
Using of Pool pedal	Pain on low back, hip ,knee ,	03	Corlett 1976	01
Knee lining	Increased the hart rate and Oxygen composition on neuropathies	04	Sato et 1973 Feldman 1983	02
Squatting	Compression neuropathies	02	Feldman 1983	01
Sitting w / Back support	Compression neuropathies	02	Feldman 1983	01
Sitting W/O Back support	Low Back Pain.	01	Grandiean et al 1983.	01

Mild Flexion / Trunk	Increased the hart rate and Oxygen compositio n on neuropathi es Back Pain Neck pain & Stiffness	06	Sato 1973 Anderson 1981 Punnett 1991 Grandiean et al 1983.	04
Severe flexion / trunk	Back Pain Increased the hart rate and Oxygen compositio n on neuropathi es	05	Sato ,1973 Anderson 1981 Punnett 1991	03
Twisted /bend /trunk	Back Pain Increased the hart rate and Oxygen compositio n on neuropathi es	05	Anderson 1981 Punnett 1991	02
Severe flexion / Neck	Pain in the neck ,upper	06	Ringadahi 1986 Grandiean	02

	back & arms , Neck pain and stiffness		et al 1983.	
Twisted /bend /trunk	Neck , shoulder pain , Headache	04	Tola et 1988 Travaell , 1967	02
Extensio n / Neck	Neck Pain	01	Travaell ,1967	01

This table explains the postures and their related effects during work. In this table posture and the complication is highlighted. According to the table the most important postures which can apply to the ERBA can be identified.

2.7.3 Reasons for Ergonomic Malpractices

It is identified that above ergonomics issues which affect the workmen are linked with the following factors. This will help to find out the actual impact on ergonomics risks and find out solutions for the risks.

- Social and cultural effect
- Adaptation to technology
- working with the tools and machines
- Skills education and knowledge

When considering the mental and physical health relation in awkward postures, there is no direct impact observed with mental health and awkward postures. But considering physical health, awkward postures are affected in many ways such as MSDs , fatigue etc. Other than that risk rate to accidents are increasing due to relationship of awkward postures and physical health. It is realized that majority of

workmen having low nutrias due to food pattern and less performance due to drug and smoking addiction.

When considering repetitive work pattern, rebar workers, plastering workers, material transporters, bar benders are mainly affected as workers have to work continually more than 12 hours in a day to complete their work. This leads to ergonomics base on static posture. Vibration and force may also affect the ergonomics. Most of the time workers are willing to work to fulfill their duties but his or her capacity is not enough for task accomplishment. In other words, they think they can do but they are unable to perform because of their physical health, especially when working with vibration tools and special tools. Extreme temperature is the most significant problem to the workmen in the industry. Most of the time they fail to perform effectively due to extreme temperature conditions.

2.7.3.1 Social and Cultural Impact

In many industries a major error of practical implementation is that whatever the risk factors affect them, they are not willing to change the ways of working, systems of working, equipment and tools which are used for working. It is an error of adaptation and thinking pattern. In consequence of that workers may face many ergonomics issues in the work sites.

2.7.3.2 Adaptation to Technology

Work Process is another factor that ergonomics risk factors are incised. This has some relationship with social and cultural impact. While working at site, workers are willing to use very primitive tools, methods even when the companies force them to use modern things and provide all new adaptations. This also leads to boost ergonomics issues at construction sites.

2.7.3.3 Working with the Tools and Machines

According to Sang, (2008) it has a relationship with tools, technology and methods used in construction sites. Use of high tech during construction also they used black – belts for prevent injuries . Proper mechanical material handling equipment has to be used such as forklifts and hand carts should be available during work also. Inadequate amounts to feel will effected to the . If they have sufficient amount equipment's

workers that they do not have to move everything manually. The employees should be trained on what material handling equipment is on-site with the ergonomically .Also it is necessary to identified how they work and any other types that they could request if they feel it is necessary to over come the fatigue . Training on the specific types of materials that will be used throughout the job and the hazards associated with them are also considered in means of safety and risk of them has to have identify trough out is needed. Cable, (2007).

2.7.3.4 Education and Skill

One of the major issues that cause to increase ergonomics issues in construction industry is the use of unskilled staff. This issue has driven workmen to perform their tasks incorrectly. In literature reviews in journals such as "The Construction Industry in the Twenty First Century: Its image, employment prospects and skill requirements" published by ILO (2001),

According to Vaid (1999) and Anand (2000) said and According to Lu and Fox (2001) In most of the big cities of the world, the construction workers are those who are born and bred in the city itself and mostly they can be identified as the most disadvantaged sections of the society and this situation is more or less the same in China where the majority of construction workers comprise of migrants 50% is migrants and 600,000 in number and they have not proceeded beyond primary education and some are not even literate.When considering skills much strong evidence can be found. According to ILO (2001) in traditional apprenticeships and a similar situation prevails in Brazil, India, Kenya and Mexico.

Transferring knowledge and skills through informal tradition is not a very systematically developed system in many African countries because sometimes the master craftsmen, themselves lack perfect skills and techniques to be passed on and as it was observed in Malaysia, such passing on of knowledge was often restricted to family to tribe or to clan and when it was required to pass on knowledge to outsiders. such transfer would happen with some preservation of skills and techniques.)

(Abdul-Aziz., 2001). Debrah and Ofori (1997) stated in the ILO (2001), Singapore

2.8 Summary

This literature review was conducted to find out ergonomics risk factors and how they affect the workmen while at work and how these factors bind with the human factors such as knowledge, skill, social intention etc. Most of the literature mentions that construction industry has high possibility of ergonomic risks and its dynamic nature is always adding additional hazards to workers. In many occasions, workmen are not taking precautions to minimize the risk due to various reasons such as the employers' condition, lack of supervision, lack of knowledge, social and cultural influence etc. Workers do not know that ergonomics related health issues affect them from the first day and it continues long term. No tracking system has been invented to overcome those malpractices.

It is emphasized and evident that this way should be changed. Management, professionals of OHSE and workmen should get together to overcome this matter. Every construction organization has to maintain an action plan to overcome ergonomics risk in industry and review it periodically. Based on that concept, some objectives can be stated as a summary of the conclusion.

1. Improve the Quality of the work
2. Adopt human capacity to the optimal situation
3. Increase productivity
4. Make easy human performance
5. Provide a safe and hearty working environment
6. Reduce disorders
7. Improve moral of workmen

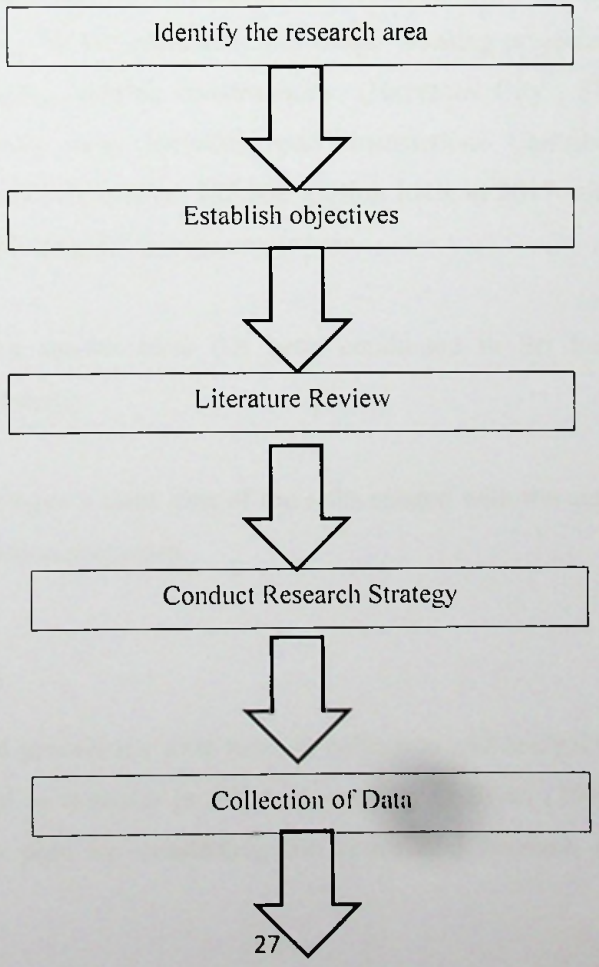
CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to describe the methodology of research which would be followed to obtain the evidence required to fulfill the objectives described in Chapter Two. The methodology includes research design, data collection, process pathway, method of data collection with statistical tools are used for the analysis. As an example, Posture, Activity, Tools, and Hand (PATH) Analysis Can be utilized. According to Bryan et al. (1996), this method can be used for the analysis of rebar work at sites. This research needs primary data as well as secondary data to obtain the final outcome, since there is not much of secondary data available with respect to the field of this study in Sri Lankan context. Therefore, priority will be given to primary data sources at ground level.

