Ergonomically Designed Intervention towards Occupational Wellness of Women Tea Leaf Pluckers in Assam

A thesis submitted in partial fulfillment of the requirement for
the degree of Doctor of Philosophy

By
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Abstract

The Tea Industry is one of the largest employers of women amongst organised agro based industries in North east India, particularly in Assam. Women constitute nearly 51% of the total workforce in Assam. Many of the activities, especially the plucking activity (40 per cent of the total cost of production of tea leaves) performed by the workers in tea plantation demand a high degree of physical effort because of repetitiveness and assuming static awkward posture, leading to early fatigue and work related musculoskeletal problems. To make best way of work performance and increasing overall productivity of the workers an ergonomic interventions study in easing out the ergonomic risk factors in tea garden leaf plucking was carried out that can reduce work related hazards and improve work comfort and productivity.

In order to maintain the quality, the tea garden managements still prefer selective plucking of two leaves and a bud through hand plucking instead of any mechanical development in the process. Thus the present study aims at assessing the current working condition and feasibility of introducing low-cost ergonomic design of work tools that to improve occupational health and the work performance so that finally productivity of the workers can be enhanced with comfort.

Followed by the study of occupational load, the design development of work accessories was identified as a priority area; and the attempt was made to see the feasibility of a tea leaf plucking aid that can be used by individual workers in the tea garden. The new plucking device consists of a cutting blade imbedded on a thimble type finger (index / middle finger) guard. Evaluation of effectiveness of the new device was carried out with subjective opinion, discomfort ratings, selected physiological parameters, productivity and comfort in use. If the breaking of tea shoots (two leaves and a bud) from the tea table can be made easy, the force required and frequency of hand movements can be controlled (new device lessens false hand movements) will ultimately reduce holding of the awkward posture longer; this would facilitate dynamic movement. Thus the new device addresses the ergonomics risk factors responsible for occupational stress as well as productivity and work comfort. Such small development, looking into implementation possibility with the corporate decision, for a vast end users group i.e., women tea-leaf pluckers would result in an effective way.

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This thesis material presented here in by MS. Nandita Bhattacharyya was undertaken under my guidance and supervision. The volume of work here in for the Degree of Doctor of Philosophy of Indian Institute of Technology, Guwahati was not submitted by her earlier for any other degree or diploma.

She has undergone six specified courses and fulfilled all the requirements as mentioned in the rules and regulations for submitting the thesis for the Ph.D. degree of Indian Institute of Technology, Guwahati.

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Preface

Occupational ergonomics is a work related problem solving technology, and its application requires an organized approach. In any occupational settings the stresses to which the human body is subjected to experience over a long time will cause loss of efficiency, musculoskeletal injuries, or disability over a period of time. There is a large latent period before the effects are manifested. Moreover, in industrial situation, failure to match the work requirements and the characteristics of work tools/machines with the capabilities of the workers causes early fatigue, reduced rate of work and lower productivity. The occupational stress is multi-factorial. The emerging approach for relieving stress focuses on a pro-active response with emphasis on preventive measures and elimination of the causes of stress, rather than on the treatment of its effects. This very complex issue is covered by a broad field of occupational ergonomics.

Possibly because of academic dominance of ergonomics in the past three to four decades, there have been very few attempts at an organized approach to apply ergonomics in Indian industry, especially in North East India. Women around the world including in North East India have moved into Industries and service sector (almost 50 percent of the workforce). Gender-based criteria for the division of work are supported by traditional cultural assumptions. Choices for occupation selection are limited, they end up in doing monotonous and low-paid work and involves in long hours of work. In North East India participation of women workers in different sectors are mainly agriculture, followed by livestock, weaving and textiles products, food products and petty retail trade.

Tea industry is the second largest agro based industry of Assam which is highly labour intensive. The large work force employed in tea industry is comprised of majority of women workers. Seventy percent of work time in tea industry is spent on plucking of tea leaves in the tea gardens which is a woman dominated activity and performed manually. Mechanization of tea leaf plucking is not practiced, especially in Assam due to its preference of selective plucking which is a pre-requisite for quality tea production. Tea-plucking is a highly repetitive task, conducive for developing musculoskeletal problems of upper limbs and strains in other body parts; needs design development which can assist in selective plucking, thereby increasing productivity and work comfort.

The present study looked into to highlighting some prevailing occupational health and safety issues of woman tea-leaf pluckers of Assam with appropriate design interventions.

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Summary of the Research

In India joining of women in the main stream workforce is increasing in numbers day by day, especially in industries and service sectors. In many cases employment of woman workforce are preferred as a common belief that woman can do repetitive work and can work in a close group formation. Due to their low literacy level and lack of technical knowledge, mostly such women workers are engaged in occupations with repetitive, monotonous and low-paid work. The sectors where women workers are the prime workforce include agriculture, agro based industry (tea, fruit processing, cottage industries, etc.) and services; making up about 42 per cent of the estimated global working population who also bear their homemaking responsibilities. They are therefore prone to suffer from work-related hazards, which are further complicated by social, psychological and physiological issues. The exposure of women workers to these issues may affect them in one or more of three ways: health, performance, and comfort. Studies have shown that roughly, 1 out of 300 female is suffering from some occupation related health problems. Musculoskeletal disorders are one of the major problems among many women workers in such industries (NIOSH, 1997; OSHA, 2000; Perimalam et.al, 2005).

The causative factors of work related health problems are poor ergonomic design of work place, work accessories, static work, poor working posture, repetitive work, and frequent bending and twisting, lifting and forceful movements and vibration. Individual factors like age, sex, anthropometric dimensions, muscle strength and physical fitness, lack of task variation and posture change facilities, insufficient rest break, psychological exhaustion and social factors contribute to work related health hazards. The women workers often suffer from work related body pains because neither the tasks nor the equipment they use, which are normally designed for men, are being adapted to women specific built and physiological limits.

In most industrial situations women workers usually perform manual tasks involving repetitive arm movements. The task may not involve heavy exertion, but early fatigue, pain and repetitive strain injuries in arm, shoulder and neck region are prevalent. It is also agreed that working for prolonged periods while performing repetitive tasks can be very damaging to both productivity as well as worker's health (Das and Sengupta, 1996). This is because static muscle exertion inhibits blood flow and causes muscle early fatigue. The buildup of fatigue minimizes the overall effectiveness of worker and finally productivity is reduced.

The ergonomics risks factors in an occupational set up while performing any activity can be tackled by developing safe, trust worthy work equipment and workplace design (Chakrabarti, 2009). Hence, to increase efficiency in work performances, importance should be given on the working conditions, design of the work accessories/machines and health of the workers as well as providing better work methods and facilities for them. Work accessories/machines should be designed according to ergonomic principles. In practice, while attempting design development studying the risk factors in occupational setting in organized way would be the correct approach

Women constitute nearly 51 percent of the total workforce in Assam; they are mostly seem to be engaged in handloom industry, fruit processing industry and tea industry apart from traditional agricultural field works. The activities performed by them is highly repetitive, causing health problems i.e. work related musculoskeletal problems thereby reducing the productivity along with increasing the absenteeism in duties. Therefore, to make their best way of work performance and increasing overall productivity it should be the main attempt to reduce the early fatigue and incidence of work related health problems.

The Tea Industry is one of the largest employers of women amongst agro-based corporate industries in India. Many of the activities, especially the tea-leaf plucking activity (40 per cent of the total cost of production of tea leaves) performed by the workers in tea plantation demand a high degree of physical effort because of repetitive hand movements and assuming static awkward posture, leading to early fatigue and work related health problems. Based on the observation on the task performing and opinion survey, it came to fore that ergonomic intervention in designing work accessories can be a way to reduce work related stress by assisting the plucking operation.

Since ergonomic risk factors assessment is still lacking in this sector, there is a need to study on the prolonged working task with awkward postures with a strong empirical evident and analysis. Thus, this study aimed at finding out the ill effects on upper limb and lower back during prolonged repetitive tasks of tea-leaf plucking. Some occupational health related issues were studied with relevant ergonomic techniques including physiological measures to understand the workload and its relevant subjective rating so that this can be used in evaluating any new design development scopes

Work accessories design development identified in priority is a cutting blade imbedded thimble type device to relieve ergonomic risk factor prevalent in the activity. Evaluation of effectiveness was carried out with subjective opinion, discomfort ratings and productivity context. Small development with vast implementation possibility due to corporate decision the developed plucking device would yield a good result.

In a nutshell, the aim of the present study was to assess the current working condition and to suggest the low-cost ergonomic means to improve occupational health and work performance through work tool development possibilities. The study results in a thimble type plucking device development to aid the productivity and work comfort of the workers.

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1.0 Introduction-Occupational ergonomics in India

Indian labour intensive production scenario is taking impetus with wide use of ergonomics. It is evident through recent publications of India relevant studies in various production areas covering both corporate sectors as well as small scale investments.

Occupational health is specifically concerned with safety and wellbeing of the workers, as well as its motive is to improve productivity, using optimum level of human cost comparing the productivity outcome. In normal circumstances, occupational stress appears as an unavoidable part of working life. Occupational stress is a situation where in the work related factors interact with the human factors in such a way that the individual is deviated from his/her normal functioning.

A strong relationship exists between the occupational stress of workers and their productivity. Occupational stress of the workers results in reduced production due to inefficiency of the workers and sickness absenteeism. Moreover, the workers have to be paid sickness benefits and compensation wherever applicable. In many cases workers have to face the loss i.e., no work no pay. Occupational stress is becoming an increasingly global phenomenon affecting all countries, all professions and all categories of workers, families and society in general. The World Health Organization has characterized occupational stress as multi-factorial. A number of risk factors e.g., physical, work organizational, psychological, relevant individual constraints and socio-cultural issues contribute to causing of occupational stress (WHO, 1986).

Neglect of occupational stress and safety may result in invisible burden to the economy, which, in some cases, may be substantial. The major occupational hazards concerning work motivation and quality productivity in India is the musculoskeletal injuries. The emerging need should be focused on a pro-active response to occupational stress, with emphasis on preventive measures and elimination of the causes, rather than on the treatment of its effects and there by bringing occupational wellness among the workers.

The main objective of ergonomics is to achieve an optimal relationship between people and their work environment, where the approach has to be context specific. The two conflicting factors in this optimisation process are workers' productivity and physical wellbeing. The work conditions of workers may be hazardous due to various responsible ergonomic risk factors while at work situations. It results in a variety of occupational health problems which includes loss of efficiency and onset of early fatigue, discomfort, disability of varied degree and musculoskeletal problems to the workers. The factors that play roles in the process of occupational wellness and stress are body postures, movements, exertion required, environmental factors, and poor design of work method/work tools, technical systems, inappropriate relationship between workers performance and their tasks demands (Fig.1).

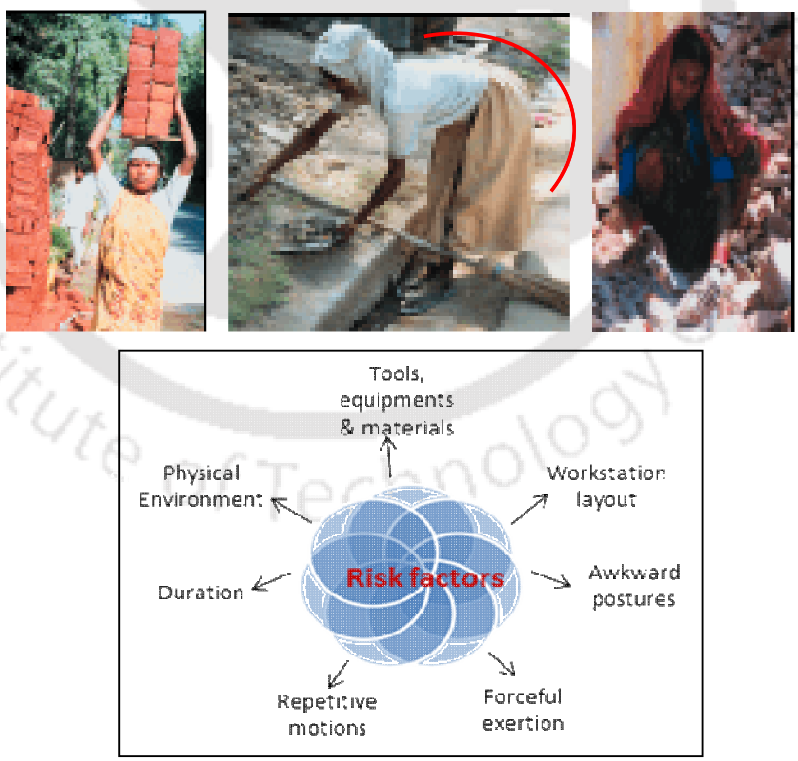


Fig.1: Ergonomic risk factors: women at work are exposed to such hazards

Occupational ergonomics is a solution oriented domain of ergonomics that deals with the human physical factors as well as the psychosocial factors to evaluate stress at work viewing to minimise its effects. The goal is to optimize worker's well-being and productivity by treatment of the stressors of work; specifically when it concerns with human labour force those who have to bear dual pressure of household daily chores and being engaged in specific work for earning with specific reference to women workers.

Work related health hazard (in terms musculoskeletal disorder) is an indicating parameter of occupational stress which roots in lack of various ergonomics considerations in the way the work is performed. The most commonly occurred work related musculoskeletal disorder are found in upper extremities, and neck-back, and have been described by a number of generic terms including cumulative trauma disorders, work related upper limb disorders, occupational overuse syndrome, etc. It is noticed that unplanned work methods and use of inappropriate work equipment to carry out a task are the major cause of work related musculoskeletal disorders in the workplace. Sometimes these are reported and records are maintained to refer but the majority of the affected workers remained silent and are seemed to be reluctant to report, probably due to fear of getting exposed of the injury and health disability to lose job or wage and ultimately suffers. The existing legislation does not protect the vast majority of the women workers as well. The Factories Act, 1948 covers working conditions, health and safety, basic amenities like toilets, crèches, working hours etc. but does not apply to work places with fewer than 10 workers using power driven machinery or less than 20 workers without such machinery (Padma, 2004).

The work related discomfort and pains are being presently looked as a leading cause of occupational injury and disability in the developed countries. Recently the awareness has come to industrially developing countries like India, mostly through academic discussions and relevant research studies, and few corporate sectors have in house ergonomic remedial facilities. It is needless to mention that the cost benefit effects of ergonomics application are enormous, but in practice it appears that the vast small scale private owned enterprises are unaware of such benefits.

Major Indian ergonomics activities are centered on the improving of traditional village technology, tools and work methods that go along with the existing skills and know-how knowledge. Studies revealed that predominant work hazards in rural India industrial enterprises are related to use of age-old work methods and traditional practices, lack of scientific work organization, malnutrition causing early physical deterioration and other public health problems affecting health and safety of the teeming million. Perhaps for this reason, application possibilities of ergonomics in small scale production sectors continue to be the component of highest academic research priority since the beginning of ergonomics activities in India (Sen. et al, 1981; Nag and Pradhan, 1992; Kogi, 1997; Gosh, 2005).