According to Punch (2005) the research process content is described as follows,



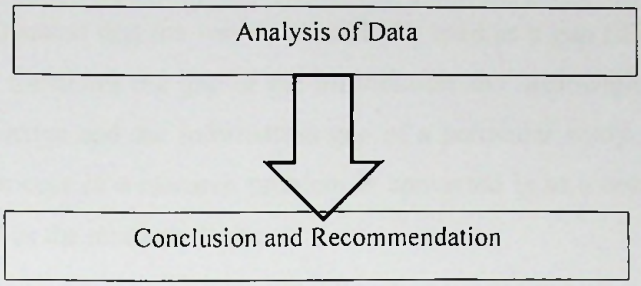


Figure: 3.1 The research process

3.1.2 Identify the research area and establish the Objectives

The following points were identified as the major problems faced by the construction industry with respect to the health and safety practices utilized by the sector which paved the necessity for conducting a researching dealing with this segment.

I. Industry has widened up and lots of first aid issues are observed at sites
From 1980's Sri Lankan construction industry has been advanced in a rapid style specially with the introduction of mega housing projects such as "Gam Udava", massive building constructions (Havelock City , Shangri-La, Port City) and many more including road constructions. Contribution to annual GDP from the sector reaches 185,000 million LKR in 2017 with a work force of 500,000 including the foreign employees.

II. Comprehensive studies have not been conducted in Sri Lanka related to construction industry.

III. People do not have a clear idea of the risks related with the activities dealt up in the construction processes.

3.2 Research Design

A set of methods and procedures were used in collection and analyzing the measures of variables specified in research problem. According to Brian (2009) the research design is an overall plan for connecting the conceptual research problem to the

pertinent empirical research. Also, there are several definitions related with research design. Punch (2005) stated that the research should be used as a gap filling tool. As per Punch (2005), it illustrates the gap of the information and meanwhile it explains how to fill the knowledge and the information gap of a particular study. Tan (2002) stated that the full process of a research problem is converted in to a conclusion and this process is named as the research design.

Furthermore, in research design, following requirements also should be fulfilled such as how the data collection is in progress, what are the methods of data collection, ways of data collection, and types of analysis of data, ways and methods of answering the questions.

Also in research design, it is a requirement to collect all correct data in means of the research problem and the way the data, methods are been configured in the research project is also typical. This descriptive study consists of four phases of where primary data and secondary data with qualitative approach were used.

3.3 Literature Review

It was identified through the literature review that worldwide studies have been conducted regarding ergonomics risk factors under several disciplines. As per the referred documents, most studies had been conducted in work stations or factory related operations. Most of the articles were published by medical related practitioners. Therefore, construction related ergonomics literature is far rare even in the global construction arena. In fact, majority of ergonomics literature illustrate ergonomics risk factors which are faced by common professions such as computer operators, mechanics, sales girls, drivers etc. Consequently, it was able to establish the fact that there is a research gap in the selected research area at present in Sri Lanka.

Problem solving is the fundamental part of the ergonomic analysis. There are many tools available for ergonomists to analyze the ergonomic risks faced by the industries. Also, they may help to change the risk and identify the root cause. Many tools are invented during researches and the tools for ergonomics will be developing continually throughout the years. (Alison Heller @worksite international)

As per the scholar articles, there are several risk factor calculating methods being used for the researches including,

- NIOSH lifting formula
- Rapid upper limb Assessment
- Strain index
- Rapid inter body Assessment (Alison Heller @worksite international) & Etc.

3.4 Research Approach

Considering on the types of research methodologies explained, there are three research methodologies described by Niglas (2004) namely qualitative, quantitative and mixed methods Also in addition to that, research strategies can be found such as case studies, surveys, experiments, ethnography, action research and grounded theory. Alzheimer,(2009), Wedawatta et al (2011).

Also as per the scholarly articles, objective of the research differs from approach to approach. It may find out the truth of a problem, test the hypothesis, determinate the frequency of something against something else.

Moreover, some illustrate the research categorized in a systematic manner.

More or less, ergonomics risk factor analysis is basically based on applied vs. fundamental strategies. But Follow and Liu (2003) explained that the quantitative approach will collect factual data and it is usually connected with more relationships in a research. According to Creswell (2005) quantitative research approach is an educational type of research which converts numerical data to solutions of the research problems.

As per Byrman (2001), qualitative research methods are more based on words not on quantification, but through questionnaires the data will be converted to quantitative data which can be user bale.

In this research, the main objective is to identify how ergonomics risk factors affect the workers' health as well construction process. That could be used to analyze the ergonomics issues at construction projects in Sri Lanka. To acquire the research objectives, it is necessary to collect data from all relative parties as the people who are implementing the operation as well people who are actually participating in the work.

Therefore, data collections along with the simple questionnaires were conducted for mainly workers and interviews were conducted for the implementers at project level. Ellis, Victoria, Cornn, Dickson, Fielding, Sleney and Thomas (2006) stated that the combined methods for data collection and analyzing are giving more accurate results than single approach methods But on this study qualitative approaches will be used as per the requirements according to literature review

Research methodology and guideline to research are emphasized in the research strategy Bryman (2007). Also it's a step-by-step plan of action that gives direction to your thoughts and efforts, enabling you to conduct research systematically and on schedule to produce quality results and detailed report

With regard to the research topic, sample selection has to match with the research process and sample should represent the focused group's features and the characteristics. For the ergonomics risk factors reinforce workers were selected as a sample. Therefore, ten reinforce workers were selected out of 150 workers for the case study. Also, in the selected premises, daily reinforce bar handling capacity is around 40 tone and daily basis approximately 250 kg would be handled by single reinforce worker and average reinforce handling is 50kg for the worker since most of ergonomics postures are noted in the reinforce operation. Rebar workers are selected as a sample other than foam workers and block workers and concrete workers. During sample selection selected cases were chosen according to the work zones and their operations.

The scope of this research is limited only to the building construction projects in Sri Lanka. The considered value of the project is considered over 5 billion LKR. As per the sample,10 rebar workers were selected. The staff contribution to the research was considered from the officers who were fully engaged in the execution of work at site and project managers and above level staff had not been taken into sample groups.

The interview guidelines and observation guidelines are mainly on the forces of the reinforce workers, work patrons and work-related operations. The primary data collection was divided as follows.

3.5 Case Study Strategy

A case study is a story about something unique, special, or interesting and can be about individuals, organizations, processes, programs, neighborhoods, institutions, and even events Yin (2003). Case studies have been used in varied investigations, particularly in sociological studies, but increasingly, in instruction. Yin, Stake, and others who have wide experience in this methodology have developed robust procedures.

Considering the case study strategy, data will be collected at field. According to the objectives reinforce workers have to be studied during their work. Therefore, separately case by case workers will be studied during their work and the total day shift was taken for the study while the two tea breaks and lunch time have not been taken as working hours, and since it is a long time process, the overtime hours were not taken into consideration either. Discussions will be conducted during the case data collection. Separate time slots were selected for studying the case and posture movements are checked according to the assessment tools. For gathering the information, case operation types are divided based on the operation among the selected cases. To avoid the absenteeism all the cases were observed at a selected time of the respective month, most of times in the mid days of the month.

After a careful consideration of the literature review and other factors such the work force, construction industry capacity etc., reinforce workmen are selected for the study. It was noted in the preliminary observations that more than 20 tons were tied in the selected work place by a day for the reinforcement. There are more than 250 workers involved, and two worksites being continued. Many reinforcement activities are being done by workmen at location. That was the prime reason for selecting 10 workers for this case study. They were selected for the study considering the above mentioned activities performed during duty. Also the working locations selected were not less than a total capacity of 500 workers and production of 20 tons of reinforcement per also considered . Size of the construction sites with a turnover of 5 billion LKR were selected for the sample.

3.5.1 Case Selection

Since Most of ERF tools are based on technical formats, the research, mainly focuses on a case study-based data collection process. In the case study, ten rebar workers were taken as a sample and all the rebar work was observed during the work hours. Among the rebar workers some of them were bar benders & some were bar bender helpers (BBS) . Most occlusion BBs are selected by organization based on their work experience qualifications or the training not been considered. Considering on BBHs they were mainly helpers for the reinforce work, they are not capable of reading drawings , handling bending operations etc. BBHs were assigned the tasks of handling reinforce bars , loading and unloading reinforce bars, line marking , laying reinforce bars & etc and. for BBHs qualification & experience had not been considered .

3.6 Unit of Analysis

Unit of analysis is the description of the measurement which is used for analysis in this research. In the literature, it was mentioned that the unit of analysis is described from the sample specifying what or who is to be analysis. For the study, therefore, the unit of analysis is EFR s which affect the RWs.

3.7 Data Collection Methods

Appropriate techniques need to be identified to capture the data, once the research approach is set which provide the way to answer research problem. The primary data was collected form , Short interviews during data collection of rebar workers while case studies on going , important data on rebar workers also collected filling simple questioner . Primary data was generated only for the selected purpose. A survey was used to collect the information required to fulfill the above stated objectives 1 to 3. Also the literature survey was conducted to describe the similar condition which was observed in previous situations. On this similar regard, Case study, research or questionnaires will collect the valuable data to this research and it may help to find suitable questions and methods, tools which are used to get the final outcome.

Table 3.1: Data Collection Method Summary

Collection method	Forces on	Data captured by
Preliminary Interviews	Work patterns during reinforcement work	questionnaire
Questionnaire survey	work related with personal data	Sheet of questionnaire
Observations	Work related postures / operations	Photos of work postures
Assessment tools	Work related postures / operations	Assessment calculation sheets

Preliminary Interviews

Preliminary interviews were conducted with some workers who are having long work experience and service in selected sections and interviews conducted with staff officers who are engaged in rebar works at sites, interviews of both type of worker categories will help to develop the case study and the identification of key ergonomics risk factors in construction related activities as a guide.

Questionnaire Survey

Klandermans and Smith (2009) describes that a questionnaire is a set of various questions about the opinion, knowledge, attitude of responders to achieve the goals of the research. When a questionnaire is prepared, the priority must be given to which data is been collected, analyzed and interpreted. Also the questionnaire is mainly in two parts, one for general data collection and other for gathering data across the ERF analysis tools. Also the collected data was contained

Observations

Important observations are linked with the risk fact analysis specially posture analysis methods, material handling, case movements, rest hours, extra works, additional tasks, work patterns changes and support required during work. Based on the observations analysis can be directed to get evidence to objectives. Observation will help to develop

connections between objectives and the assumptions. Also it related to recognizing recommendation on RFA s and it will help further studies.

Under all three methods several guidelines were applied to collect data. These guidelines can be categorized in several segments as mentioned in the following table. In section C, all the observations are based on guidelines. Under Section C, Following posture guidelines were considered

Table 3.2: Posture guide lines

Selected Postures
Awkward Seated
Awkward standing
Awkward twisting
Pushing & Pulling
Bending neck
Holding long time
Hanging by hands
Twisting body
Twisting wrist & Arms
Walking short distance
Arm Movements
Bending Trunk

Under Table 3.2: selected postures for observation were mentioned as a part of the RULA & REBA assessments. These postures were extracted from the RULA & REBA assessments.

Table 3.3: Distribution of RULA & REBA posters Among the selected sub postures

RULA Postures	Extracted postures
Locate Upper arm Position	Hanging by hands
Arm is parallel to body + 15 to -15 ^{0}	Twisting wrist & Arms
Arm Moved to Back words -15^0	Arm Movements
Arm Moved to forwards -+15 to 45^0	
Arm Moved to forwards -+45 to 90^0	
Arm Moved to forwards –Above 90^0	
If Shoulder is raised	
If Upper arm Is Abducted	
If arm is supported or person is seating .	
RULA Postures	Extracted postures
Arm is parallel to body 0 to -90^0	Hanging by hands
Arm bend from elbow 90^0	Twisting wrist & Arms
Arm is moved side from shoulder level	Arm Movements
If arm is working across the midline of the body	
If arm is out side of the body	
RULA Postures	Extracted postures
Locate wrist position	Twisting wrist & Arms
Wrist is straight	
Wrist move up	
Wrist move down	
Wrist is bent side to side	
Wrist bent from mid line	

RULA Postures	Extracted postures
All Muscle Use Score	Awkward Seated Awkward standing Awkward twisting Holding long time Hanging by hands
If posture mainly static	
If Action is repeating	
RULA Postures	Extracted postures
Add Force / load	Holding long time Hanging by hands Walking short distance
Load less then 2 kg	
If 2kg to 10 kg	
If 2kg to 10 kg static Or repeated	
If 10 <more –repeated or shocked	
Vibration	
RULA Postures	Extracted postures
Locate Neck Position	Bending Neck
Neck bent 0 to 10^0	
Neck bent 0 to 20^0	
Neck bent 20^0 +	
Neck bent back	
If neck twisted	
If Neck is bending side to side	
RULA Postures	Extracted postures
locate trunk Position	Bending Trunk
Trunk is well supported while seating	
Trunk is not well supported while seating	
Trunk back 0 to 10^0	
Seated	
Trunk bent 0 to 20^0	
Trunk Bent 20 to 60^0	
Trunk Bent 60^0 +	
Trunk is twisted	
If trunk is side bending	

RULA Postures	Extracted postures
Align with the body	Leg bent movements
One leg bent on the knee	Walking short distance
	Push & Pull

This table contains the posture guidelines extracted according to RULA & REBA assessment sheet main posture criteria some postures were extracted according to the usage of observations.

Table 3.4: Observation of patterns during case study

Question No / Observation	Objective
Section A	
1 & 2	Details of respondents
3 & 4	Knowledge
Section B	
Employment Info	Work capacity and suitability to work
Section C	
1 to 6	Work related patterns
7 & 8	Ergonomics risks
Work study sheet	Work related patterns
Work posture Image	Work posture identification
ERFA sheet 1 –RULA	Rapid upper limb assessment
ERFA sheet 1 –REBA	Rapid entire body assessment

This table illustrate the Observation of patterns during case study done On the study sheet, case patterns were observed with work carried out by cases as a guideline. Daily reinforcement handling details, work study tasks given by Quantity surveying department, site work progress charts were considered.

Photo images were taken during cases of those who are fully engaged in the work. Also another guideline is to make sure during work, all the related postures has to captured in one setting. For RULA & REBA observations RULA & REBA operation

guidelines has to be studied. Based on the data, prepared observation sheet is used during observation of RULA & REBA Assessments for RWs.

3.8 Followed Steps on Case Study

In order to conduct the case study as mentioned in the above paragraphs, following steps were followed. These steps were common for all data collection methods.

Step - 01

Ten reinforce workers were selected for the sample who are engaged in a various reinforce activities in the site, work section was also considered during the selection. . Among the rebar workers some of them were bar benders & some were bar bender helpers (BBHs) .when mentioned two categories considered Bar benders (BBs) skill then the helpers , Steel cutting ,bending , tieing & final completion of reinforcement were given tasks to them by their in charges ,more over BBs are capable to manage reinforce drawing during tieing work. Most occlusions BBs are selected by organization based on their work experience qualifications or the training not been considered. Considering on BBHs they were mainly helpers for the reinforce work , they couldn't capable on reading drawings , handling bending operations etc. BBHs were assigned for handling reinforce bars , loading and unloading reinforce bars, line marking , laying reinforce bars & etc. for BBHs qualification & experience had not been considered .

Step – 02

Work task of workmen has been divided in to main categories, based on work time. task area. Work hours mainly focused on 12 hour shift and additional work hours has not been taken to study , however additional time was taken as a backup for help to to the study & for comparison of all selected data related to the data collection . In preliminary studies during reinforce work it was noted multiple postures used to perform their works by BBs & BBHs therefore to reduce the overlap of tasks inspecting during case study, maximum 04 prime tasks per worker is considered to study postures during that time . for this step all the data collection methods were considered .

Step – 03

Careful observation was done by the data collector and filled using the RULA & REBA tools. Before data collection trained data collecting assistants were chosen for the task and training were given to them regarding data collection techniques related to RULA & REBA also observation guidelines were awarded by showing videos on RULA, REBA data collection techniques given by assessments developers. Before sending to field sample assessment sheet were fielded by data collectors. In addition to that, photographs were taken for future references and clear the gray areas during data calculation. All the data collectors were advised to take photographs of work postures and if during multiple postures all multiple postures were captured. This step is only related to technical data analysis tools.

Step – 04

Collected data was entered to the RULA & REBA calculation sheet on daily basis for the final data analysis. Separate RULA & REBA sheets similar to common sheets has been developed to filled the data Original RULA & REBA sheets were used with other developed sheets .

Step – 05

After collecting all the respective data, final analysis will be conducted. Data were analyzed based on general analysis method such as mean made and percentage. During analysis, if complicated postures and more than four postures found in one setting additional photograph were consider & separate column was added to assessment sheets to re assess the posture data.