Low levels of productivity are the results of inadvertent neglect of ergonomic aspects in the design of agricultural equipment (Gite and Yadav, 1990). Several researches have shown that the application of ergonomic principles and programs in almost all workplaces result in increasing productivity and decreasing work related health problems (Saraji et al 2004). Hence, it becomes necessary to see how ergonomics specifically with its design application to the work accessories helps. Many of the ergonomics studies on women workers in India have been carried out in the field of agriculture, beedi industry, handloom industry, tea industry, fish processing, and construction workers (as reported in HWWE proceedings under Indian Society of Ergonomics, 2003, 2005, 2008, 2009) have shown good progress which is reported in many forum from time to time.

With the ergonomics research activities applied to the design of a job, task, process and procedure, and work tool, in any industrial work situation, the work related problems can be eased out. Studies on epidemiologic evidences associated with occupational health problems and the joint effects of work related musculoskeletal disorders (mentioned as one of the potential risk factors) are needed. It can be a priority objective to the developmental efforts. It is noticed that in many cases productivity and morale show direct proportional relation.

The International Ergonomics Association (IEA) and the Federated Ergonomics Societies (in India ISE, Indian Society of Ergonomics) provide opportunities to promote exchange on ergonomics research and meaningful applications in specific context. The future sustainability of the domain will be dependent on the provision of ongoing research opportunities in ergonomics and the transitioning of the research findings into practice. Humanizing the Work and Work Environment (HWWE, the conferences and annual meeting of ISE) has become foreface of the Indian ergonomics activities and provide platform for international dialogue. In HWWE of the 2005, a special evaluating workshop was held on ‘Draft standards on agriculture and farm machineries relevant to IIIrd world developing countries’ to have Indian scientist’s opinion. In all the HWWE workshops stress is put on requirement of Indian context studies. The current thesis work is inspired with this note.

Many ergonomics studies on manual machines and hand operated tools generated a great deal of scientific knowledge, which are unique to our situation and increased production, betterment of health of the numerous people involved (Chakrabarti, 2001). To find such possibility the present study emphasised on certain development of work accessories that through a corporate decision can be implemented in mass, at least to their own concerns.

Participation of women workforce in industrial sector is on raise. In the past 15 years, they have become almost 50 percent of the global workforce. Women workers suffer from work related health problems because neither the tasks nor the equipment they use, which are normally designed for men are adapted to their built and physiology (Srivastava and Bihari, 2000). These problems result from working conditions such as a fast pace, heavy lifting, repetition or working in an awkward posture and use of uncomfortable work accessories. These injuries can be prevented, if causes of injuries are identified. The North East part of India remains a virgin field for ergonomic intervention where a large women workforce is being engaged in corporate sector like tea, where traditional labour intensive work culture prevails. The economic loss due to work related health problems affects the individual worker as well as the organisation and the society as a whole.

The current approach of study relates with the effective application of ergonomic principles to improve occupational health. Work related health problems (musculoskeletal disorders) among the women workers have been taken as one of the reference parameters to evaluate the work tool design development process for improving productivity along with their overall wellbeing. North East India is a women workforce dominated land, which required such studies, handloom, and agro based involvement is commendable.

1.0.1 Priorities of Ergonomics research, North East specific

Ergonomics is relatively young to Indian society compared to its development in the west. In India, ergonomics started in1970s in terms of awareness mainly through academic interests but gained its acceptance as a productive tool has come very recently. It is still an emerging area with heterogeneous nature of research and practices in different spheres of technological needs. The major focus started with analyses, evaluation and optimisation of workplace, work methods and tools in agriculture, including informal sectors and mining (Sen, 1984; Nag, 1986). Though many of the work environment studies and work place modifications were made on an ad-hoc basis, these strongly reflected an increasing trend of ergonomics practices (Ramanathan and Nag, 1982) suitable to our country.

Vast population of North East India with varied traditional occupations that supports the livelihood of locals and having export benefits remained unexplored from viewpoints of ergonomics. Studies reported so far have been carried out mostly in the field of agriculture, tea cultivation and in some craft based fields as academic interests in various students' academic assignment levels in Home Science College, Assam Agricultural University, Indian Council of Agricultural Research and North Eastern Regional Institute of Science and Technology from time to time. Department of Physiology of Calcutta University carried out a number of academic projects as master theses in Eastern India and conducted first ergonomic study in Tea gardens of Assam in 1979. A Ph.D. thesis work entitled "study on work posture and muscle load of cane and brass metal artisans of Assam" was carried out in the year 2007 in the Ergonomics laboratory of the Department of Design, Indian Institute of technology, Guwahati. Under the study an ergonomic intervention was carried out on male dominated ergonomic work space and tool development in Brass metal craft and cane craft of Assam; intending to reduce occupational stress with relevant design solutions.

Among the North Eastern states, Assam appears to be progressing in industrialization. It has a few agro-based industries and mineral based industries. Agro-based industries like jute, rice mills, fruit processing, tea industries, etc. are of great economic importance. As it is shifting from local ethnic life style to industrial perspective various levels of ergonomic hazards reference to these highly labour intensive industries specifically fruit processing and tea industries are silently imposing on large number of women workforces. The works in these industries are done manually as machines are either not convenient or do not go along with the traditional skills practiced so far. Work related health problems cause lost work time and lowered work performance. To improve the situation demands systematic ergonomic studies for alleviation of the conditions of work and possible design development of work tools and accessories practicing standardised methods. In Assam such approaches in recent years on women workers are not carried out much, few attempts have been taken with academic interests as mentioned above.

The critical question concerns with the priority to be allocated for work simplification-the method of performing the work or context specific design intervention; proper examination of examining feasibility for making improvement is necessary. In this efforts, the present status of local small scale agro-based works transparent the need on the study process to be considered; people engaged in respective fields of work may be taken into confidence in valuing them through participatory approach to choose development measures sustainable with their capability and resources.

1.1 Participation of women workers in economic activities-special reference to Assam

There are estimates that over 90 percent of working women are involved in the informal sector (The World Bank, 1991). Seeing gradual increment in inclusion of women in economic activities, today it surely has risen with participation in white collar jobs in urban locations. The informal sector includes jobs such as domestic servant, small trader, artisan, or field labourer (Dunlop and Victoria, 1999). The 1991 Census estimated about 90 million women workers, out of the 314 million total workforces (Sharma, 2006).

In India, participation in economic activities varies considerably according to gender, the type of task and the place of residence. Gender-based criteria for the division of work are supported by traditional cultural assumptions (South Asian Research & Development Initiative, 2004). With the changing socio-economic scenario, women's productive roles have assumed new dimensions. Women workers have been an important segment of the workforce of India. Different segments of labour where mostly women workers engaged are wage workers: casual or regular either in formal or informal industrial sectors, making up about 42 per cent of the estimated global working population. As a whole women workforce in NE India, particularly in Assam are getting engaged in varieties of occupations and gradually increasing participation in upcoming small scale industrial enterprises; agriculture and employments in tea fields remained the major participating till today (Fig.2).

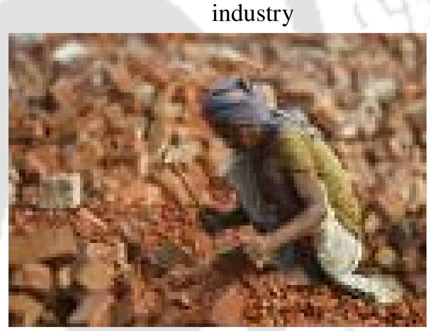
a) Women workers in fruit processing industry

b) Women workers in beedi industry

c) Women workers in agricultural field work

d) Women workers working in an industry

e) Women workers in bamboo basket industry



f) Women workers in construction work

g) Women workers in handloom industry

h) Women workers in tea industy

Fig 2: Women workers in different occupations

Specific to rural areas family economic condition has compelled women to take up jobs which are low paying and they work for long hours without any benefits specific to compensate with and even face sexual harassment which led to establish women commission to look into and deal with appropriateness.

With the advantage of employing women in small scale industrial tasks as they can do better repetitive tasks and less vocal in their demands, the consequences are low average earnings and high poverty risk (Das, 2009). This quite often reflects in their productivity; working women of Assam face the grave draw back. With a holistic view, studies covering work environment as well as their socio-economic issues would provide a social platform to better performance.

1.1.1 Cases of North east and Assam

As per legendry evidences, North East India is powered with women workforce and women are engaged in diverse activities; e.g. as per socio-cultural tradition girls must know how to weave. Now the honour has become income generating employable workforce being engaged in different occupations (Fig.2). In North East India participation of women workers in different sectors are mainly agriculture, followed by livestock, tea, processing of fruits and vegetables, weaving and textiles products (Fig.2 and Fig.3), petty retail trade and food products (Sundaram, 2001). Many women are also engaged in self-motivated independent unclassified activities and add to family income.

Fig.3: Women workers working in fruit processing and tea industries as means of major sources of income generation.

Among four thrust crops in Northeastern agro-horticultural belt- orange, pineapple, ginger and cashew nuts; pineapple has industrial feasibility in Assam. Few agencies also impart trainings for women self-help groups but not much benefit in reality. The working women group gets from these schemes of financial and know-how supports (The Telegraph, Guwahati, Monday, 28th March'2011), which transparent the need for awareness programme on overall occupational wellness and work methods in fields and in process units. Need for assessing ergonomic design intervention to help in improving work performance may also be looked into.

To see the feasibility of such development, an upcoming fruit processing unit at Boko in Kamrup district of Assam was visited. Pineapple processing requires skills and involves a variety of repetitive movements of hands (Fig.4).

a) First peeling of pineapple b) Removal of eyes slicing c) Coring of pineapple slices

Fig. 4: Peeling and coring of pineapple

In the processing unit it was found that women workers were engaged in peeling and coring of pineapple. Mostly the activities were found performed with simple long knives and cylindrical tools (Fig.5). The workers reported to face problems for unavailability of sound peeling and coring tools. Need of the hour is suitable equipment to upgrade the peeling process and equipment to be designed should be suitable for small scale industries.

Moreover, in fruit processing units it was found that during lean period of pineapple, women workers are engaged in various tasks of varieties of fruits processing activities, requiring specific tool development with local materials suitable for specific tasks.

a) b)

(c) (d)

a) Knives used for pineapple peeling
b) Knives used for peeing and removing eyes
c) Device used for peeling after slicing
d) Peeling and coring device, available in the market but not found effective in comparison to traditional knives and cylindrical device

Fig 5.: Knives and tools used in pineapple peeling in Assam

The weaving industry has got imbedded in the culture from time immemorial whereas the fruit processing and tea industry are seen totally as employment generation for the women workers, they comprised of local as well as migrated from other parts of country settled in Assam. The group of workers engaged in tea industry is known as tea-tribes. Both the corporate and local small entrepreneurial participation are very strong in tea sector with the task and work schedule followed almost similar in both the sectors.

In a state like Assam, because of her large population size and low general economic status, the use of manpower may likely to persist on a larger scale in the coming decades. The large work force employed in industries and many other occupations comprises of majority of women (Behal, 1992).In this context, mechanization vs. continuation with manual labour is debate in society.

1.2 Occupational wellbeing and productivity

Occupational health study is concerned with safety and wellbeing of the workers. As per NIOSH (National Institute of Occupational Safety and Health, 2002), occupational stress is the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources or the needs of the worker. Some records of nineties mentioned that globally about 120 million occupational accidents 2,00,000 fatalities were estimated to occur annually in addition to 68-157 million new cases of occupational diseases due to various exposures (Niedhammer, et al ,1998). While solutions to certain ill effects are readily available, there are most cases they do not lie in the hands of occupational health specialist or physicians. In order to safeguard the health of the workers, it is advisable to take preventive measures. Question arises how in advance it can be known and how to measure its degree of severity-still remained unanswered.

An approach of primary prevention will be more appropriate to address the root causes of the problems. Understanding of the mechanism of causation of occupational injuries and accidents will put us in a better position to design effective strategies of control and prevention. Ergonomic design of work, machine, tools and equipment and work environment with due consideration of humane capabilities and limitations from the physical dimensions, physiological and psychosocial points has been recognised as necessary. Not only it is useful for ensuring health, comfort and safety of workers, is also improving effectiveness of the production system. Occupational wellbeing and productivity enjoy a proportional relationship in any work situation.

Several ergonomics approaches were attempted to tackle the occupational health problems in specific work settings. Brouha (1967) demonstrated a considerable improvement in recovery heart rate responses by partial mechanisation of a job requiring human effort in an industrial situation. In examining the job demand fitness compatibility by Sawkar, et al (2008), it was evident that the relative load (%) on Indian female agricultural labourers was above acceptable limits of workload means proper attention is necessary and attempts are in progress (Gite, et al 2007). With these evidences it is clear that ergonomic research needs to be carried out to ensure job demand-fitness-compatibility in order to make the activities more humane in various jobs context to Indian requirements. Specific stressors parameters (indicating work related musculoskeletal disorders severity) may be chosen as a measurement.

1.2.1 Work related problems: Musculoskeletal disorders (WRMSDs) specific

Work related musculoskeletal disorder (WRMSDs) is one of the indicating parameters of occupational stress. The term of work related musculoskeletal disorders (specifically expressed in terms of body pains) is referred to conditions where the worker experiences discomforts of neck, shoulder, low back, elbows, hands, hip and knees, as well as multiple joints manifesting ache, tingle, swelling and pains. At present around the world, these work related problems are one of the most important problems, which ergonomists encounter in the workplace. In many countries, preventing this is considered even as a national priority. Indian studies have shown good database which is reported in many forums from time to time. Studies (Halim, Rahman, Omar, Hayati, 2004) have shown body pains as a major occupational health problem amongst the workers in metal industries in Malayasia. The economic loss due to those problems not only affects the individual performance but also the organisation and the society as a whole.

These work related musculoskeletal disorders are not recent problem. Date back to 1706 Bernardo Ramazzini, an Italian physician considered as the father of occupational health, reported that poor working conditions often expose workers to multiple risk factors for musculoskeletal disorders (Najarkola, 2005). The level of risk depends on the duration a worker is exposed to risk factors, the frequency at which they are exposed, and the magnitude of the exposure.

Many industrial operations are being carried out in awkward postures; repetitive movements and repetitive bending that trigger various health problems (Mallory and Bradford, 1989; Genaidy, 1995). Both physical load and psychosocial factors at work have been shown to play a role in the etiology of musculoskeletal disorders (Hoogendoorn et al., 1999; Ariens et al., 2001; National Research Council and Institute of Medicine, 2001; Riihimaki and Hiihimaki, 2005; Ganguli, 2007). Ijadunola et.al (2003) observed that, poorly designed workstation and work equipment impose unnecessary physical efforts, which ultimately results in reduced performance efficiency and there by productivity loss also.

Humanizing work and working environment are two of the significant catch words in today's world production scenario. Safe working conditions are considered as vital contributor to ideal occupational health in most industries. It can be said that musculoskeletal problems can be reduced by optimizing the biomechanical and psychosocial load at work. In recent years that some workers, trade unions, employers, manufacturers, and researchers have begun to give attention to how workplace/work methods/work tool design can improve the health of worker and ensure safe working aiming at improved productivity.

1.2.2 Women's Safety and Health Issues at Work

Women often face different workplace health challenges than men do, partly because men and women tend to have different kinds of jobs. Because of this, men and women experience different job-related problems.

In terms of health, women generally have more work-related cases of carpal tunnel syndrome, tendonitis, respiratory diseases, infectious and parasitic diseases, and anxiety and stress disorders compared to men. Women are more exposed to repetitive and monotonous work and to stressful conditions (Srivastava and Bihari, 2000; NIOSH, 2010). A report on women garment workers of Ahmedabad, India mentioned that women's workplace health problems are frequently compounded by getting more of the same at home - the "double jeopardy" of domestic work (Ghoshal and Chakrabarti, 1987).

According to the Bureau of Labor Statistics, women workers suffer a disproportionate number of many types of ergonomic risks. These problems are often referred to as work related musculoskeletal disorders and are common in a wide variety of occupations. Study on 'Women's Safety and Health Issues at Work', conducted by NIOSH (2010) revealed that sprains and strains, carpal tunnel syndrome, tendonitis, and other musculoskeletal disorders account for more than half (55 percent) of the injuries and illnesses suffered by female workers, as compared to 45 percent for male workers.

Through extensive research studies and surveys carried out in different countries, numerous health problems have been identified among industrial workers (ILO Encyclopedia, 1998). But most of the studies on women workers were mainly confined to large and medium scale industries in Indian context and very few reported studies (Calcutta University dated back to 1979 and Assam Agricultural University, engaged currently) in North East India have been carried out, mostly in the field of agriculture and tea cultivation.

Since labor intensive economy prevails in India, the musculoskeletal problems may in fact be acute and the more neglected the more its severity resulted with ill effects in working life and productivity. But insufficient awareness and a lack of proper documentation makes it very difficult to quantify. Further research is needed to determine the factors that place women at greater risk for this work related health problems; and women dominated work environments in Indian context. It is necessary to focus as such efforts will examine if physical differences between men and women, differences in the jobs they hold, or work equipment mismatch with work need and human resource compatibilities contribute to this increased risk for women.

Work related health hazards of women workers have been traditionally under-estimated because occupational safety and health standards and exposure limits to hazardous substances are mostly based on male populations and laboratory tests. The design of machinery and equipment has demonstrated to be a major cause of health problems (body pains) when is not conceived or not used properly, particularly in the industries, where the operations require more of repetitive work and exertions. In the design of equipment and work tools, the anthropometric data used do not always reflect the characteristics of the working population who will use it. Most of the personal protective devices and work equipment and tools used worldwide are designed based on male populations (Silverstein, Fine, and Armstrong, 1986) that does not appear compatible to the women workers. Still not much importance is given in this aspect though women now-a-days share equal responsibilities for income generation.

Moreover women's issues are often absent from health and safety policies; the hazards involved are either unknown or underestimated, and priorities are defined in male-dominated sectors and occupations. This failure to take account of women's health issues in the workplace constitutes a barrier to frame effective policies on occupational health and equal opportunities specifically in case of Indian workforce scenario where entry of women workers in the erstwhile male dominated and specifically women intensive working is relatively new.

1.2.3 Occupational risk factors and Work-related Musculoskeletal Disorders: some issues

Work posture related health problems (musculoskeletal problems), the resultant effect of consequences of interaction between different factors/demands are recognized as leading causes of significant human suffering, loss of productivity, and economic burdens on society. Ergonomists over the years found out a casual relationship between some specific health problems (body pains) and the jobs (Van Willy, 1970; Smith, et al 1981). Some of the common work related health problems (body pains) are carpel tunnel syndrome, thoracic outlet syndrome, tendinitis, cumulative trauma disorders, repetitive strain injuries (Putz-Anderson, 1993).Musculoskeletal problems are a common health problem and a major cause of disability (Bernard, 1997; European Agency for Safety and Health at Work, 1999; Smith et al., 2006). In contrast to many occupational diseases that has their origin in exposure to particular hazardous agents. Most work related health problems (musculoskeletal disorders) are characterized as multi-factorial that a number of risk factors contribute to causing the problems (WHO, 1991).

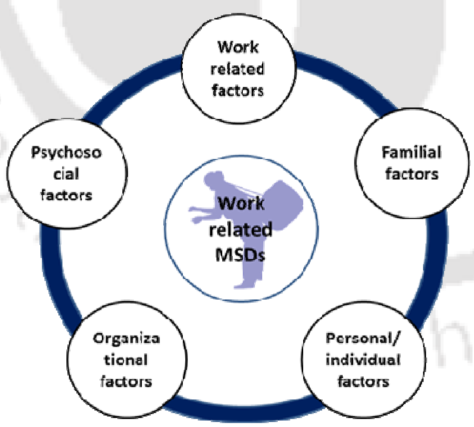


Fig. 6: WRMSDs as consequence of interaction between different factors with reference to tea plucking activity

Findings of scientific research have identified different groups of factors, including workplace related (physical and biomechanical), organizational and psychosocial factors, individual and personal factors (Fig.6), these may act uniquely or in combination (Hagberg et al., 1995; Nordander et al., 1999). On the basis of a number of recent critical review of the literature (Burdorf, 1992; Hagberg, et al, 1992; Winkel and Mathiassen, 1994; NIOSH, 1996; Punnett and Bergqvist, 1997), it was noticed that many of work related health problems have substantial work-related component. This is especially true where there is a high level of exposure and there are combinations of adverse conditions, e.g. carrying loads on back, hanging from head with the arms outstretched along with frequent finger movement is stressful for the shoulder region, neck and arms, the posture is assumed by workers during tea-leaf plucking (Fig.6) .

Epidemiological studies suggested that factors such as job demands, time pressure, and stimulus from work activities are also significantly associated with work related health problems development (Bongers, et al 1993; Ariëns, et al, 2001; Buckle and Devereux, 2002; NIOSH, 2002).

1.2.3.1 Work related factors/demands:

Work related health problems (musculoskeletal problems) are supposed to be causally linked to physical load resulting from occupational activities. Pains or injuries affecting muscles, tendons, joints, ligaments and bones are mainly caused by mechanical overload of the respective biological structures. Workplace risk factors include the physical demands imposed by performing the task, such as posture adopted, force applied, frequency and repetition of movement, task duration and vibration experienced (Kilbom, 1994; Bernard, 1997; Burdorf and Sorock, 1997; European Agency for Safety and Health at Work, 1999; Melhorn, 1999; Smith and Leggat, 2003). Ergonomics risk factors include varied degree of work related adapted postural issues, force application required and frequency of operation and movement necessary.

1.2.3.2 Organizational and psychosocial factors:

The epidemiologic studies of work related health problems by National Institute of Occupational Health (NIOH) suggest that certain organizational and psychosocial factors (including intensified workload, monotonous work, and low levels of social support) have a positive association with these disorders though there is considerable confusion regarding the contribution of psychosocial factors to musculoskeletal illness and injury. Psychosocial factors such as work or time pressures, job insecurity, poor pay structure, financial conditions, lack of social support and poor job satisfaction can contribute to work related health problems (Lee et al., 1989; Bernard et al., 1994; Toomingas et al., 1997; Hoogendoorn et al., 2000; Woods, 2005). Lack of privacy and control, constant supervision and organizational effects on workers motivation also affect the performance and causes occupational stress.

1.2.3.3 The personal/individual risk factors:

Individual risk factors include age, gender, body type, anthropometry, muscle strength, years of employment, poor lifestyle and habits (smoking/alcohol consumption, lack of exercise/recreation, poor nutrition) and physical fitness (Armstrong et al., 1993; Punnett and Herbert, 2000).

1.2.3.4 Socio-cultural factors:

The socio cultural factors affecting the work related health problems symptoms are marital status, number of children and daily time spent on housework. Dual role of a home maker and bread earner for a woman daily contribution to health disorders accumulates to a considerable amount but proper assessment is yet to be carried out.

Assessment of the level of exposure to work-related health problems (musculoskeletal disorders) risk factors can be an appropriate basis for planning and implementing an interventional ergonomics program in the workplace. Model of MSD hazards analysis system followed by US NRC, and Institute of medicine (National Research Council and Institute of Medicine, 2001) as mentioned below appears to be appropriate to consider, Fig.7.

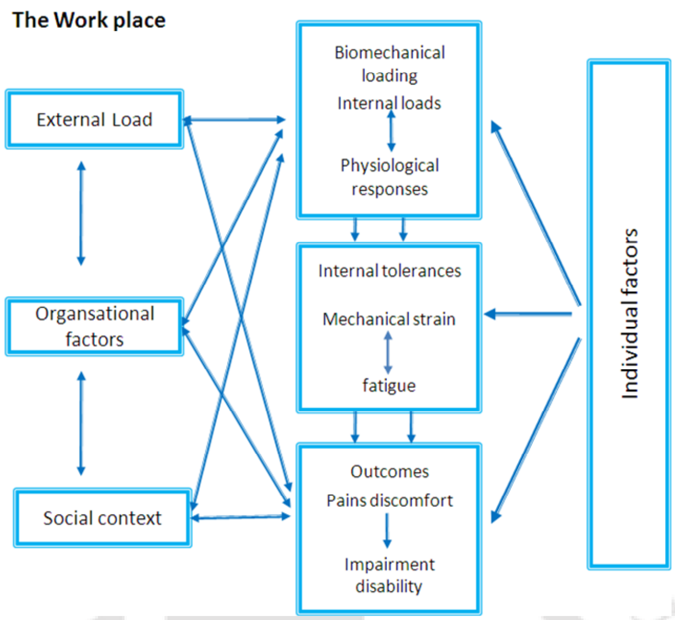


Fig.7: Model of MSD hazards (produced by: US NRC and Institute of Medicine, 2001)

1.2.4 Need justification for the study in selected sectors

Despite high prevalence rates of work-related health problems, the causes and pathways are not fully understood. Multiple factors (physical, psychosocial, and individual) have been associated, but causal inferences are not available.

Workers in different economic sectors generally have work related health hazards which are characteristics of those sectors. Work related health issues as mentioned by Kumar in his literatures revealed that "people in agricultural field activities, construction, and production premises have a higher proportion of back injuries. Those working in office type jobs involving typing, prolonged record keeping have musculoskeletal pains in upper limbs (also called cumulative trauma disorders). Since it does not happen the other way round, i.e. the heavy physical workers developing cumulative trauma disorder and the office workers injuring their backs, this offers credence to the argument that the nature of the physical stress and the region enduring the load largely determine the affected area and probably the nature of injury. If, therefore, one is able to delineate the mechanism of injuries and the quantitative details of the relevant variables one may be able to develop a more effective intervention. An effective intervention will result in a better control of injuries which clearly has a significant pay-off" (Kumar, 1998)". This situation is identical in Indian scenario and effect is the same.

For long term success in controlling occupational problems depends on understanding the causation of the problems. A clear understanding and establishment of the mechanism of problem causation has been somehow elusive. Therefore, an appropriate scientific approach is required to examine the situation so that theories of body pains causation can be constructed. The purpose of the present study was to examine the epidemiologic evidence that associates the prevalent work related problems such as work related discomfort and body pains (musculoskeletal problems) of the upper extremity and the low back with exposure to different work related factors (physical, work organizational, psychosocial, individual, and socio-cultural factors) at work in the field of agro-based industry (tea industry), specific to tea-leaf plucking. The goal of epidemiologic studies is to identify the relevant factors that are associated with the development or recurrence of adverse medical conditions. Understanding these associations and relating them to problem etiology is critical in identifying workplace exposures that can be reduced or prevented.

1.2.5 Ergonomic Intervention-work accessories design and methods

The work-related portion of the injuries and resulting disability is potentially preventable and it is important to identify ergonomic interventions that are effective in reducing both the incidence of initial work-related health problems and/or reducing disability from injuries, their personal costs and the monetary costs associated with them (Frank et al., 1996).

Ergonomics interventions aimed at improving work at both the level of individuals (micro) and at the level of work organization (macro). Clearly, these levels interact with each other. There has been an increasing effort in recent years to investigate the causes of work related health problems (body pains) and to take action to prevent them. The science of ergonomics and its application to these problems that associated with the modern workplace provide both an important perspective and a preventative approach to develop work tool design as presented in Fig.8 may be used.

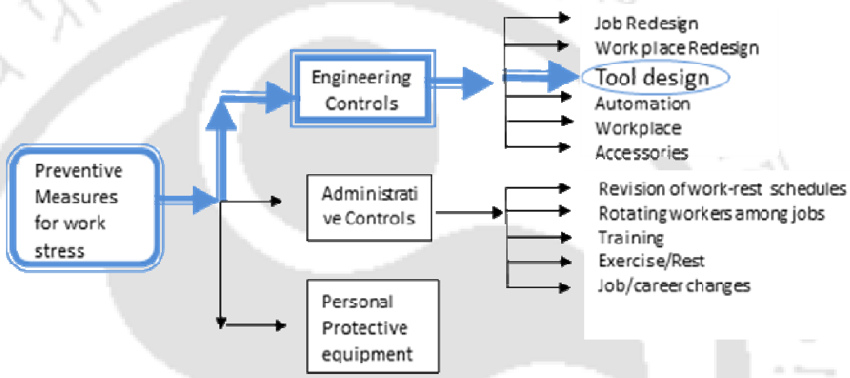


Fig. 8: Schematic illustration of preventive measures for WRMSDs: pathway shows the design development strategy followed in the present study

The control strategies for preventive measures are: engineering controls, work practice controls and administrative controls (Federal Register, 2010). Engineering controls include workstation modifications, changes to the tools or equipment, and altering production processes. Work practice controls include use of neutral positions or postures (keeping wrists straight, lifting close to the body) and team lifting. Administrative controls include employee rotation and job enlargement. The final rule goes on to say that "engineering controls are the preferred method of controlling work hazards in cases where these controls are feasible (NIOH, 2010). In contrast to administrative and work practice controls or personal protective equipment (PPE), which traditionally have occupied lower tiers of the hierarchy, engineering controls fix the problem once and for all". With these principles in mind, the specific objective of the present study was to develop and evaluate engineering controls for the reduction of upper extremity injury risk in workers in the selected industry (tea-leaf plucking).

Mismatch between man and machine/work tools are one of the major factors contributing to work related health problems (body pains). Some tools are advertised as "ergonomic" or are claimed to be designed with ergonomic features; but how far they conform to the ergonomic many-a-times put a doubt, when a design fulfills context specific ergonomic criteria to its inbuilt features, it becomes a good design, and everybody will like to use it. A work tool specifically becomes "ergonomic" only when it fits the task which is being performed, and fits the working hand that relieves, harmful contact pressures, awkward postures and other safety and health risks. A tool that does not fit the hand or needs to use the tool in a way it was not intended, injury may be developed, such as carpal tunnel syndrome, tendonitis, or muscle strain. These injuries do not happen because of a single event; instead, they result from repetitive movements being performed for a long period of time, force application which in combination may result in damage to muscles, tendons, nerves, ligaments, joints, cartilage, spinal discs, or blood vessels. Thus not only the design as static features of the work tool e.g., shape, size, weight, etc., its mode of use i.e., the work method also need to be considered.