Table 3.5: Summary sheet of Data collection

Case	General Information	Objective related Information for case study	Tasks & Outputs related Information	Ergonomically noted facts.
E	Age of the case E is 27, education is Grade 8 pass. Professional qualification gained by experience. Less than 05 years' experience in the construction field. Worked as shop worker before. Case E Profession is categorized as a Reinforce worker Case E used to work more than 25 days per month. 14 days leave taken after three months of work. Case E also worked as a general labor at site Daily work target is above 50 Kg of lifting & tying of re bars. Reinforce work was performed by him as a group worker, but he may not receive any help from others. According to the Case E statements No chronicle illness related to work. Case E has no any complications during tie up re bars.	Mainly case E perform his duty as a Reinforce worker . since is less experienced worker he is not able to do bar bending at site level he is considered as skill worker . Case E has assign for lining of stacked rebar at prepared foam work area and tie up column stirrups and further period of coupler fixing too. Case E is performs his duty independently with his team. He doesn't have any previous experience in rebar work and he is categorized as a reinforce worker at site. It was noted during the observations, all the assigned tasks has not only to be performed by case E in bending posture and varies according to the regular work. It is heighted during the study The Case E has No any Back Pain or other complain During & After his takes. Seems to be with multiple changes of posture during daily work may help him preventing unnecessary stress to the body. Case E is too not aware on Ergonomics according to his educational level? Also During his total work hours he has to bent his trunk, push & pull movements with some force & wrist to be rotated also.	1. By 08.00hrs duty stated by the Case E According to the observations His first duty was lining of stacked rebar's which involves lifting & carrying etc. Two hours taken for the task. 2. 10.00am Tea break 3. 10.40 continuing lining of re bars at prepared foam work area for 1hour 50 minutes. 20-30 reinforce bars are loaded during the period 4. 12.30 Lunch break 5. Second session stars with shifting to tie work- column stirrups are tied. Posture changes & difficult movements are noted. 5-6 mts rest taken while in tie work. Task completes after 2hrs. 6. 3.30pm Tea break 7. New task began 4.00pm and assigned for fixing couplers. Existing work as an Assistant. Push/Pull actions are commonly involved and continued for 2hrs 30 mts. 8 After a small Tea break for 15 mts continued same work for one more hour till 7.45pm 9. Standing posture/wrist movements/Push Pull actions with low back involvements were very common.	1) During lining of Rebar's lower & upper arms & back postures highlighted. 2.) during lining of debars trunk bending . arm & wrist movements also highlighted 3) During tie up column stirrups low back muscles / straightening & bending postures are more significant. 4) During fixing of couplers shoulders, upper & lower arm and trunk bending posture is noted. 5. According to the operations worker has to stand up, bend forward, push & pulls are more frequent. 6. In total day work time, high frequency posture changing movements noted in a selected time.

Table 3.2: mention that the collected data on the field has entered to summary sheet for the reference there are 10 sheets were developed and all the data were summarized.

Table 3.6: Summary sheet of Collected data II.

	Case A	Options -1.2.3		
		1	2	3
	Age ;	52		
	Experience: years	17		
	Leave Days	7		
	Total Work Hours	12H		
	Total Rest Hours	1h 50m		
	Additional work hours	4		
	No of breaks taken during work hours	5		
	Performing no's task per day	02		
	No's of different tasks per day	02		
	No of Reba's handling - no's / Kg per Hour	50Kg		
	No's of Kg's tie per day	150		
	Total time worked with a helper			
	Total time spent for work organizing	45m		
	Type of Awkward posture			
	Bend forward	35m		
	awkward Seated	1h		
	Awkward standing	1h45m		
	Awkward twisting	30m		
	Pushing & Pulling	45m		
	Bending neck	3h30m		
	Holding long time			
	Hanging by hands			
	Twisting body			
	Twisting wrist & Arms			
	Walking short distance	5m		
	Arm Movements			
	Awkward Position Hours	6h		
	RULA Rating	14		
	REBA Rating	12		

In this sheet all the collected data were entered to single summary sheet according to the case by case this was the final summary which data was taken to analysis . In here 10cases were considered to summarized data . if postures more complicated additional options were filled .

3.9 Data Analysis Techniques

Data was checked for completeness and accuracy before analysis. Therefore data analysis techniques involve converting data into logical and meaningful language.

3.9.1 The Mean

In calculating the mean rating, in simple , the total of all selected items are divided by the total number of responses or occurrences. In data analysis ,As examples the mean can be used to find out the past ergonomics related issues or past illness of workers which affected his work life and general living pattern. Through mean, the past health surveillance issues related to ergonomics, usage of tools and equipment during work performance, multiple tasks performed during work hours can be analyzed and decide whether there is a direct connection on ergonomics risk factors.

The sample mean formula is:

$\bar{x} = (\Sigma xi) / n$

Σxi = Total of all RULA values

N= Numbers of RULA value

For using mean on collected data of cases, specially mean value can be adopted for RULA and REBA analysis of RULA deviation against RULA matrix in all posture levels. These patterns could be the mode for the comparison on postures based on ERP under several disciplines in reinforces work.

3.9.2 The Mode

In general, the mode is the function which appears more times in a respective data group. In data analysis, the mode also can be used to analyze the past ergonomics related issues or past illnesses of workers which affected their work life and general living pattern as examples most ill-health issues noted workers , mode of postures hours , mode of Awkward postures etc. Also it can be compared with the mean the past health surveillance issues related to ergonomics, usage of tools and equipment during work performance, multiple tasks performed during work hours and directly on

ergonomics risk factors. Therefore mode will be used for as a general tool to study which is the highest & lowest among the selected criteria's.

3.9.3 Range

The difference between the highest and the lowest values within in a set of numbers

Xh - XL = R.

Therefore, range can be utilized for analysis with the Ergonomics functions following conditions such as age range of cases, leave range, over time and the age, working.

3.10 Summary

In this research methodology as a key factor for the research qualitative data is used. And for continue research . ten cases were selected to study the objectives .also primary questionnaires interviews ,observations , used for data collection . based on literature review , fined risk factors are short listed and one ERF has selected for study. For case study five steps were followed , based on literature review sub posture positions were chosen as per the scholar articles. RULA & REBA assessment were used for the posture movement data analysis .

CHAPTER FOUR

DATA ANALYSIS AND RESEARCH FINDINGS

4.1 Introduction

The previous chapter of this report describes the methodology that was adopted for the collection of data. The chapter 4 describes the findings of the study. Research findings are described under the following headings. During analysis of data , two main criteria were considered , one was analysis of posture observation data & Analysis of RULA & REBA data . Objective of analysis of posture data is to develop more supportive evidence on RULA & REBA Analysis and two methods can be compared during analysis (chapter 3 table 3.3:)

4.2 General Details of the Respondents to Questionnaire and Case Study

A modified mentioned questions was asked during observation & data collection from 10 selected reinforce workers at site. Mainly the workers were selected for the case study to study all the work task operations posture during the working days. Apart from that, asked questions were noted regarding the study.

Since this is a case study based questionnaire the respond rate was 100%. Out of these 10 workers, following observations were noted.

Table.4.1: General Information on Cases

Case No	Age	Main Task Category	Experience	Work Hours	Leave Status Days	OT Hours	Task P/Day
Case A	52	Bar bender	17	12	08	04	02
Case B	28	Bar Bender	04	12	03	02	03
Case C	52	Bar Bender Helper	10	12	05	02	04
Case D	32	Bar bender	05	12	10	02	0
Case E	27	Bar bender Helper	05	12	14	02	03

Case F	49	Bar bender Helper	07	10	08	02	01
Case G	24	Bar Bender Helper	02	10	10	02	02
Case H	39	Bar Bender	07	15	10	06	03
Case I	27	Bar Bender	07	12	05	03	0
Case J	26	Bar bender Helper	05	12	08	03	02

In this table general details of reinforce workers were considered, this details based on BBs & BBHs . the details were taken during data collection and data captured on interviews. With regard to the general detail of workers, following were noted. The Age range of RWs was 52 years to 26 year. Therefore, age range is double than oldest worker compared to youngest when considering the hands on experience. When considering the work hours, pattern was almost the same. Extra work hours, leave status, additional tasks performing a day patterns were almost same.

Figure 4.1: Examples of Working postures of Case - B

During observation on Case B , was engaging in line marking according to the given drawings . multiple awkward postures were noted in several time laps all were recorded in assessment sheet relates with time laps .

Figure 4.2: Examples of Working postures of Case - C

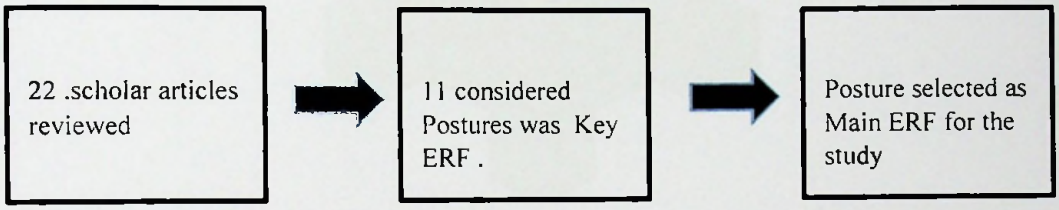
During observation on Case C , was engaging in Unloading reinforce bars to the work location in upper left and right pictures . below left & right pictures workers was engaging in reinforcement tieing multiple awkward postures were noted in several time laps all were recorded in assessment sheet relates with time laps . apart of that pulling & Pushing posture also noted .

4.3 Key Ergonomics Risk Factors Faced By Reinforce Workers

The first objective of this study was to identify the various types of ergonomics risk factors that are affected to the RWs. Regarding this matter a comprehensive literature review was done in chapter 02 (2.3) Meanwhile in chapter 03 some limitations were highlighted to adhere all the ERF to research which was faced during data collection and sample selection there for out of several ERFs Posture has been selected and studied.

Based on the Literature review and analysis findings eight risk ERF s were found and all of factors were illustrated by scholar articles and reviewed. Out of 22 articles 11 articles were highlighted by posture, therefor posture was taken as key Ergonomics factor for the RWs.

Figure 4.3: posture selected path



4.3.1 Posture considered as an ERF for Reinforce workers

This part was carried out with the help of RULA and REBA assessment techniques in ergonomics to assess the posture patterns while rebar operations were on going as mentioned in the above parts of this chapter. In order to select the posture patterns as mentioned in the chapter 3 under data collection methods, RULA and REBA assessments were used as a guideline.

4.4 Findings and Analysis on interviews, questionnaires observed data

In this section data which was collected in the interviews, questionnaires and observation apart of RULA & REBA assessments which supported the objectives are discussed. Before discussed RULA & REBA Data posture comparison & work task data is considered for achieve third objective.

4.4.1 Posture Comparison during Reinforce work

Posture was selected as a significant ERF to study to . In the case study posture has been subdivided into posture categories as per the RULA and REBA assessments. Therefore, 12 postures were selected to compare that are performed by the cases. Time calculation also were taken to consideration of posture type and time consumed.

Figure 4.4: Posture & Sub posture linked pattern

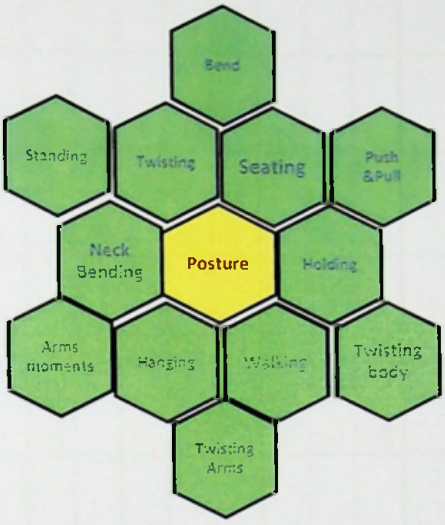


Figure 4.4: illustrates the pattern which was posture linked with the other postures which were considered during data collection & analysis.

Tale 4.2: Posture & Work Pattern Summary of Cases A – J. Part I

	Part I	A	B	C	D	E	F	G	H	I	J	Total time
1	**Bend forward**	35m	45min	2h20m	40m	1h50m	6h	5h	6h	5h	5h	**33.1h**
2	**Awkward Seated**	1h	5h45mi	1h	2h40m	2h50m				3h		**16.5h**
3	**Awkward standing**	1 h45m	2h45mi	45m		2h30m	6h	5h	6h	2h	5h	**31.h**
4	**Awkward twisting**	30m	1h									**1.5h**
5	**Pushing & Pulling**	45m		45m	1h	2h30m			1h			**6h**
6	**Bending neck**	3h30m	7h45mi				2h	3h	2h			**16.25h**
7	**Walking short distance**	45m	2h45mi		30m						1h	**4.3h**
8	**Twisting wrist & Arms**			2h30m		2h	6h	2h	6h	6h		**22.5h**
9	**Holding long time**											
10	**Hanging by hands**			2h	2h	1h50m			6h		2h	**13.8h**
11	**Twisting body**			2h							1h	**3h**
12	**Arms Movement**	.		30m	2h	2h	2h	2h			1h	**10.1h**
	Posture Hours minutes	**8.8h**	**10.25h**	**9h**	**8.8h**	**8.5**	**8h**	**10h**	**9h**	**10h**	**10h**	**92.3**

Tale 4.3: Posture & Work Pattern Summary of Cases A – J. Part II

	Part II	Repeated Actions hours	total work Hours	Additional hours	Total Rest Hours	No of breaks taken during work hours	Performing no's task per day	No's of different tasks per day	No of Reba's handling - no's / Kg per Hour	No's of Kg's tie per day	Total time worked with a helper	Total time spent for work organizing
1	A		12	4	1h50m	5	2	2	50	150	12	45mi
2	B	4	12	4	2	5	0	0	150	50	12	45min
3	C	2	12	4	2	6	4	4	200	5	12	2h45m
4	D	2	12	2	2	6	2		50	210	4h20m	0
5	E	6	11h45m	2	2	11	3	3		150	2h30m	
6	F	3	9h45m	2	2h30m	20			50	15	12	
7	G	4	10h20m	2	2	12	2	2		40	12	
8	H	4	15h20m	6	2	22	3	3	200		12	1h30m
9	I		12	3	2	40	2		200	250	12	
10	J	2	12	3	2	6	3	2	50	150	12	
	Total quantity of tasks	27	119h20m	32	20.1h	133	21	16	950	1020	102h50m	5.7h

Table 4.2: Part I ,II is the total summary sheet of the all postural activities and its related operations. In part I first 12 numbers sub postures of awkward posture was mentioned & time s that workers were engaged are marked. In part II activities & functions which related to postures were marked. These two parts were taken during observation of worker activities.

According to the table 4.2: Following analysis summary can be mentioned in regards to postures & work patterns. Performed two or more posture in one case taken as separate to avoid repetition, Based on the posture summary table, one posture (bend forward) common to all cases. Other postures are spread among the detail sheet without a pattern.

In consideration of posture percentage, out of ten main postures bend forward was affected 100% to the all cases, Awkward standing was affected 90% of workers Three cases are affected 50 % of categorized postures during their work. Another three cases are affected 40% of categorized postures during work and 30% of postures are affected to one case and 10% of postures was affected.

In addition to that based on the findings following posture percentage were affected by cases.

Once considered the posture comparison Case C was engage in 8 postures out of 12 postures. A & E were engaged 7 postures, also Cases B , D , H, J , were engaged 6 postures during their work. G & I were engaged 5 & 4 were the lowest percentage that workers are affected during work.

According to table 4.2: **bend forward** posture was consumed 33 .2 hours under the total cases that is the highest rate and reason was that is standing is common to all cases during their work .Second highest occupied postures was **Awkward standing** it was 31 hours among the rates. **Twisting wrist and arms** also occupied a significant hours of 22.5. Considering of total work hours 107, out of 107, 99.1 hours were consumed by workers under awkward posture.

Then comes to Part II of the Posture & Work Pattern Summary, following key observation were noted .Out of ten cases 8 cases were repeated their posture during work time it means postures were overlapping or simultaneously performing multiple tasks. For ten people the average work hours was 10.7 h per head. If additional work

hours were not considered for the study but as a figure 32 hours were worked by 10 cases during their work shift . During the work 20 hours were taken for resting as usual . 133 numbers of short breaks been taken by all the workers during their works. Five workers (Case E,F,G.H,I,) were taken highest rates of short breaks during the work . also 80% of cases were engaged in additional tasks during at work. During work time 950kg reinforce bars were handled by all the cases . considering tieing reinforce bars 1020kg reinforce bars were tighten by selected cases during their time . Out of ten cases only two cases get help of helpers for their work & out of ten workers four cases spend time for work organizing during at work .

4.4.2 Impact On ERF to reinforce workers during at work Base on Postures

The third objective of the study is to determine which factors influence the reinforce workers during their work. The impacts may differ according to various types of aspects such as health, social issues, job matters, work effectiveness etc. some facts & figures for this objective were addressed in the literature review chapter, Over view of data analysis is discussed in this chapter in regarding primary interviews as well case study stage. Since postures are main ERFs for the analysis, the comparisons are done with in relation to postures and other observed data. When consideration on RULA & REBA assessments posture is to be used as the key comparison factor.

4.4.3 Age and Work hours of RWs

This table was highlighted that relationship between Age, Work hours, & Awkward posture hours. The aim of this illustration was to notice that as per the Literature review Chapter 2 (2.5.1) work long hours , awkward postures will affect to the physical health.