Most designers of agricultural equipment concentrate to improve efficiency and durability; very few seem to give importance to the operator's comfort (Gite et al .2007). The ergonomically refined designs of tools and implements minimise the drudgery of the workers and at the same time increase the productivity at reduced expenditure levels. In several studies carried out on farm machineries, the available agricultural hand tools/equipment viz., direct paddy seeder, groundnut striper, fertilizer broadcaster, sugar cane harvesting knife, etc. were critically analysed for their ergonomic characters in order to improve man-machine system efficiency without sacrificing performance, which are still in documentation stage (Gite and Mazumdar 2005; Kathrivel, K. 2009). In North East India such studies in tea fields are required; if good work tool can be developed addressing to the above mentioned needs.

1.2 Motivation to the thesis work

From the above considerations it is now established that ergonomic risk factors prevail in different occupational settings. The consequential effects of prevalence of ergonomic risk factors are development of occupational stress (physiological, organizational and psychosocial, familial). One of the important indicating parameters of occupational stress is work related musculoskeletal disorders expressed through body pains which are very common among workers. Several studies have shown that there exists a relationship between work-related musculoskeletal disorders and repetitive movement while performing manual jobs.

In spite of its relationship with productivity, safety, health and well-being of workers, practicing ergonomics in industries of Assam is still off the rhythm. This close association has not been so far investigated; in particular the agro-based industries in Assam. An understanding of risk factors causing the work related musculoskeletal disorders due to ill adopted work posture among the workers, repetitiveness of the activity (frequency),have requirement to perform the task and long duration of work become critical domain of research (Fig.9).

There are many areas where application of ergonomics is likely to produce immediate benefits. The people involved at various levels must be identified and proper awareness created, so as to enable them to think in terms of ergonomics, and thereby create a need. Unless the users feel the need, no ergonomics recommendation can hope for successful implementation, no matter how serious the problem or how elegant the ergonomics solution.

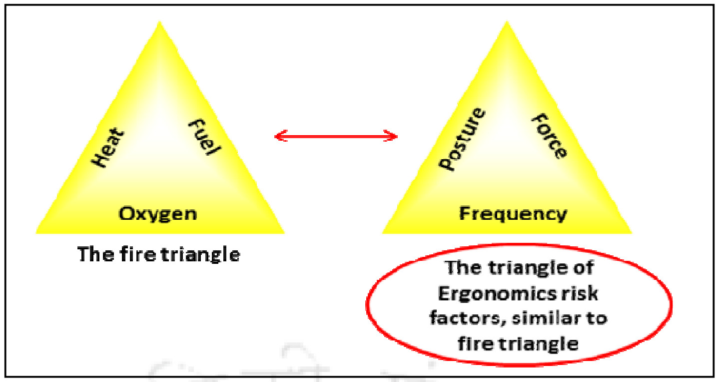


Fig.9: Ergonomic risk factors similar to fire triangle
(if the intensity of any one of the factors i.e., heat, fuel and O_2 or together the fire damaged be controlled, similarly posture, force and frequency impose the ergonomic risks)

Tea industry and fruit processing industry of Assam are highly labour intensive. In both the sectors the activities involve numerous combinations of arm and finger movements and their use varies with the skill, experience and degree of fatigue of the worker (Sen et al, 1981; Chakrabarti, 2001; Bhattacharyya, et al, 2005).

The present study was conducted in two phases. The initial phase was as a whole among women workers engaged in repetitive activities, i.e., tea-leaf plucking operation and fruit processing activities (specifically pineapple peeling) requiring repetitive hand movements to determine work related health problems (musculoskeletal disorders) prevalence rate among women workers and to assess the level of exposure to ergonomic risks. Efforts were also made to study the scope for development of design interventions in both the selected areas. The interaction with the management as well as the workers in tea, the organized sector revealed that a substantial number of workers are engaged in a single task job for considerable shift duration. A specific design development may produce a good result through a corporate decision towards mass implementation. Where as in small scale unorganised sector of fruit processing units, workers are engaged in multi-task jobs depending on availability of raw materials to work with and with varied levels of skill in an unpredictable supply-demand production scenario, the design development may need context specific approach and the developmental efforts may be participatory.

Thus the main phase to see the effect of design (work tool) intervention applicable for a large working group with corporate decision tea leaf plucking operation was considered for in-depth enquiry. As background support of such development need occupational study assessment may be conducted.

The goal of the study was to identify factors (such as physical, organizational, psychosocial, and work related factors) that are associated with the development or recurrence work-related problems and the remedial measures through assessing work tool development in tune with affecting normally practiced work methods.

Tea-leaf plucking is a single-task job. Workers perform the activity by assuming a front bending posture and moving fingers repetitively and arms intermittently for entire time spent in work. Though the workers have to pluck a bud and two leaves selectivity during green tea harvesting, which is a pre-requisite for quality Assam tea, no appropriate method to assist the selectivity (the specific apex part) was developed or any specific design development to smooth the tea-leaf plucking task was carried out. The domain of the study of the ergonomics design intervention with respect to selective plucking for productivity improvement and reduction of work related physical hazards (included body pain) offers considerable scope for research. A specific design development and for a method to select and pluck the selected shoots may produce a good result through a corporate decision to implement that would be used in the field.

The study was conducted to examine the epidemiologic evidence that associates selected work related health problems of body pains specific to the upper extremity where more repetitive arm and hand movements are required and the low back pain with exposure to various physical factors at work. Understanding these associations and relating them to disease etiology is critical in identifying workplace exposures that can be reduced or prevented. It is assumed that through development of a proper work tool that in turn helps reducing the chances of work related stress and improve productivity would contribute over all women worker's occupational wellness with specific reference to tea-leaf plucking activity.

1.4 Hypotheses

01 It is assumed that: There is a proportionate relationship between work performance and occupational stressors specific to the work context.

02 Development strategy assumes that there is no significance of variance in terms of severity of MSDs with the variance of age, body mass index (BMI), and years of experience but the method of task performed imposing varied levels of physical stress.

03 Proper work equipment and work tool design improves work performance and occupational wellbeing in terms of work comfort and operational easiness.

1.5 Aim and objectives

Aim:

The study aims at looking into Ergonomic Design Intervention towards occupational wellness of Women tea pluckers and productivity in Assam

Objectives of the study are:

1. To examine the ergonomic risk factors prevailed among women workers in agro based industries specific to tea-leaf plucking activity that influences the work performance and relevant health issues; with reference to work related musculoskeletal disorders (WRMSDs) through body pain and strain feeling in order to select the appropriate methods for development in the present set up.

2. To assess the occupational loads on women workers engaged in tea-leaf plucking activity to identify specific design development of work tools and accessories that suits the specific nature of task requirement.
3. To demonstrate the possible design support viewing to improve tea leaf plucking comfort and easy operation without changing the present method of work culture followed in the tea gardens of Assam.

1.6 Methodology followed and flow of work

The whole work has been undertaken in three stages and the material is spread over in the following four chapters.

Chapter I: Occupational Ergonomics relevance to women agro-based industry workers- reference North east India

The stage I constituted the current chapter I of the thesis, with an overview of relevant research attempts stressing work related musculoskeletal disorders and women specific occupational health issues on participation of women workers in economic activities. This section emphasizes the need for ergonomic intervention in the development of agro based work culture with special reference to Assam. Occupational wellbeing and productivity, an ergonomic approach in North East women dominated occupations constituted the background work presented in the thesis. A pilot enquiry (as stage I of the thesis) among various agro based fields of engagement, spreading over fruit processing small scale enterprises and tea industry, the tea-leaf plucking was identified (to work upon as stage 2 of the thesis) a potential area where small and low cost tool development can be attempted.

Chapter II: Occupational status of the women workers engaged in tea-leaf plucking

Under stage 2, detailed questionnaire survey was undertaken with the workers, supervisors in tea garden management and relevant experts with specific interview schedule and direct observation in the work site to understand:

- The occupational health problems of women workforce engaged in tea-leaf plucking;
- The felt need on the extent of mechanisation vs. traditional practices of selective hand plucking of two leaves and a bud ensuring quality produces;
- The physical and demographic characteristics of women workers to decide upon development strategy and design features;
- The influences of organisational factors and psychological risk factors on health related stress.
- The feasible design development strategy of work tools that can create an assertive effect on the situation.

Ergonomic cost of tea leaf plucking was studied by measuring various stress factors of the workers while performing the activity. This is to understand where the design development would be beneficial.

Ergonomic risk factors prevailed among tea-leaf pluckers associates productivity and relevant health issues were studied by OWAS, RULA, QEC, OCRA and Nordic Questionnaire. The body map was developed for evaluating musculoskeletal disorders using body part discomfort rating/ ranking assessment methods

Chapter III: Design Development of a finger guard plucking aid and Evaluation

Design development of a specific work tool that can be used as a finger cover with a cutting ridge to assist the tea-leaf plucking was attempted. This exercise was done with a participatory approach, taking the workers in confidence for understanding the needs, what type of work tools they feel to be useful.

Thus an ergonomic plucking device was conceptualised, designed, developed to a certain trial stage and was tested on the workers of its suitability. The design was not only found suitable to improve productivity, its work comfort value was also accepted by the workers.

Chapter IV: Discussions and conclusions of the whole thesis work constitute this part including the salient findings and recommendations for further study scope.

Chapter-II

Occupational status of the women workers engaged in tea plucking

2.0 Introduction: Tea Industry and women workers

Assam's biggest contribution to the world is tea. It produces some of the finest and expensive tea and has its own variety *Camellia assamica*. Assam tea (Fig. 10) is famous for its quality in international level. To maintain its quality till today the garden management rely on hand plucking of tea shoots method of tea harvesting in their tea gardens (Fig. 11) and workers are also traditionally well versed with it.

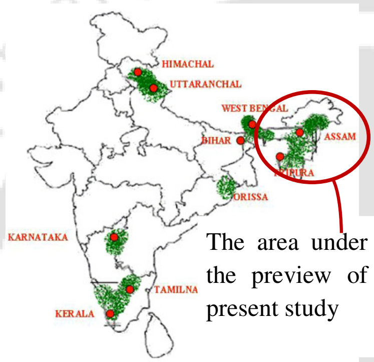


Fig 10: Tea growing areas of India (relevance Assam - famous for quality tea)

Tea is the most important plantation crop and the largest organized agro based industry in North East India, and provides year-round employment to workers - mostly women. Though both man and women workers are involved at every stages of production, women workers are being engaged in activities starting from nursery development to the packaging of tea leaves (Lama, 1983).

Women are mostly involved in tea leaf plucking activity in the tea fields. Tea-leaf plucking constitutes the major time consuming part of the total employment in the tea production. Worker requirements in the tea industry can be broadly classified into two categories i.e., among the workers a bulk of labour absorption is required for harvesting (plucking), which accounts for as much as 70 per cent of the workdays and 40 per cent of the cost of production. Fertilizing, weeding, pruning and processing account for most of the rest of the field-level labour force (ILO, 2000).

As reported earlier, the Calcutta University team (Sen, Ganguli, Ray, and Chakrabarti), in 1978 for the first time put efforts to assess the women tea-leaf pluckers occupational status at gardens situated in Jorhat. district of Assam. The study though opined the tea plucking as a ‘light’ category job in terms of human energy expenditure; it involves many types of fast repetitive movements that put significant physical demands on the workers leading to produce considerable local fatigue (Sen et al, 1984).

a) A typical tea field

b) A tea-leaf plucker plucking tea leaves

b) Selective plucking “a bud and two leaves”

d) Handful of plucked leaves

e) Ready tea leaves for sale in market

f) Packet of tea leaves

g) Cups of made tea ready to sip

Fig.11:The tea cycle, from field (a) to cup (g) where the selective plucking (c) is a key factor in quality

There are several areas where small changes in the job content or job context or designing work tools and accessories are likely to reduce the physical efforts of the workers (Chakrabarti, 1987). Thereafter though it is felt in many discussions and forums, still not many ergonomic efforts are made to see how design can better the work condition. No further occupational health study focusing design development to assist the working easier was undertaken till date in the tea gardens of Assam.

This chapter devotes to understand the occupational status and background of the workers and a survey on looking at the prospect of mechanisation vs. traditional practices of tea-leaf hand plucking to find out the appropriate developmental strategy that needs to be focused.

2.1 Aim and Objectives

Aim

The present study aims at identifying an area where design development strategy that can smooth the situation based on current work method followed in the tea gardens of Assam and occupational load on the women workers.

Objectives

1. To examine the ergonomic risk factors and occupational loads prevailed among tea-leaf pluckers that associated with the work performance and relevant health issues.
2. To understand the design development support in terms of continuing with hand plucking vs. mechanisation focusing at improving tea-leaf harvesting quality of produces and productivity.

2.2 Materials and Methods

The current research addresses the multiple risk factors associated in work related health problems (in terms of body pains) development in occupational settings specific to tea gardens. Under the current study efforts were made to identify the possibilities of ergonomic intervention to relieve the work related health problems among the workers engaged in tea leaf plucking.

Study strategies followed with opinion survey on the workers and management. Direct observations on the task were performed in the tea gardens and in laboratory.

Below are the detailed steps taken to obtain relevant information.

2.2.1 General survey on looking prospect of mechanization vs. traditional practice

A preliminary survey was conducted to collect information on extent of mechanisation of tea leaf harvesting activity in tea fields, bulk production vs. quality of hand plucking production. For the survey a total of twenty five tea gardens located in Assam under different management i.e., proprietary, corporate, and Assam Tea Corporation were selected as per representatives of respective categories. The sample tea gardens selected consisted of small and large tea gardens of Assam. Relevant information were obtained based on interview and meetings with production and management, the findings led to go to in depth enquiries on workers' field related issues to understand the ergonomics risk status.

2.2.2 Study strategy followed on subject

The field survey was conducted to understand the risk factor exposures and effects thereby. Along with physical, demographic, psychological, social, familial information, the work related risk factors were assessed through questionnaires and rating scales, and few basic physiological measures. Occupational stress questionnaire was prepared to assess the occupational stress among the workers in the selected tea estates (Fig.12). This was a self-administered questionnaire with a 5-point Likert type response scale consists of 51 items (appendix A). Items were drawn from the Job Content Questionnaire (JCQ: Karasek et al., 1998) and the COPSOQ (Copenhagen

Psychological Questionnaire) developed by the National Institute of Occupational Health in Denmark (Kristensen et al., 2005). Only questions from categories that were relevant to the current task were included (e.g. questions on job security, remuneration, social relations with co-workers, etc.). The workers were asked to respond to each and every items of questionnaire by giving subjective opinions in terms of always, often, sometime, rarely and never. These responses were transferred to point by assigning the ratings from 5, 4, 3, 2, and 1 respectively. The items of the questionnaire were classified into various factors i.e., the organizational and psychosocial factors, physical and work-related factors, and familial factors.