Table 4.4: Age and the Work Hours pattern Vs. Awkward posture

Case	Age	Work Hours	Additional work Hours	Total hours	Awkward Postures
A	52	12	4	16	8.8h
B	28	12	4	16	10.25h
C	52	12	4	16	9h
D	32	12	2	14	8.8h
E	27	11h45m	2	13.45	8.5h
F	49	9h45m	2	11.45	8h
G	24	10h20m	2	12.20	10h
H	39	15h20m	6	21.2	9h
I	27	12	3	15	10h
J	26	12	3	15	10h
		119.2h	32	150.3	92.3

Considering the work hour pattern the Average of the work hours of reinforce workers is 11.9 hours, and mode of the working hours is 12. As per the referred daily work records, Average 3.2 hours of additional work was done by all the cases. Average posture hours of the case was 9.2 hours. And total work hours with additional work hours are 150.3 hours, it average is 15. Hours per head.

According to the Table 4.3: it is noted that patterns of work hours, additional work hours & cumulative work hours are almost same. But the age limit variation is higher. According to the pattern it was noted over age, middle age and young workers are performing the same work tasks, with regards to awkward postures as follows 8.6 h, 8.8h , 10.1h .the range of hours limit was nearly 1.5 hours for over age and young workers . therefore it can suggest ergonomically older workers will face more risk than the young. As a result of this, it can be suggested that old age workers will lose their performances in short time due to ill-health and fatigue.

4.4.4 Percentage of Awkward Posture Hours against Total Work Hours

According to the data given Table 4.12: 76.6% work hours are consumed by workers on awkward posture out of work hours. Since total work hours are not been considered for the study, awkward posture hours may increase. Awkward posture is also an ERF which was mentioned in the chapter 3 as sub criteria of posture. Therefore, in study awkward posture hours which was worked by selected cases have been studied.

4.4.5 Working Days Pattern Entire month and considered day

As per the table 4.1: It was identified in primary interviews distribution of working pattern of cases was mainly based on monthly salary and wages. All the cases were willing to take leaves after salary. However the leave patterns differentiation would be based on personal interest of cases. As per the table mean working days for all cases are 25.8 and mean leave days are 8.1

Therefore significant impact was not noticed regarding work day and leaves. According to the table it was noted that most of rebar workers continually work at site, and taking leaves continually. In means of ergonomically working long hours and continues work is considered as strain / fatigue generated activities. As per social factor working long hours and continually working without taking leaves have impact to worker in means of ergonomics.

4.4.6 No of Breaks taken during work hours

Considering the impact on ERF to RWs numbers of short breaks taken were also taken in to consideration Table 4.2: During case study, each case has been studied regarding short rest taking during main work hours. Time of this short breaks were 1 to 5 minute. Two tea breaks and lunch has not been taken in to consideration for this count. It is clearly visible the fatigue of the workers during the work if they have taken more short rests it highlighted the fatigue. Also it emphasis the involving of awkward posture works. In addition to that short rest are highlighted the worker suitability to work effective skill etc.

In data analysis short rest and awkward posture hours were compared to find out relationship between both factors. Average value of the rest hours might be highlighted by the average rest hours taken. As per the table 4.12:. positive relationship can be observed, for the total work hours the pattern was same.

4.4.7 Handling Reinforce bars per day (Kg / Nos)

Handling Reinforce bars was also taken as a criteria to show the impact on posture as ERF to RWs. In site condition there are approximately 40 tons has to be tied up per day for achieve site construction targets. There for 40 tone's which has been divided among the reinforce workers. Handling reinforce bars were divided to several categories to benefited case study. Moreover, reinforcement markers, bundle unloaders, reinforce stackers, cupper tiers, reinforce tiers,, etc. were performed by BBs & BBHs during their work ,Handling reinforce at a selected location is common to all reinforce workers. However, the way of handling rebar's were different to work type and the operation type and worker to worker based on the skill. Analyzing handling reinforcement is another criteria to find posture as ergonomics risk factor how effect to the reinforce work.

Table 4.5: Handling Reinforce Bars during work hours

Case	Work hours	Handled Reinforce Kg	Handle Reinforce per hour (avg) Kg	Awkward Postures
A	12	150	12.5	8.8h
B	12	450	37.5	10.25h
C	12	210	17.5	9h
D	12	750	46.8	8.8h
E	11h45m	550	39.2	8.5h
F	9h45m	500	41.6	8h
G	10h20m	350	31.8	10h
H	15h20m	410	24.1	9h
I	12	250	16	10h
J	12	380	27.1	10h
Average	**11.9h**	**400**	**29.4**	**92.3**

This table highlighted the comparison between work hours , handled reinforce bars per day & handled reinforce bars per hour. Aim of analysis this table is to

As a general fact during handling reinforce bars in various conditions, all the rebar works has to be on awkward posture during this operation. As an average on these facts, one case has to work 13 hours per for reinforce work and 400kg of reinforce bars to be handled, lined up or tighten up. That is average of 29.4 kg per hour.

4.4.8 Number of Different Tasks performed during work time

This was noted in case study & highlighted in the table 4.2 part II, During work hours it was instructed to reinforce workers to perform some task related to RW by their management to overcome the site efficacy barriers. Therefore during work time majority of workmen used to performed multi-tasks during main task. As per the review scholars articles it is highlighted that ERF such as posture, repetitions, awkward postures will be increased during performed multi-tasks.

Therefore numbers of tasks performed by workers were taken as considered factors. According to the table only one given task was handled by two RWs, out of 10 additional task was handled by one workers, two tasks were done by three workers, additional three tasks were handled three RW, finally four tasks were done by one RW. Therefore more than one task have been performed by 90% RW .

Preforming additional tasks during main task was impact on the work progress and the health condition of the worker, also worker may get fatigue due to multi-task operation fatigue may cause to ER. As an operational matter work efficiency can be reduced of total operation and individually RWs.

4.4.9 Ill-health complication during work

During case observation , all BBs & BBHs were asked about health complication during reinforce work , table 4.5: displaying this data with Awkward posture hours that cases were completed during at work .

Table 4.6: Ill-health complication during work

Case	Response	Suffering acute/Chronic illness	Type of illness	Awkward posture hours.
A	Yes	Yes	Back pain	8.8h
B	Yes	Yes	Ankle /Back pain	10.25h
C	Yes	No	No	9h
D	Yes	No	No	8.8h
E	Yes	yes	Pain s in arms	8.5h
F	Yes	Yes	Back Pain	8h
G	Yes	No	Back Pain	10h
H	Yes	Yes	Pain of hands & wrists	9h
I	Yes	Yes	No	10h
J	Yes	No	No	10h

During primary data collection all RWs were asked about the health complications while work was performed. Objective of this is to find evidence on health reasons because of their working postures. Here RWs comments were categorized as respond, acute & chronic ill-health & type of ill-health. Considered all the cases were respond as Yes for the complications during at work. Out of 10, six cases were mentioned that they have suffered in some kind of ill- health. Consideration of type of ill –health conditions back pain were mentioned by 04 of RW. Four mentioned that they have complication but not suffering in Ill- health on work. Arms and wrists pains were highlighted by three RWs. For further study along with the health complication awkward posture were linked to table to for more evidence.

4.5 RULA Assessment findings

RULA analysis is one of the recommended modified methods for the posture analysis.(chapter2 ,table2.4) This has been used in most of sectors to calculate the posture movement of persons. In RULA rating movement of Arm & wrist are assessing under 06 contains. Neck Trunk & legs are assessing in 03 sections. All the sections were point rated accordingly posture movement for assessing ratings. Matrix was given during assessing to score in RULA ratings. Score can be compared for recommendations or precautions which need to be taken for working patterns.

Table 4.7:RULA Rating for Posture Analysis

Case	Score
A	11
B	09
C	12
D	11
E	10
F	11
G	08
H	08
I	10
J	11

RULA Matrix	
Score	**Recommendation**
1 – 2	Acceptable
3 – 4	Investigate further
5 – 6	Investigate –Change Soon
7 Above	Investigate –Change Immediately

Table 4.7: shows the Summary of RULA assessment for the work postures for all cases. In left column indicates the cases & scores right column shows matrix of the RULA Sheet. that with respect to the study During that, significant findings and the given scores . The main significant finding was that all of posture scores for All Cases were above point 07. This was obviously high rating regarding the matrix. The highest score is 12 and lowest is 08. Therefore as **per the RULA matrix immediate investigation has to be done for posture** patterns and posture of the RW has to be changed immediately in means of ERF.

According to the RULA assessment it was clearly noted that as a first finding RWs are having high risk of working in various postures. Parallel to that ; the below table distributes the posture hours pattern of two worker category's BBs & BBHs which were deployed at construction site.

Table 4.8: Comparison on RUAL & Work Posture with worker Group.

Category		**RULA / Score**	**Posture hours**
Bar Benders	Case A	11	8.8
	Case B	12	10.5
	Case D	11	8.8
	Case H	08	9
	Case I	10	10
AVG		**10.4**	**9.42**
Bar Benders Helpers	Case C	12	9
	Case E	10	8.5
	Case F	11	8
	Case G	08	10
	Case J	11	10
AVG		**10.4**	**9.1**

In table 4.8 under the bar bender category five cases were selected and BBHs were five for the comparison RULA scores and Posture hours were taken in to consideration. In group vice average were taken in RULA & Posture values .