2.2.2.1 Locale of the study:

The present study was carried out in Jorhat district of Assam (Fig.12). Jorhat is called as the 'Tea Capital of the World' (Mishra, 2007). It has 139 tea gardens spread over 24,274 hectares of area (DRDA, 2008).

2.2.2.2 Sampling Procedure:

The sample of the present study was selected by multistage sampling method which is represented diagrammatically in the figure.12. In the first stage of the sampling procedure Jorhat district was selected purposively on the basis of its tea gardens coverage. In the second stage to select the tea gardens, a list of tea gardens under different management i.e., a) private-proprietary and corporate, b) public-Assam Tea Corporation (ATC) and Tea Trading Corporation of India (TTCI) was collected. From the list six tea gardens representing from different management were selected randomly.

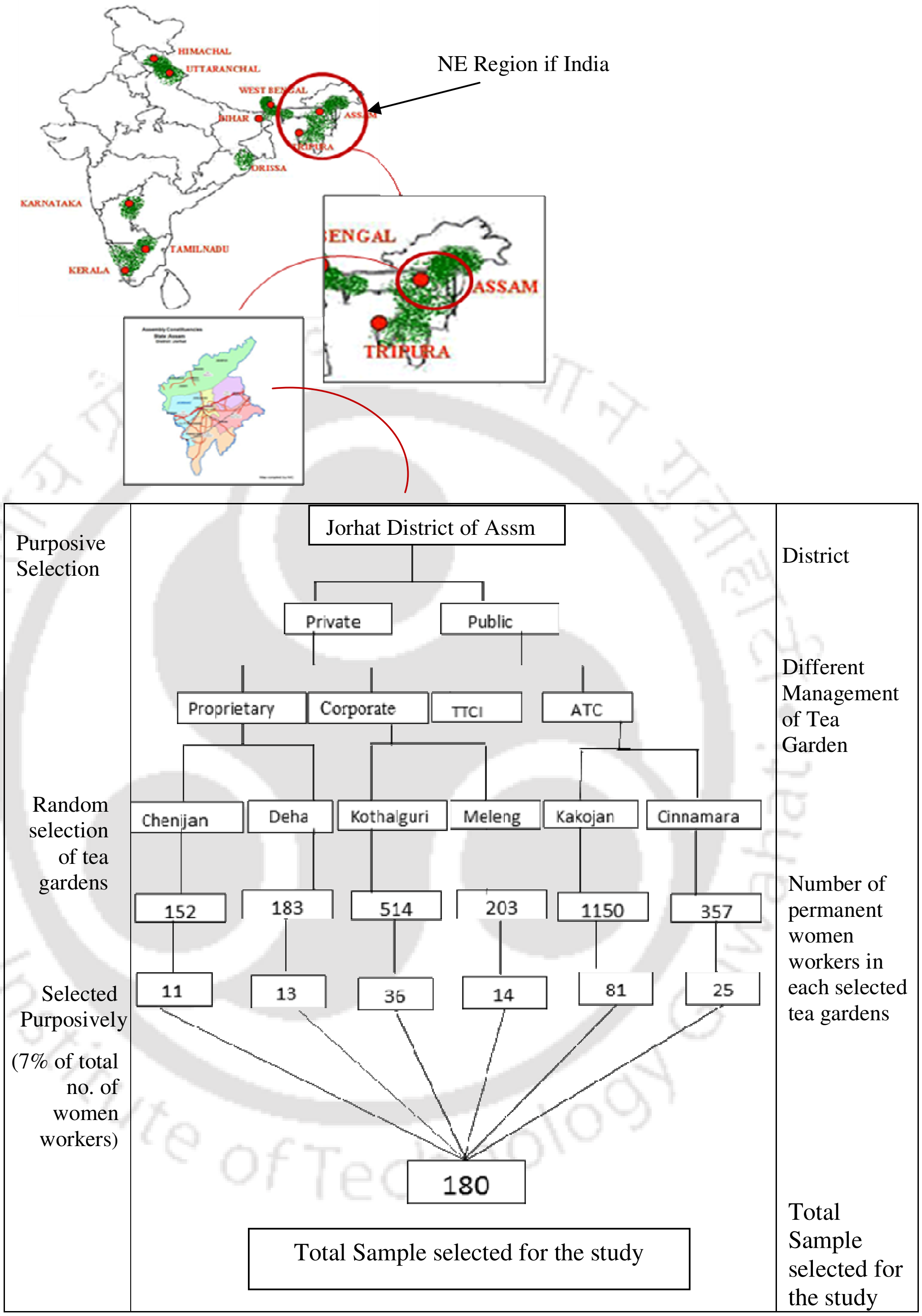


Fig. 12: The Sampling plan

To select the subject for the survey, lists of permanent women workers were collected from the selected six tea gardens authorities. Finally a total of 180 women workers entirely involved in plucking operation were selected purposively (7% of the total population from the selected tea gardens). The selected subjects for the present study were non-pregnant, non-lactating permanent women workers without having any physical ailment, deformity and chronic illness. Subjects were apparently looking healthy and fit for the job.

2.2.2.3 Selection of variables and their empirical measurement

The dependent and independent variables selected for the present study along with their empirical measurements are presented in table 1.

Independent variables:

- Age (Above 18 years)
- Years of experience (Number of years in the activity)
- BMI (The working capacity)
- Hours of work and rest period (Shift duration with break)

Dependent variables:

- Musculoskeletal disorders (body pains in terms of severity and frequency)
- Occupational stress (in terms of physical, organizational and psychosocial, familial)
- Rapid upper limb assessment score (upper limb exposure score)
- Quick Exposure check (body area exposure score)
- Strain Index (repetitiveness of the action, the hand and finger movement)
- Rating of perceived exertion (subjective rating of feeling of tiredness)

Table: 1- Variables and their empirical measurement

Variables	Empirical Measurements
Dependent variables	
I. Work related musculoskeletal disorders (body pains)	Occurrence of MSDs was studied with - Nordic Questionnaire -.Body map with two rating scales for severity and frequency of occurrence.
II. Postural analyses	OWAS and RULA work score sheets, QEC worksheet for body part exposure score were used.
III. Strain Index	Exposure index (OCRA), a model for assessment of exposure to occupational repetitive movements.
IV. RPE	Modified Subjective rating of feeling of tiredness scale was used (Varghese et al, 1994)
V. Occupational stress	A rating scale based on Job Content Questionnaire (JCQ: Karasek et al, 1998) and Copenhagen Psychological Questionnaire.
Independent variables	
I. Age	Chronological age of the respondents at the time of interview in complete years.
II. Years of involvement	Number of years over which the workers have been engaged at the time of interviews.
III. Hours of work and Rest period	Number of hours per day spent actually in performance of plucking operation and duration of rest taken during the day.
VI. Body Mass Index	Body Mass Index (BMI) was determined on the basis of body weight and height measurement using the formula, $BMI = \frac{Weight(kg)}{Height^2 (m)}$ (Deurenberg, et al, 1991)

2.2.3 Ergonomic risks factors and occupational load analyses

2.2.3.1. Ergonomic risk factors

Ergonomic risk factors prevailed among women workers (tea-leaf pluckers) that associate productivity and relevant health issues were quantified using four techniques: a) Ovako Working Analysis System (OWAS).b) Rapid Upper Limb Assessment (RULA), c). Quick Exposure Check (QEC), and d)Occupational Repetitive Assessment (OCRA),

a) Ovako Working Analysis System (OWAS)

OWAS is a chart-based posture evaluation system, developed in Finland and one of the earliest whole posture coding systems for industrial use. OWAS is used for postural recording

The OWAS method (Karhu *et al,* 1977) has been employed to identify and evaluate harmful postures (Kharhu et al, 1981; Kant, Notermans and Borm, 1990; Mattila et al 1999). The OWAS code for a posture comprises a record of the posture itself in the first three figures (Fig. 19), the load of force used is indicated by the fourth figure and a record of the stage in the cycle or task is recorded in the fifth figure. This method utilizes combinations of four digits (the OWAS code) to describe body posture i.e. the OWAS code of 212301 (2 for back position, 1 for arms, 2 for legs and 3 for amount of necessary force).

The procedure is to glance at the work to take in the posture, force and work phase, then to look away and record it. Thus the work activities can be sampled, and from these samples estimates can be made of the proportions of time during which forces are exerted or postures held.

b) Rapid Upper Limb Assessment (RULA):

Rapid Upper Limb Assessment (RULA) is a survey method developed for use in ergonomic investigations of workplaces where work related upper limb disorders are reported. RULA is a screening tool that assesses biomechanical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs.

Posture score is obtained after recording the values representing the observed postures in the score sheet (Appendix I). This RULA score sheet was developed by McAtamney and Corlett (1993) to assess the exposure of people to postures, forces and muscle activities known to contribute to upper limb disorders (ULDs).

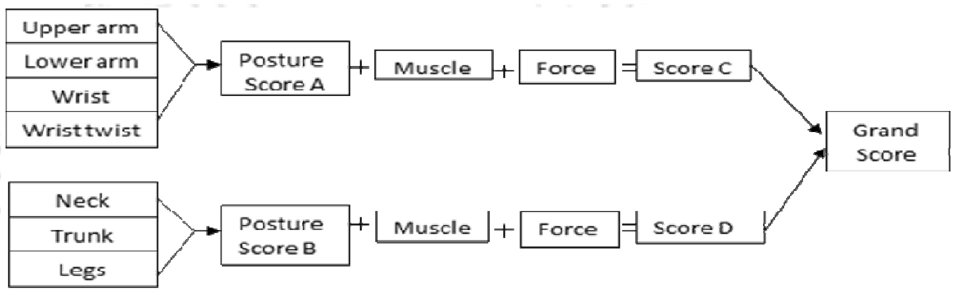


Fig 13: The RULA scoring sheet

Table 2: The RULA injury risk scores and respective action levels

Action level	RULA Grand score	Interpretation
1	1-2	The person is working in the best posture with no risk of injury from their work posture.
2	3-4	The person is working in a posture that could present risk of injury from their work posture, This score most likely is the result of one part of the body being in an awkward position, so this should be investigated and corrected.
3	5-6	The person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury.
4	7≤	The person is working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury.

To conduct the assessment by RULA system, the workers were videotaped during their routine job activities. Postures were analyzed from the tapes and pictures by following specific RULA score sheet (Appendix I) to get grand score for each case (Fig. 13). Consequently, the level of interventional action required (score and corresponding interpretation is presented in Table 2) to reduce the risk of musculoskeletal injury due to physical loading on the worker was determined.

c) Quick Exposure Check (QEC):

QEC, developed by Li and Buckle (1998), designed to assess the exposure to musculoskeletal risk factors of the back, shoulders and arms, hands and wrists, and neck, was used to analyze the tasks performed by the workers in selected occupational activities. It involves the practitioner (i.e. the observer) who conducts the assessment, and the worker who has direct experience of the task indicate change in exposure scores. The action levels derived from QEC % score is presented in table 3.

Table 3: The action levels from QEC

Action Level High	Intervention Recommended	QEC % Score
Acceptable Risk	Acceptable posture	<40%
Moderate Risk	Further investigation needed; changes may be required	40-49%
High risk	Investigation and changes needed soon	50-69%
Very high Risk	Investigation and changes needed immediately	70%≤

d) Occupational Repetitive Actions (OCRA):

OCRA is a concise exposure index model for the assessment of exposure to occupational repetitive movements of the upper limbs, conceptually based on the procedure recommended by the NIOSH for calculating the lifting Index in manual load handling activities. The OCRA model was presented and introduced by Entrio Occhipinti from Ergonomics of Postures and Movement (EPM) Research Unit in Milan, Italy, in1998 and then was completed and developed by D. Colombini from the same research unit (Najarkola, 2005). OCRA index is based on the relationship between the daily number of actions actually performed by the upper limbs in repetitive tasks (ATA), and the corresponding number of Reference Technical Actions in the shift (RTA).

In practice:

$$\text{OCRA Index} = \frac{\text{ATA (No. of Technical Actions Actually carried out in the shift)}}{\text{RTA (number of Reference Technical Actions in the shift)}}$$

Where,

ATA =F×D,

F is frequency

D is duration,

RTA=30× FoM×PoM×ReM×AdM×D (30 is constant)

FoM is force multiplier

PoM is posture multiplier

ReM is repetitiveness multiplier

AdM is additional multiplier

D is net duration

OCRA Index final score is determined, the risk level determined by OCRA and corresponding measures suggested is presented in Table 4 (Colombini, et al 2001)

The OCRA checklist describes a work-place and estimates the intrinsic risk, as if the work-place were used for the whole of the shift by one worker. This procedure makes it possible to find out which work-places in the company are at risk because of their intrinsic structural characteristics. The OCRA checklist supplies an early estimate of the intrinsic risk of each work-place, but not the exposure indexes for the operators, because that part of the assessment must be completed later. The analysis system suggested with the checklist begins with the establishment of pre-assigned scores (higher with the higher risk), for each of the 4 main risk factors (lack of recovery periods, frequency, force, awkward postures and movements), and for the additional factors. The sum total of the partial values obtained in this way (weighted for the net duration of the repetitive task in a shift) produces a figure (a score) which then enables the estimation of the actual risk level (Appendix K)

Table 4: Scores and area of the Risk in OCRA (OCRA Index and checklist final score)

Risk Area	OCRA Values	OCRA Checklist Values	Risk Level	Consequences
Green	UP TO 2.2	UP TO 7.5	VERY LOW RISK WRMSDs prediction is similar to the one for the reference group	No consequences
Yellow	2.3-3.5	7.6-11	LOW RISK Prediction of slight increase (up to three-fold) of CTDs	Advisable to set up health surveillance
Red	3.6-9	11.1-22.5	PRESENCE OF RISK The higher the index, the higher the risk	Re-design of tasks and workplaces according to priorities, health surveillance, training, information.
Violet	MORE than 9	MORE THAN 22.5	HIGH RISK Index values provide criteria for action priorities.	

(Najarkola, 2005)

2.2.3.2 Occupational work load

Occupational work load of tea leaf plucking operation was studied by measuring the following stress factors:

a) Rating of Perceived Exertion (RPE):

Subjective rating of feeling of tiredness was studied by using the Rating scale of Perceived Exertion (RPE), developed by Varghese et al (1994). The exertion perceived by the subject during and after the activity was recorded and was categorized as very heavy, heavy, moderately heavy, light and very light based on the scores from 5,4,3,2 and 1 respectively.

b) Physiological cost of work

Heart rate is an indicator of cardiac stress due to physical workload. Heart rate was recorded after every five minutes at work during the experiment period using polar heart rate monitor. From the average values of heart rate, energy expenditure was calculated with the help of formula given by Varghese *et al* (1996) as below:

$$\text{Energy expenditure } (Kj^{-min}) = 0.159 \text{ x AHR (beats per min.)} - 8.72$$

c) Occupational stress-Work related Musculoskeletal Disorders faced

Nordic Musculoskeletal Questionnaire (NMQ) and the body map (of pain feeling) along with rating scales (for severity and frequency of occurrence) were used to gather data on work related musculoskeletal disorders.

The SNQ was developed by a team of Nordic researchers organized to create a simple standardized questionnaire that could be used for the screening of musculoskeletal disorders as a part of ergonomic programs and for epidemiological studies of musculoskeletal disorders (Kuorinka et al 1987).

2.2.3 Statistical Analyses

Statistical analyses of the data were decided according to the objectives of the present study. The frequencies, percentages, mean and standard deviations were calculated to answer the various questions relevant to the objectives of the study.

To find out the association of the independent variables i.e., demographic factors, familial factors, psychological factors, physical factors, work-related factors with the dependent variables i.e., work related musculoskeletal disorders; analysis of variance (ANOVA) was used.

2.3 Results and Discussions

2.3.1 Plucking Activity- women workers specific

Plucking tea leaves is crop harvesting. Removal of young and growing shoots comprising the apical bud and the two internodes immediately below it from the tea plant stem, which constitute the crop in tea, is called plucking. Tea leaves are plucked from tea bushes at regular intervals with two spells a year during early spring and early summer or late spring. Tea plucking in Assam is still carried out in the traditional manner: the tea leaves are hand plucked and gathered into wide baskets carried on the backs of the tea leaf pluckers. The hand plucking (Fig.14) ensures that only the best leaves of the tea plant are collected and used for producing the tea. Selective plucking of "two leaves and a bud" is done by hand when a higher quality tea is needed or where labour costs are not prohibitive. Hand-plucking is done by pulling the flush with a snap of the wrist and does not involve twisting or pinching the flush, since doing the latter reduces the quality of the leaves that also seen to be practiced to have bulk plucking.

a) Tearing the tender shoots by bending with thumb and index/midle finger

b) Plucking by garsping the shoots followed by matching motion

c) Tearing by bending the shoot, holding from top

Fig. 14: Plucking of tea leaves

Tea buds and leaves can also be harvested by using mechanisation (though there will be more broken leaves and partial buds). It is considered that the mechanised method damages the tea leaves and as a result the tea leaves bear a lower grading (Wissotsky, copyright 2007, © created by YKM). It is also more difficult to harvest by machine on mountain slopes where tea is often grown (Fig.15). Though there are shade trees required for tea bushes in tea gardens (Fig. 16) the whole ambience is very humid that puts additional environmental load on the workers.

Fig.15: Tea bushes on mountain slopes

Fig.16: Shade trees grown in tea fields

Production of tea depends upon accurate plucking. For best quality tea, fine plucking is required, which consists of only two leaves and a bud (Fig.14a). It is an artistic job and in tea parlance, this activity is overwhelmingly labour-intensive, relies completely on manual labour. Tea estates labours mostly female workers who pluck tea leaves from tea bushes are called pluckers (Sharma, 2006).

Plucking requires patience and dexterity. Though men folks are employed in certain cases, as women are commonly known to good at repetitive and patience requiring tasks, the plucking task is carried out by women workers mostly. Women workers fit to the task better than men, because the male workers, who are engaged in plucking during busy season, handle roughly the tea plants and thus harm the plants physically. The tenderness fits; it is said that women workers whose tender hands give less trouble to the plants while twisting 'two leaves and a bud' from the bushes. There is a fall in the quality and quantity of leaves plucked by men. The quality of tea is the summation of the desirable attributes comprising internal essence and external appearance i.e., aroma, flavor, strength, colour and briskness.

Tea-leaf plucking is a strenuous work, as the plucker has to carry a basket into the garden in which she would collect the plucked leaves. When the basket gets full and heavy, the workers come to a specific location for unload; leaves are weighed and collected from individual workers together and taken to the factory for processing. Women have to pluck the tea bushes in steep terrain, and find their way through rows of tea bushes. Moreover tea-leaf plucking is a single task job, involves repetitive movements of whole arm along with an awkward posture. While performing the activity, workers stand in a forward bending position (near neck and back regions) with load at back with a strap to support hanging and arms outstretched forward and sideways to pluck young tea leaves (Fig.17).

Fig. 17: Women workers in plucking operation

The workers lean forward to reach the periphery of tea table (the top horizontal surface of tea bush) to pluck the ready leaves and are forced to adopt the same posture for a complete cycle (till filling both the hands with plucked leaves before throwing in the basket, carried on the back). The mean angle of deviation from neutral posture at lumber sacral region while plucking was found 4.2°. Moreover workers need to move in between the tea bushes with a load at the back and cover a reasonable tea plantation field. These risk factors led to assess the scope for design development strategy suitable for plucking operation.

2.3.2 Productivity improvement and labor relations

Increased productivity is obtaining more output against the same input. In the tea industry, which is overwhelmingly in the private sector, the primary profit orientation is interwoven with the objective of productivity. Significantly, the two major inputs in the tea industry- land and labour- are neither as abundant nor as cheap as they were when the tea plantations were established more than 100 years ago by the European settlers.

The factors currently affecting productivity in tea estates are basically, threefold:

- Uncontrollable, such as weather, temperature, altitude, variety of tea, type of planting, and age of bush;
- Controllable, varying with management practice;
- Related to worker productivity: encompassing not only wages and incentives but, also aspects such as motivation, individual talent, experience, absenteeism, health, training, pregnancies, nutritional status, and most importantly availability of appropriate work accessories to perform the activity with comfort.

Several yardsticks are available by which to judge the production efficiency of the tea industry and its effect on reducing costs. The most important is tea leaf collection from the garden, which represents the quantity of green leaf harvested per workday, the objective being to increase that quantity without detriment to quality.

2.3.3 Organizational characteristics of selected tea industries of Assam

The garden specific characteristics of work organisation followed are often acts sources of occupational stress and long-term health consequences. At the organisational level, the policies and procedures of an industry affect work related health through the design of jobs, the length of exposure to stressors, establishing work-rest cycles, defining the extent of work pressures and establishing the psychological climate regarding socialisation, career and job security etc. In addition, the organization defines the nature of the task activities (work methods), employee training, and availability of assistance and supervisory relations.

In Assam, tea estates fall under proprietary, corporate, Tea Trading Company of India (TTCI) and Assam Tea Corporation (ATC), belonging to different management of public and private sectors (Fig. 12). Workers in tea estates are paid a fixed daily wage plus a cost-of-living allowance (revised every quarter of a year, based on published index numbers). As normal practices tea leaf pluckers have to harvest a minimum quantity i.e., 23kg of green leaf per day. For any excess quantity harvested above the norm, they are paid an additional plucking incentive. This is constant amount per kilogram of leaf but, in due course, the system was refined by having two incentive slabs. This led workers to put efforts to gain additional benefits they earn and results additional physical discomfort also. In almost all the tea gardens studied subject reported to have medical facilities and casual leave facilities.

2.3.3.1 Hours of work and rest period

Shift duration in all the tea gardens, selected under different management was found similar. One hour lunch break and a total of 10 minutes (5 min. before lunch shift and 5 min. after lunch shift) break for drinking water etc. is given as rest period during the shift whole day. A schematic diagram of work and rest followed in tea garden is presented in figure18. Total time of shift (excluding breaks) is found to be ranging between 400 min. to 440 min. per day.

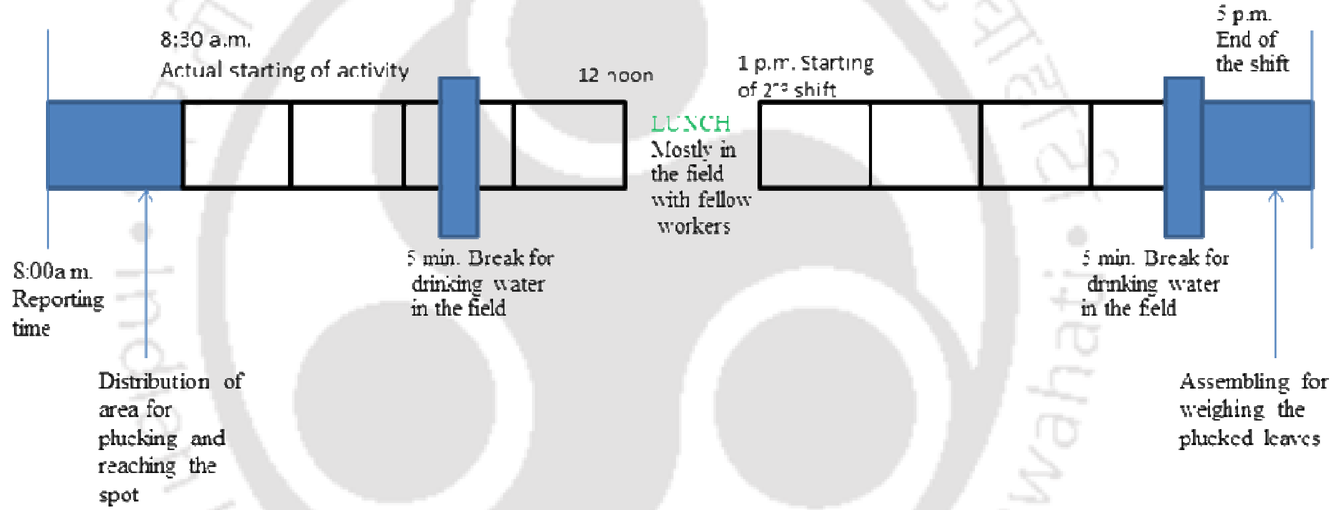


Fig.18: Shift duration and breaks followed in tea gardens

2.3.4. Extent of mechanisation: machines Vs. hand tools for tea-leaf harvesting

Use of machines, either wholly or in part, is to replace human or animal labour. Unlike automation, which may not depend at all on a human operator, mechanisation requires human participation to provide information or instruction, human keeps final control of operation. Mechanisation, where possible, is necessary not just to reduce the costs in the context of increasing wage bill; it also lightens the burden on the worker and makes the work more comfortable and interesting. Many attempts have been tried out, (Fig.19) but not found welcome in Assam tea garden managements.

Hand plucking of tea leaf is a highly skilled operation and is traditionally the work of a woman. They have acquired this skill of selecting the 'two leaves and a bud' over the years. The opinion survey expressed that no machine can match their uniquely nimble fingers which break the tender leaves and transfer them in handfuls in the baskets they carry on their backs. In addition to this motorised and manual shears devices damage the tea plants as the present design concern and to operate in the way these are perceived to work, women force at this region do not fit in terms of physical efforts required and skills to acquire specifically.

During peak plucking season, which coincides with the cultivation of other *kharif* crops, absenteeism of plucker is a recurring problem of the industry. As a result, maintenance of proper plucking round is difficult. To tide over the situation, use of mechanical aids for plucking gained importance. But in practice it was observed that in all the studied tea gardens, mechanical and shears plucking was not seen being used. Though it was tried, but with mechanisation there are chances of immature tea shoots along with over matured tea leaves are being plucked as compared to hand plucking (as reported) thus quality suffered.

(a) Plucking shear (b) Motorized mechanical harvester (with reciprocating blades) (c) Motorized mechanical harvester (with rotary blades)

Fig.19: Plucking shear and machines, tried in studied tea gardens

It was found from the managements of the studied tea gardens that though motorised mechanical harvester crop evenly the tea table but there are chances of over matured leaves and immature buds are being harvested. The findings of the present study were also supported by Nyasulu (2010) that the proportion of immature shoots along with over matured tea leaves was lowest with hand plucking and highest in case of mechanical harvesting. It is considered that the mechanised method damages the tea leaves and as a result the tea leaves bear a lower grading in the international tea market (Wissotsky copyright, 2007). Due to its high content of fiber in over matured leaves and immature shoots, mechanical plucking deteriorates the quality of tea produces.

An attempt was made to design a shearing device suitable to operate by Indian women tea pluckers (Fig. 19 a) at National Institute of Design, Ahmedabad under a project sponsored by Parry Agro Industries aiming for Indian context (Chakrabarti, 1996). Because of requirement of selective plucking the device was not preferred in Assam.

The available mechanical plucking devices in the market which were being tried by few of the studied tea gardens (20 percent) revealed that the available machines (Fig 19 a, b and c)) were found not suitable for Assam condition. Due to the planting type, movement between the tea bushes with the machine is not easy. Traffic lane between the bushes is essentially required as two or four numbers (depending on the type of machines) of workers need to hold the machine and move while doing machine harvesting. Shade tree, which is the requisite for tea plantation in Assam climate, provides hindrance to movement with the harvester (Fig.16). To cope with the labour-shortage during peak plucking season, use of hand-operated share shears (Fig 19a) for harvesting tea was found practiced earlier (found not in use during present study time) in many of the tea gardens in Assam.

The findings revealed that the available machines harvesters and shears cannot select the ready shoots to be plucked for quality production and they cut the matured leaves and stems projecting over the plucking table. Moreover in shear and machine harvesting, coarse component of harvest is more and the same need to be sorted out from the basket. It was also reported that the percentage of damaged shoots are more while using machine and shear, as compared to hand plucking.

Therefore because of the problem of non-selective harvesting with machine and shears and possible drop in quality, it was not favoured though net weight of plucked leaves with machine and shear harvesting was found more (Sharma, 2006). In case of using the shears, workers were found to have the tendency to keep the shear on the tea bush surface itself (due its weight) and reported to cause damage to the tea table. It was also opined by the workers that they find it difficult to throw the shear harvested leaves (which are collected in the shearing device) to the basket carried by them on their back. Moreover the workers are habituated in hand plucking. For this, the present practice of hand plucking was chosen as the study focus so that an appropriate plucking aid suitable for the current practice may be conceptualised.

2.3.5 Physical and demographic characteristics of the selected women workers engaged in tea plucking operation stature

Demographically, tea garden labour community of Assam represents around 20 per cent of the total population of the state accounting more than 45 lakhs tea garden labour population. About 17 per cent of workers in Assam are engaged in tea industry and around 50 per cent of the total tea plantation workforce in Assam is women (Assam tea labour problem, (www.vedanti.com/).

A group of tea-leaf pluckers from six tea gardens of Jorhat district of Assam were selected to form the study subject population to have a close look into occupational details.

Table 5: Physical characteristics of the respondents

N=180

Parameters	Mean	± S.D.
Age (Years)	35.44 (17-55)	11.61
Weight (Kg)	46.61	4.30
Height (cm)	159.76	2.8
BMI (score)	17.76	2.01

The mean age for the studied women tea-leaf pluckers was 35.44 years, ranging from 17 years to 55 years, having 46.61 kg body weight and 159.76cm height. The highest mean body weight of the respondents belonged to the age group of 16 to 25 years and lowest belonged to the age group of above 55 years (Table 5).