As per worker groups there is not any significant highlighting noted regarding RULA score & awkward posture. RULA average scores for both worker groups are above the matrix. When consideration the posture analysis BBs have 9.42 average rating and BBHs have 9.1 average rating, therefore BBs have high risk rating on posture arrangements, that seems more works are involved by BBs & their skill leads to more work during at work.

4.6 REBA Assessment findings

REBA analysis is one of the similar assessment methods to RULA. This also recommended as a modified method for the posture analysis. This has been used in most sectors to calculate the posture movement of persons. In REBA rating, movement of Neck, Trunk & Leg is assessing under 04 criteria. Arms and wrists are assessing under 04 sections. All the sections were point rated accordingly to the posture movement for assess ratings. Matrix was given to assess the score in REBA ratings. The matrix of REBA is quite different to the RULA rating. Score can be compared for recommendations and precautions needed to be taken for working patterns.

Table 4.9: REBA Rating for Posture Analysis

Case	Score
A	10
B	13
C	9
D	14
E	8
F	8
G	11
H	17
I	11
J	11

REBA Matrix	
Score	**Recommendation**
2 – 3	Low Risk Change Many Needed
4 – 7	Medium risk - Investigate further change Soon
8 – 10	High Risk – Implement Change
11 +	Very high Risk – Implement change

Table 4.9: shows the Summary of REBA assessment for the work postures for all cases. In left column indicates the cases & scores right column shows matrix of the REBA Sheet.

Under REBA assessment all the cases have been tested .For REBA assessment findings showed differences compared to RULA assessment. **Highest score for REBA was 17 and lowest score was 8**. According to that all the points were distributed among the high risk and very high risk Matrix. Out of 10 cases, three cases are in score 11 range and average score range was 11.2. It indicates that as a average posture scores of selected cases are in very high risk range.

As per the REBA summary here also highlighted that posture assessments are high and therefore according to the REBA assessment RW s are facing high risk of working in various postures during their work hours .

Table 4.10: Comparison on REBA & Work Posture with worker Group

Category	**Case**	**REBA /Score**	**Posture Hours**
Bar benders	Case A	10	8.8
	Case B	13	10.5
	Case D	14	8.8
	Case H	17	9
	Case I	11	10
AVG		**13**	**9.42**
Bar Benders	Case C	9	9
	Case E	8	8.5
	Case F	8	8
	Case G	11	10
	Case J	11	10
AVG		**9.4**	**9.1**

In table 4.10 under the bar bender category five cases were selected and BBHs were five for the comparison REBA scores and Posture hours were taken in to consideration. In group vice average were taken in REBA & Posture values .

Consideration of BBs REBA values was 13 that is heights rate(Very high risk) compare to REBA Matrix and posture value was 9.42 , When comes to BBHs the value was 9.4 and posture value was 9.1. according to the comparison for REBA on two worker groups Bar Benders are more likely risky group under the REBA assessment .when considering on posture values & REBA value of BBHs group the matrix rate was in high risk . Under REBA assessment Again it is noted that BBs , (most skill work group) is under high risk in considered both factors.

4.7 SUMMARY

In this chapter was intended to analyse the findings in order to accomplish the objectives of the research. The aim of the research is to identify the key ERF faced by reinforce workers in construction industry & impact on it to them. During the literature review ten Ergonomics risk factors were noted, out of ten posture has been selected according to impotency, previous studies, compatibility to study area. Ten reinforce workers were selected as cases, Primary interview and case study done. REBA & RULA posture assessments taken as a technical assessment tools. Others criteria were developed based on case observations. The analysis was done based on REBA & RULA scores and case finding details. It was noted acceding to posture assessment tools, risk of working postures of BBs were very high then the BBHs . working postures of BBs are not in a satisfactory level. Moreover, since less study done relate to ERFA some primary models and assessments which were used.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In this century, construction industry is the one of the main mechanisms of driving the development parameters of economy. As an indicator for the economic growth most of the civil construction sites and construction work places have been enhancing due to expansions of industry, new comers, new foreign investments, as a part globalization such as various reasons. As a part of that specially construction industry is being divided in to several segments based on technology, work patterns etc. Also it was noted that implementation of new technology has been drastically increased. As a reason of that competiveness is increased among the contractors. Therefore, cost effectiveness of constructions and timely completion of projects, progress and speed of work are hightailed as critical factors in construction. Hence, to overcome these criteria parallel to technology man power has been increased by the managements. Therefore workforce, worker involvement to tasks is also a significant factor in the industry.

As a summary due to above mentioned all reasons Environment Health & Safety (EHS) matters will be increased during construction on going. When considering EHS matters, accident, incidents may increase. Moreover, to overcome EHS matter EHS implementation has to be strong. This is also a new strategically approach to win competition among the construction organization. The organizations which maintain high standards of EHS as well quality will be the leaders of industry. So as a part of EHS, Ergonomics is not considered in construction industry due to various reasons, especially since this is something about work patters, this was not taken care by workers as well as the management. Therefore as new trend to increase efficacy and speed of work during work, ergonomically aspects are conceded by managements.

In Sri Lankan context, since lack of knowledge, awareness, traditional approaches, practicing ergonomics in industries is in a very primitive level. Since with the new global changes in construction industry Sri Lankan contractors have to powered on manpower as well technology. Chinese contractors' arrival to Sri Lankan construction market also a challenge. According to the current contexts Sri Lankan civil contractors

are trying to speed up the works with available manpower and technology. In EHS aspects it will effect to work force in short term and long term. The study has done as a primary approach, since industry has not been recognized the impact of ERF.

Chapter one of this report includes the background of the study, problem statement, aim, objectives, and summary of the research methodology and chapter break down. Chapter two describes the literature review of the subject. Respectable amount of publications on this subject is available in other countries but related to construction industry is somewhat rare in the other countries. In Sri Lankan context no publications are available in regard to ergonomics studies. Quantitative and qualitative methodologies were used in this study and research methodology is described in chapter 3. The chapter 4 is to explain the findings of the research. The conclusion and recommendation are mentioned in the chapter 5.

The objective of one of the research was to find out the key ergonomic risk factors which are affected to the reinforce workers. In order to accomplish the objective a comprehensive literature review, case study and preliminary interviews were done. As per the literature review ten ERF were selected, All were analyzed based on articles which were published by scholar articles and researches done in the past and usage of analysis techniques. In chapter 02 under literature review out of 22 researches 11 authors highlighted posture under their researches and as ERF vibration also noted by 10 authors as critical ERF. Repetition is selected 09 times by authors as critical ERF; due to several practical matters vibration was omitted. Therefore, posture was selected as criteria for study since repetition as third option was also has link to posture. Once selected the ERF, assessment of RF has to be done. For that in Chapter Two ERF assessment tools were selected. After several studies, RULA - Rapped Upper Limb Assessment & REBA Rapped Entire Body Assessment was selected. Based on that, posture calculation was carried out. Under primary interviews & questioners selections, 18 criteria have been selected to gather other data on ERF in posture. Under posture criteria, Posture has been divided to 12 awkward posture types to get more information on posture. Separate Case study was conducted by selecting 10 cases to study the worker movement. For case selection reinforce workers were taken as study group. Selection of study group based on the work place work pattern, Operation pattern & worker exposure to the risk. All the cases were studied during on work, and RULA & REBA assessments were filled while on work. Other information was

gathered during their work. Furthermore, all the workers have been studied during their work shift. Additional work hours have not been taken in the consideration. According to the literature review RULA & REBA analysis are the most suitable and commonly used in tool in posture analysis. On RULA & REBA assessments filled, and case study primary data was converted into secondary or useable data and analyse for final objective. Data colleting, case study and assessment are more time consuming compared to other ways.

The second Objective of the research was to Identify and review the available ergonomics risks factor analysis (ERFA) tools and impact of the ergonomics tools in application .For this objective ERFA tools were analysis in literature review based on the selected data on ERFA tools & their impacts appropriate tools were selected (see table 2.1:/2.3:2.4:) for further studies the data was gathered from case study and the interviewed questionnaire data. As mentioned in above, under 18 criteria, 12 cases were selected to study. For the case study all the case data collected under four categories as general information, objective related information, task and output related information and ergonomically noted facts. These categorized data have been converted in to analysis sheet for analyse for final output. Under second objective as per the first objective posture was taken as ERF. Furthermore, Health impact, work arrangements, working awkward postures, social aspects, work distribution etc. were studied.