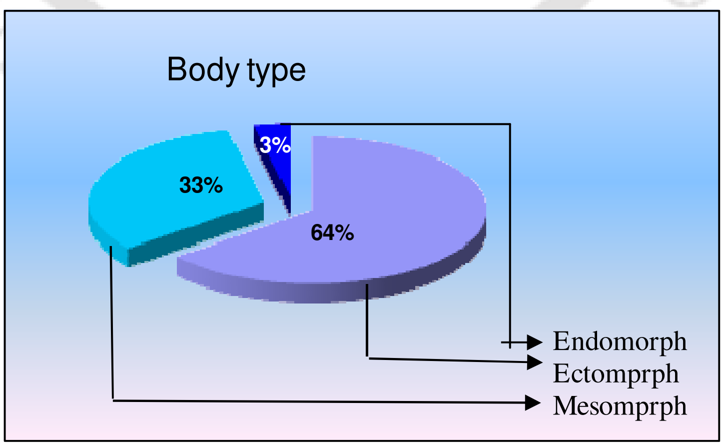


Fig.20: Body type of the respondents (n=180), as per Deurenberg, 1991

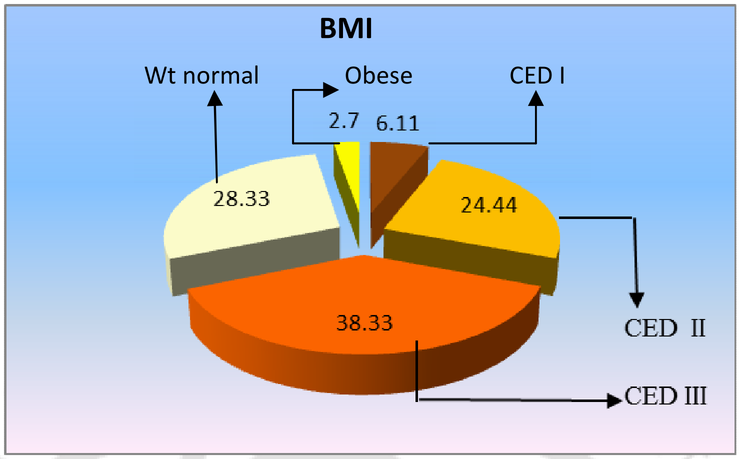


Fig. 21: Body Mass Index (BMI) of the respondents

Somatotyping was calculated from skin folds measurements of the subjects, Deurenberg, 1991. Majority (64 percent) of the workers belonged to ectomorph type, 33 percent represent mesomorph type and 3 percent represent endomorph type (Fig. 20)

The Body Mass Index (BMI) or Quetlet's Index was calculated to study the physical fitness of the respondents. It is an important indicator of energy adequacy, which influences the person's capacity to do work. From the data (Fig.21) it was observed that BMI of only 28 percent of the respondents were found normal, belonging to the age groups of 16 to 25 and 26 to 35 years. Nearly three percent belonged to obese (grade I) category of BMI and remaining 69 percent belonged to the categories of Chronic Energy Deficient (CED) grade I, II, and III (Appendix-C).

As regards to the years of experience of the studied workers it was observed that about 33 percent of subjects had experience of working in tea leaf plucking activity for 10-15 years which was followed by 18 percent each for both 5-10 years and 15-20 years. Nearly 95 percent workers were illiterate. Only 5 percent of the subjects studied up to primary school. Majority of the subjects (75%) had medium sized family (having 4-6 numbers of family members). About 73 percent subjects were married, 22 percent either widow or divorcee and only 5 percent unmarried. Detailed demographic observations are presented in table 6.

Table 6: Demographic observations of women workers engaged in Tea-leaf plucking activity

Sl. No.	Demographic factors	Frequency (n=180)	Percentage
1.	Age (years)		
	Below25	30	16.66
	26-35	61	33.88
	36-45	38	21.11
	46-55	39	21.66
	Above 55	12	6.66
2.	Marital status		
	Married	132	73.33
	Unmarried	9	5
	Widow /divorcee	39	21.66
3.	Education		
	Illiterate	170	94.44
	Primary school	10	5.56
4.	Size of family		
	Small (1-3)	24	13.33
	Medium (4-6)	134	74.66
	Large (Above 7)	22	12
5.	Work experience (years)		
	Below 5	24	13.33
	5-10	32	18
	10-15	59	32.66
	15-20	34	18.66
	Above 20	31	17.33

2.3.6 Occupational Stress: assessment of multi factorial risk factors in tea leaf plucking

Occupational stress is multi-factorial. The assessment of occupational stress is a process in which risk factors of the workplace are identified, assessed and controlled/eliminated as close to source (location of the hazard) as reasonable and possible. It is essential to correctly diagnose the characteristics of the work and employment conditions that are perceived as risks by employees and to investigate the consequences of these risks. As technology, resources, social expectation or regulatory requirements change, stress assessment focuses controls more closely toward the source of the stress.

Modern occupational safety and health legislation usually demands that a risk assessment be carried out prior to making an intervention. It should be kept in mind that risk management requires risk to be managed to a level which is as low as is reasonably practical.

This assessment should:

- Identify the risk factors
- Identify all affected by the risk factors and how
- Evaluate the risk
- Identify and prioritize appropriate control measures

The calculation of risk is based on the likelihood or probability of the harm being realized and the severity of the consequences. This can be expressed mathematically as a quantitative assessment by assigning low, medium and high likelihood and severity with integers and multiplying them to obtain a risk factor, or qualitatively as a description of the circumstances by which the harm could arise.

Tea companies face new challenges due to increasing international competition, e.g. higher productivity, higher quality and new product.

Ergonomics considerations in the design of work methods, workplaces and work tools may support productivity increment and quality and also promote the health of the employees by controlling stressors. In the present study occupational stress was studied in terms of physical (work related) stress, organizational and psychosocial stress, and familial stress by quantifying the individual responses to the stress related factors.

2.3.6.1 Physical stress (work related) - prevalent ergonomic risk factors

Epidemiologic observations have provided strong evidence of an association between works related musculoskeletal disorders and work related physical factors when there is long exposure in combinations with physical factors such as repetitiveness, force exertion level, adoption of awkward posture etc.

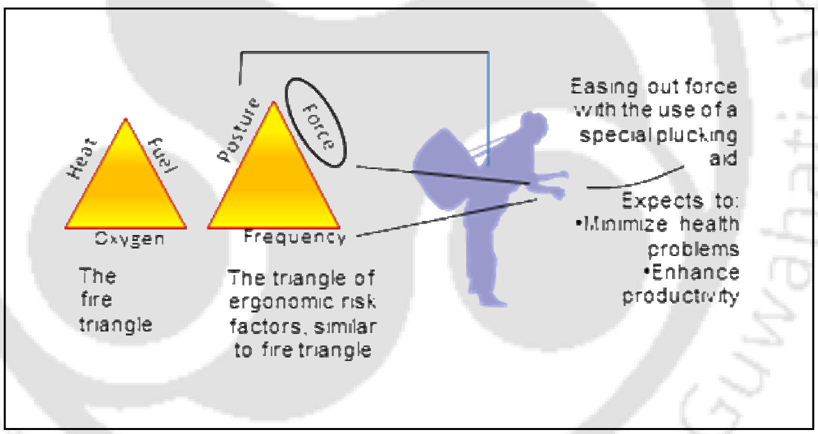


Fig.22: Ergonomics risk factors in occupational settings of tea leaf plucking (Chakrabarti, 2006)

A good understanding of ergonomics provides the basis for a sound analysis of the current situations. With the current awareness of the ergonomics of work conditions to industrial injuries, it is seen as increasingly important to identify such contributions and work to reduce their impact (Haslegrave and Corlett, 1995)

In the present study efforts were made to identify the ergonomics risk factors in tea leaf plucking activity. It was observed that the workers perform the activity in standing posture with slight bending near neck and low back (Fig.17 & 22). The arms were found outstretched to reach the selected shoots and finger moves repetitively to tear them. The workers carry the plucking baskets on their back, hanging mostly from head (with a strap) to keep the plucked leaves. From the observed posture it can be said that ergonomic risk factors such as the awkward posture, force with twisted movements at wrist and fingers used to pluck the leaves. The workers perform the activity in the entire shift with highly repetitive movement.

According to Wiker et al (1990) that sustained work with awkward and biomechanically stressful postures increased the risk of encountering work related musculoskeletal disorders. Awkward postures affect the shoulder and upper limbs in general and lead to body pains in the long run.

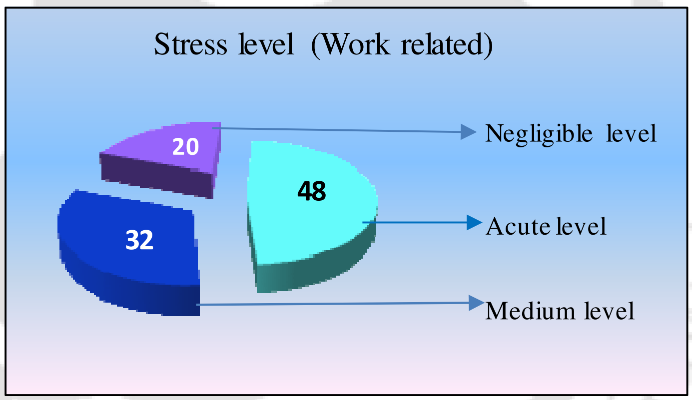


Fig. 23: Work related occupational stress, response in percentage

The above mentioned occupational stress relevant ergonomic risk factors was seen prevailing among the tea leaf pluckers. This indicates that the plucking operation and working conditions were conducive for developing musculoskeletal disorders that mostly resulted in pain feeling.

Analyses of data (Fig.23) revealed that 80 percent of the respondents had work related stress which ranged from acute level (48 percent) to medium level of stress (32 percent). Only 20 percent had negligible level of work related stress. To prioritize the work related risk factors in plucking activity, ranking was done based on calculated weighted scores and mean scores. It was found that the risk factors responsible for creating work related stress among the workers were awkward posture (rank I), repetitiveness and frequency of the activity (rank II). Forceful action while plucking and shift duration of around 440 min. (rank III) were also found as contributing factors for causing occupational (work related) stress. (Appendix F)

Fig. 24: Risk factors in tea plucking activity

Force to pluck tea leaves

Repetitiveness- Actual Technical Action for the entire shift is 40,813 (78 numbers of frequency^{-min} for 375 min. duration)

Awkward posture- Standing with a low back bending

Basket adds load on neck and back, and to counter balance body takes forward bend for the full shift period.

2.3.6.2 Organizational and psychosocial stress, risk factors prevalent

Health is not merely the absence of disease or infirmity but a positive state of complete physical, mental and social well-being (WHO, 1986). A healthy working environment is one in which there is not only an absence of harmful conditions but an abundance of health-promoting ones. A healthy work environment is likely to be one where the pressures on employees are appropriate in relation to their abilities and resources, to the amount of control they have over their work, and to the support they receive from people who matter to them.

In tea industry of Assam the plucking activity is seasonal activity and in pick seasons the women workers perform the plucking task of around 440 min. in the entire shift; they need to meet a certain demand set by the management. Therefore they have work pressure. Workers are overloaded during the pick season. They are forced to perform the operation either in hot sun shines with humid climate or in heavy rains. Apart from this they have job insecurity also.

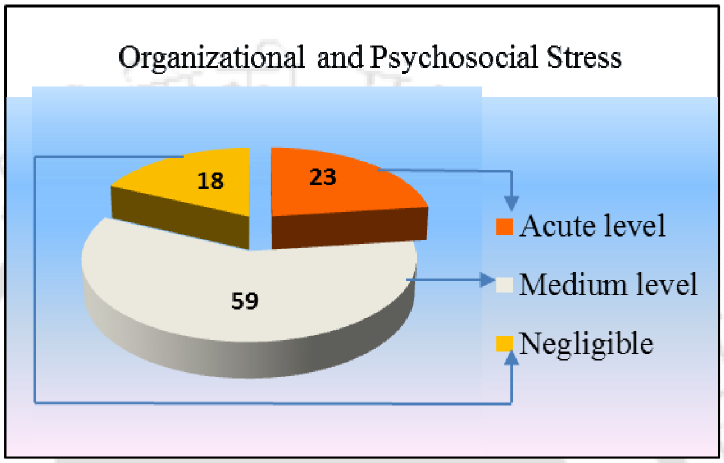


Fig.25: Organizational and psychosocial stress, , (n=180)

Analyses of data on organizational and psychosocial stress (Fig.25) revealed that 59 percent of workers had medium level of organizational and psychosocial stress. Twenty three percent were found to have acute level of stress. As regards to risk factors of organizational and psychosocial stress, job/task design (rank I), overload (rank II) and job insecurity (rank II) were mostly felt stressors among the workers. Lack of modern technology benefits availability and poor social environment were also found to have impact on organizational and psychosocial stress. (Appendix G)

2.3.6.3 Familial stress and risk factors

Stress occurs in a wide range of familial circumstances but is often made worse when the person feels she/he has little support from family members,

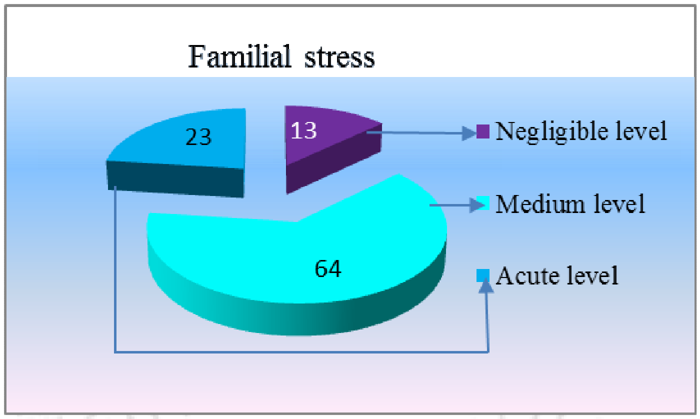


Fig.26: Familial stress, response in percentage, n=180

as well as little control over the situation. Among the workers familial stress was seen very common. Twenty three percent having the acute level of familial stress which was followed by 64 percent respondents had medium level of familial stress, response obtained from the subjects is presented in figure 26. The stressors found were: family financial conditions (rank I), alcohol consumption habit of both the spouses (rank II), and conflict with family members (rank III); details of observations are presented in appendix H.

In most of the cases the family environment creates the stress. Some are poverty driven and some are habitual in tune to the intra social mechanism. Apart from these the problems at home of workers studied were found that they do not get necessary support from their family and other household members. Yet many have no choice as they have to supplement to family earnings.

Most workers studied were found to face a dichotomy in their lives as they grapple with the traditional role expectations at home. Demands are there to do all the household activities also by the female members and this acts as additional load on them along with demands imposed on them by their jobs at the workplace".

From analyses of data, it can be concluded that out of all stressors (work-related, organizational and psychosocial and familial stressors) repetitiveness and awkward posture were the mostly felt stressors by the workers. Figure 27 represents the summary responses when the workers were asked to opine on the specific factors in order to find out where the development can be looked into as priority to perform job better. If the workers can do their jobs in a better productivity and comfort, they can contribute to the other family demands without any carryover fatigue.