The Third objective of the study was to Investigate the one ERF faced by rebar workers in building construction projects using suitable ergonomic risk factor analysis tools & other suitable Analysis methods .What are the risk faced by selected work group based on selected ERFA specially posture highlighted as Key ERF . Under recommendations it was addressed and under this study methodology was used for data collection and analyses can be used as a primary method to study the ERF at any construction premises. It will help to develop strategy to find out ways and methods to overcome some issues. Other important methods and ways were mentioned in the recommendations.

The findings of the research relevant to key objectives are summarized here. According to ERF assessment analyses are based on posture. The RULA assessment

scores were under very high risk category according to the given standard matrix. It was indicated that immediate change of work pattern and immediate inspection is required. Under REBA assessment all the cases have been tested by using REBA assessment. For REBA assessment finding was some differences shown compared to RULA assessment. Heights Score for REBA was 17 and lowest score was 8. According to that all the points were distributed among the high risk and very high risk matrix. Out of 10 cases three cases are in score 11 range and average score range was 11.2 it indicates that as an average posture scores of selected cases are in very high risk range. Therefore, reinforce workers who are exposed to such risk will be faced various ill health and Ergonomics complications. Based on Case study analyses, findings it was noted that multi-tasks were performed in a selected work range, ill-health and complication pattern of workers are in risk level. Awkward posture pattern of workers was significantly high. Proper system was not followed by management for worker duty arrangement; it should be based on skill, competency and age. Based on handled reinforce bars / kg per day it was noted. Work load for the worker is significantly high and as per the socio-economic reason leave taking rate and work hours rates are very high compared to general setup.

5.2 Recommendations

According to the construction context in Sri Lanka, a huge competition has developed among the construction organizations. Also new arrivals to market also a high, since construction market being acquired by multi-national contractors and specially low cost chines large scale contractors is a challenge to local construction organizations. Therefore, work force efficiency, high competency level of work, healthy workface is required. Once workforce is managed by management to take work done in correct way it will help for construction organizations to overcome their challenges.

1. According to the findings **overloaded work involvement** of workers under middle age and old age (close to retirement) to heavy work is very high, moreover, according to the study average work hours working on **awkward posture hours were very high** for the old & middle age worker man. This is one of main signal to organization management. The situation has to be managed for retaining experienced workers. Meanwhile young workers participation is less due to unplanted, unorganized worker setup.

Hence the work efficiency, task performance are reduced, and fatigue, health complication of worker will increased.

6. **Health surveillance is required** Time to time for workmen and ERF assessment has to be conducted periodically for analyses the ERF that are affected to work force.

5.3 Future research directions

- This study was limited to identify the ERFA in building sites in construction industry. Based on that mainly posture was considered as the studying factor for the whole setup, therefore, there're many ERF are available in the literature to assess. Specially, heat stress, vibration, is some of them.

- The health related issues on ergonomics are another area to study in future. Since ergonomic chronicle health , due to various ERFs workers may get sick without any noticed , so carefully study on health effects has to done in future , since enlargement of construction sector , several health impacts can be observed even in today such as white hand syndrome etc.

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Appendix - A .

Questioner

Identify features of construction site Ergonomics patterns of selected Ergonomics Risk Factors .

Instruction to respondent

Please answer all questions on your own `experience or your observation.

Section A

When the boxes are available in the questions ,if your answer is yes please tick or under line (X) (---) in the box to indicate you r answer.

1.Gender

Male Female

2.Age

18-25 26- 35 36- 45 46 – 55 60+

3.educational qualification

1.Grade 8 Pass 2. O/L pass 3. A/ L .4 Above

2.Proficinal qualification

1.Certificate course 2. Diploma 3. Above

Section B

Employment Information

When the boxes are available in the questions ,if your answer is yes please tick (X) in the box to indicate you r answer.

1.your Profession

2.working experience

Less then 5 years 50-10 years 10-20 years 20-30 years over 30

C **work related patrons**

1. How many days are you engaged in this work for a Month

30 -25	25 -20	20 -15	15 - 10	10 -05

2. What are the other works engaged in during this period

Form work	Plastering	Scaffolding	General labor	P & E

3. How many Kg s of reinforce bars tie per day

05	10	15	25	50	50>

4. How many hours are you continue you shift against your standard work shift.

1	2	3	4	5

5. Did you performed any other professions in other companies before . please mention .

Yes	
No	

6. Do you get ant support from others during work

Yes	
No	

7. Do you feel any complication during your work time , such as back pains ..

Yes	
No	

8. Do you suffering any chronicle illness related to your job .

Appendix - B

Employee Assessment Sheets On Ergonomics Risk Factors – Reinforcement workers .

1) RULA Assessment Sheet .

A	Arm & Wrist Analysis -	Points	Point Box			
	01) Locate Upper arm Position					
	1)Arm is parallel to body + 15 to -15 ^{0}					
	2)Arm Moved to Back words - 15^{0}					
	3)Arm Moved to forwards - +15 to 45^{0}					
	4) Arm Moved to forwards - +45 to 90^{0}					
	5)Arm Moved to forwards – Above 90^{0}					
	If Shoulder is raised					
	If Upper arm Is Abducted					
	If arm is supported or person is seating .					
	02) Locate Lower arm Position					
	Arm is parallel to body 0 to - 90^{0}					
	Arm bend from elbow 90^{0}					
	Arm is moved side from shoulder level					
	If arm is working across the midline of the body					
	If arm is out side of the body					
	03) Locate wrist position					
	Wrist is straight					
	Wrist move up					
	Wrist move down					
	Wrist is bent side to side					
	Wrist bent from mid line					

	04)Wrist twist					
	Wrist is in mid line					
	Wrist twist both range					
	5)All Muscle Use Score					
	If posture mainly static (Hold longer then 1 minute)					
	If Action is repeating (Four times in minute)					
	6) Add Force /load					
	Load less then 2 kg					
	If 2kg to 10 kg					
	If 2kg to 10 kg static Or repeated					
	If 10 <more –repeated or shocked					
	Vibration					
B	**Neck , Trunk , & Leg Analysis**					
	7) Locate Neck Position					
	Neck bent 0 to 10^0					
	Neck bent 0 to 20^0					
	Neck bent 20^0 +					
	Neck bent back					
	If neck twisted					
	If Neck is bending side to side					
	8) locate trunk Position					
	Trunk is well supported while seating					
	Trunk is not well supported while seating					
	Trunk back 0 to 10^0					
	Seated					
	Trunk bent 0 to 20^0					
	Trunk Bent 20 to 60^0					
	Trunk Bent 60^0 +					

	Trunk is twisted					
	If trunk is side bending					
	9) Leg position					
	Leg and feet supported & Balanced					
	If Not					
	Matrix of Index for Section A & B					
	Acceptable					
	Investigate Further			**1 - 2**		
	Investigate Further change Soon			**3 – 4**		
	Investigate Further change Immediately			**5 – 6**		
				7		

REBA Assessment Sheet

		Point	Action			
A	**Neck , Trunk , & Leg Analysis**					
	1.Locate Neck Position					
	Neck bent 1 to 10^0					
	Neck bent 20^0 to +					
	Neck bent Back					
	Adjustment 1					
	If neck is twisted					
	If neck is side bending					
	2. locate trunk Position					
	Trunk is rigid					
	Trunk bent back					
	Trunk bent 0 to 20^0					
	Trunk bent 20^0 - 60^0					
	Trunk bent 60^0 - +					
	Adjustment					
	If trunk is twisted					
	If trunk is side bending					
	3.Legs					
	Align with the body					
	One leg bent on knee					
	Adjustment					
	If leg bent on knee $30\text{-}60^0$					
	If leg Bent on knee 60+					

	4. Add Force /load					
	If load >5kg					
	If load is 5 to 10					
	If load > 10 kg					
	Adjustment					
	If shock or rapid build up of force					
B	**Arm & Wrist Analysis -**					
	Locate Upper arm Position					
	Arm Moved to Back / front words -20^0					
	Arm Moved to Back 20^0+					
	Arm Moved to forwards 20 to 45^0					
	Arm Moved to forwards -+45 to 90^0					
	Arm Moved to forwards – Above 90^0					
	Adjustment					
	If Shoulder is raised					
	If Upper arm Is Abducted					
	If arm is supported or leaning .					
	Lower arm position					
	Bent on elbow to upper					
	Bent on elbow to lower					
	Locate wrist position					
	Wrist is bent 15^0 from mid line (up or down)					
	Wrist is bent 30^0 from mid line (up or down)					
	Wrist is bent from mid line & twisted					
	Activity Score					
	One or more body part are hold longer then a minute (static)					
	Repeated small range actions					
	Action cusses rapid large range change in posture or					

	unstable base					

Scoring	
1	Negligible
2 or 3	Low risk , change may needed
4 to 7	Medium risk , Further investigation , change soon
8 to 10	High risk ,investigate &implement change
11 +	Very high risk , implement change

Appendix C - RULA Calculation Sheet