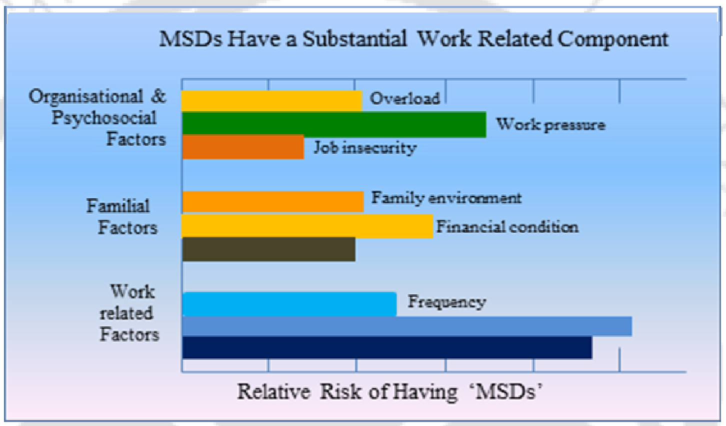


Fig. 27: Stressor components imposing uneasiness on tea-leaf pluckers as general response, n=180

2.3.7 Assessment of ergonomic risk factors and occupational loads

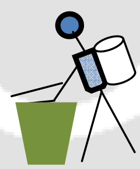
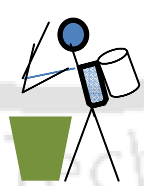
2.3.7.1 Ergonomic risk factors

For an organization to prevent occupational stress problems, it is necessary to assess the ergonomic risk factors and occupational loads. In the present study ergonomic risks factors were studied in terms of OWAS RULA and QEC scores and strain index (OCRA index).

a) Ovako Working Analysis System (OWAS)

The OWAS method (Karhu et al 1977) orders the frequency and relative proportion of time each specific posture lasts, and evaluates through a scale of 4 action categories, as shown in Table 7.

Table 7: The OWAS Code

Posture No.	Figures	OWAS code	Action categories	Remarks
1.Reaching for the leaves: Standing with a bend at lower back, arms outstretched to reach the shoots, load (storage basket) at back, hanging from head		212301	3	The working methods involved should be intervened as soon as possible
2. Plucking and holding the leaves in the palm: Standing with a bend at lower (sometimes upper back also) back, arms outstretched to reach leaves and load (storage basket) at back, hanging from head, arms and finger moves rapidly		212302	3	The working methods involved should be intervened as soon as possible
3.Throwing the handful of plucked leaves over shoulder in the basket		112303	1	No immediate actions are needed to change work postures

The scores found for all three sub tasks (posture no.1, 2, and 3) in plucking operation are presented in the table 7. From the data it was observed that while plucking shoots and reaching for the next shoots, the workers performed the task with bending position at lower back and keep the body posture relatively in static position i.e., longer contraction of back muscle to maintain the postures. The scores suggest that the load of the posture is distinctly harmful: actions to ease the posture should be taken as soon as possible.

b) Rapid Upper Limb Assessment (RULA) analysis

In order to assess physical exposure to work-related musculoskeletal risks, rapid upper limb assessment (RULA) technique, which is known as pen-paper observational method (McAtamney and Corlett, 1993), was applied. The scores were calculated for the posture of each body part by following RULA score sheet (Appendix I).

In plucking operation the RULA score observed for both the arms was 7, indicating very high risk level (Table 3) which states that the plucking operation; requires urgent investigation and need necessary action immediately towards minimising the risks (Table 8).

Table 8: RULA analyses Result

RULA Index		RULA Index Score	**1 or 2**	**3 or 4**	**5 or 6**	**Above 7**
Right Arm	Left Arm					
7	7	Risk Level	Acceptable	Investigate further	Investigate further and change soon	Investigate and change immediately

c) Quick Exposure Check (QEC)

Assessing exposure to risk factors associated with work related body pains, and subsequently to conduct ergonomic interventions in the workplace, exposure assessment has concentrated on the back, shoulders, upper limbs and neck, because most of the reported work-related injuries are in these body regions. The QEC has been designed for use by Occupational Safety and Health (OSH) practitioners to assess exposure to risk factors for work related musculoskeletal disorders and to provide a basis for ergonomic intervention at the workplace (Li and Buckle, 1998).

The analyses of plucking operation using QEC gives exposure scores to specific body parts including the back, shoulder/arm, wrist/hand, and neck. The total QEC score for plucking operation found was 110 out of 138. The maximum QEC scores (Fig.28) found was for neck i.e., 88.88, because the workers perform the activity with the stiff neck in forward bending posture with dual load in neck muscles to look at the tea table to pluck the shoots along with supporting a heavy basket (weighing up to 30 kg) hung from the head on the back to keep the plucked leaves (Fig.24).

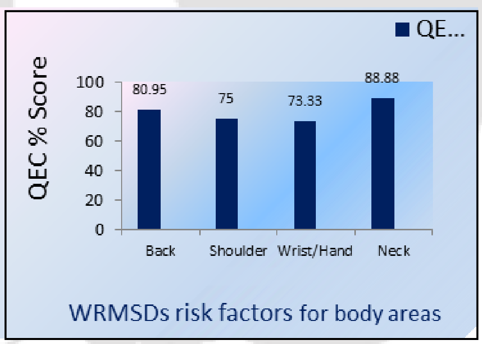


Fig.28: QEC scores of plucking operation

Fig 29.: The plucking operation

The QEC scores for back was also found high (88.23) because of when performing the activity, the back is flexed continuously with the basket on it. In case of shoulder and wrist/hand the QEC scores were more than 70 percent i.e., 75 percent and 73.33 percent respectively.

This may be due to the fact that while performing the activity the workers are forced to outstretch the arms to reach the periphery of distant tea bushes and the wrists are either in supination or in pronation action. Several studies reported that for tasks other than manual handling, static postural loading has been shown to be a risk factor for low back pain (LBP), especially when combined with long work duration (Westgaard and Aarås, 1984;).

In plucking it was observed that the QEC score was the highest and was found 36 out of 42 (Appendix L). From the data it can be said that there is a strong evidence to indicate that awkward wrist/hand posture is a risk factor for the development of wrist pains among the pluckers, especially in combination with other factors such as force, repetition and duration. Total exposure score for wrist/hand was found 34 out of maximum wrist/hand score 46 (73.33 percent). The prevalence of wrist problems increases because the plucking task is performed with the wrist deviated/flexed/extended from neutral. Steps appropriate to reduce the situational risks needs to be taken that can go along with the workers skills acquired so far as opined in common.

d) Strain Index

Repetitiveness is probably the most important risk condition for developing work related health problems (body pains). In many workplaces, the time to complete a specific unit or cycle of work is less than a few minutes. If the cycle is repeated continuously for 2 or more hours, the work is considered repetitive (Najarkola, 2005). Although the energy demands are usually low, the repetitive use of small muscle groups may cause quick muscle fatigue, and the repeated application of tension in the muscle tendon group and the repeated motion around a joint may cause soreness and inflammation.

The repetitive work causes pain and fatigue, which may lead to musculoskeletal disorders, reduced productivity, and deteriorated posture and movement co-ordination. Characterisation of repetitiveness can be used as an important factor to distinguish various sub-components of tasks performed which should be evaluated. Characterisation implies as for example that any repetitive task for the upper limbs should be analised if it requires carrying out consecutively, for at least 1-2 hour/day, which are carried out via actions of the upper limbs. Once established which tasks are actually repetitive and should be submitted to an analysis, the most important problem is the quantification/assessment of repetitiveness. In plucking of tea leaves the women workers are involved in the repetitive task of plucking and throwing the plucked leaves into the storage basket carried on back for entire shift that is for 440 minutes (with one hour lunch break, fig.18).

Force more directly represents the biomechanical involvement necessary to carry out a given action. Force may be intended as being external, applied force, or internal, tension developed in the muscle, tendon and joint tissues. The need to develop force during work-related actions may be related to the moving or the keeping still of tools and objects, or to keep a part of the body in a given position. The use of force may be related to static actions (contractions), or to dynamic actions (contractions).

While plucking, force applied is both static as well as dynamic with torque in wrist. In the literature, the need for using force repetitively is considered as a risk factor for development of musculoskeletal disorders which quite often felt as chronic pain at elbow and wrist. Furthermore, in plucking operation a multiplicative interaction was observed between force and action, frequency and duration. Upper limb postures and movements, during repetitive tasks, are of fundamental importance in contributing towards the risk. Much agreement can be found in the technical literature as to the potential damage from awkward postures and movements of each joint, from postures maintained for a long time, and from specific, repetitive movements of the various segments (van-wely, 1970; Putz-Anderson, 1993 Carayon and Lim, 1999). The analyses of posture and movements enabled to find out the risk factors in tea leaf plucking operation so that remedial measures can be thought for. To find out the strain index of repetitiveness of plucking operation OCRA index was used.

The OCRA Index

The Occupational Repetitiveness Assessment (OCRA) method was used for analyzing workers' exposure to tasks featuring various upper limb risk issues. The Concise Exposure Index (OCRA) quantified the relationship between the daily number of actions actually performed by the upper limbs in repetitive tasks, and the corresponding number of recommended actions and also evaluated the main collective risk factors. These include frequency of action, adoption of awkward postures and movements of the upper limbs to execute the task, excessive use of force, 'stereotypy' operation or lack of postural variations, inadequate recovery periods based on their respective duration. Other additional factors considered were mechanical, environmental, and organizational factors, which provided evidence of causal relationship with upper limb work related musculoskeletal disorders. Each identified risk factor was properly described and classified to help in identifying the possible requirements and preliminary preventive actions. All factors contributing to the overall exposure were considered in a general and mutually integrated framework by a synthetic index, the OCRA index, (Najarkola, 2005) in the tea-leaf plucking task in this study.

In the OCRA method, the technical action was identified as the specific variable characteristic relevant to repetitive movements of the upper limbs. The technical action was factored by its relative frequency during a certain period of time. The 'frequency of upper limbs technical action' is related to other risk factors, such as force (the higher the force, the lower the frequency), posture (the higher the joint excursion, the longer the time necessary to carry out an action), task duration and recovery periods. The concept of technical action (defined as any elementary manual action required to complete the operations within the work cycle, such as holding, turning, pushing and, cutting) is similar to (even if not identical with) one of the 'elements' considered in traditional task analysis methods (Colombini et al, 2001).

Thus, the technical actions were calculated required to complete a work cycle, in the case of tea-leaf plucking task duration of cycle considered from plucking empty handed to handful to unload into the basket. This method was applied to quantify risks of work related musculoskeletal disorders. The OCRA method proposes two risk analysis tools: OCRA index and OCRA checklist.

For plucking activity the OCRA index score was found 11.8 for right arm and 9.4 for left arm (Table 7), indicates high risk involvement (Colombini et al, 2001). Actual Technical Action for the entire shift was found 40,813 (78 numbers of frequency^{-min} for 375 minutes duration) for right hand and 32, 442 (62 numbers of frequency^{-min} for 375 minutes duration) for left hand.

Table 9: Results of the analysis of OCRA Index and OCRA check list

Task	OCRA index		OCRA checklist values		Risk Level/Risk Area	
Plucking operation	Right Arm	Left Arm	Right Arm	Left Arm	Right Arm	Left Arm
	11.83	9.4	29.5	24.5	High	High

(Najarkola, 2005)

In case of OCRA checklist (Appendix L) values for right arm and left arm, it was found 29.5 and 24.5 respectively (Table 9). The strain indices, both OCRA index and OCRA checklist values indicate high risk involvement in the plucking activity and immediate attention is required to improve the work situation comprising both the work method and work tools.

2.3.7.2 Occupation load of tea leaf plucking operation

Physical activity adds to the expenditure of energy which can be measured in different ways. Rating of Perceived Exertion (RPE) and Working Heart Rate

(WHR) were the parameters used to find out the physiological work load in the present study.

a) Rating of Perceived Exertion (RPE)

The analyses of data on RPE (Varghese et al, 1994) observed tea leaf plucking as a heavy work with a mean score of 3.14. Out of the total subject (n=180) 84 percent of the workers belonging to the age groups of 26-55 years reported the activity as moderately heavy to heavy activity. Whereas only two percent of the workers reported the activity as very heavy, belonging to the age group of above 55 years. Remaining 4 percent workers belonging to the age group of 16-15 years reported the activity as very light activity. Further analyses of data revealed that as the age increases the feeling of tiredness was also seen increasing.

b) Physiological cost

Physiological cost of work is of a great use in understanding the existing workload and to evaluate any developmental strategy taken to the work environment, work place, design of work tools and methods of performing the activity under the existing conditions. In the present study physiological cost of work was assessed in terms of average working Heart Rate (AWHR) and Energy Expenditure (EE). Average Energy Expenditure was found for plucking operation was 7.07 kj^{-min}. The average working heart rate was found was 100.6 $beats^{-min}$ ^{t}. This indicates that the workload is considerable to impose occupational health problems.

c) **Prevalence of Work Related Musculoskeletal Disorders among the workers**

Tea-leaf pluckers raised complaints when they were asked to tell about their health issues and the responses are quite similar to the findings of Bernard, (1997). Work related health hazards (specifically the pains and injuries) attributed to work includes a group of conditions that involve the different body parts (Fig 30). Often it is intensified by the work environment. These hazards are also referred to as work-related musculoskeletal disorders. These can cause symptoms such as pain, numbness, and tingling, as well as reduced worker productivity, lost time from work, temporary or sometimes lead to permanent disability. These hazards lead to financial losses associated with workers' compensation insurance, or similar forms of social security in place.

Prolonged exposure to repetitive activity can give rise to pains of the hand-arms. These pains are the initial or secondary symptom of the hand-arm disorders caused by repetitive activity. They are therefore important symptom for health surveillance. One of the most popular survey tools for detecting musculoskeletal disorders is the standardized Nordic questionnaire (SNQ) that formed the basic enquiry model in the present study (Appendix A).

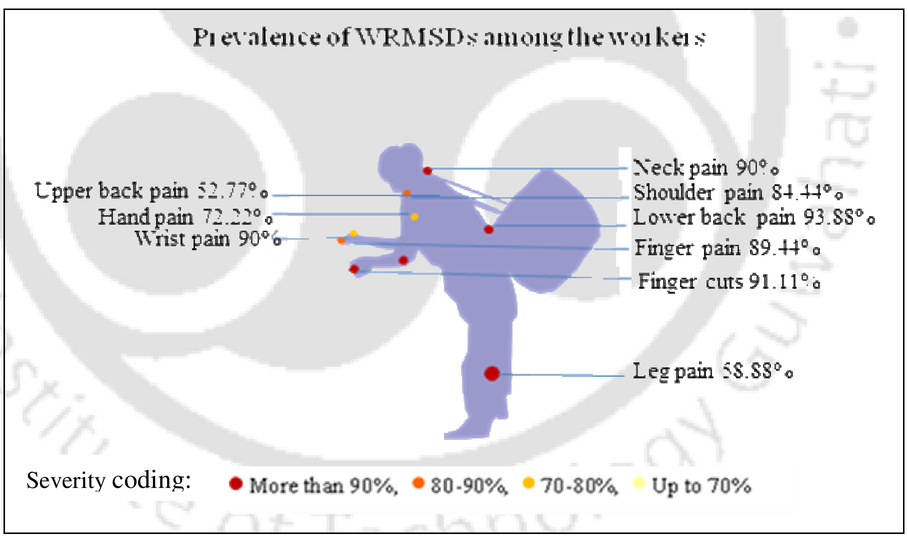
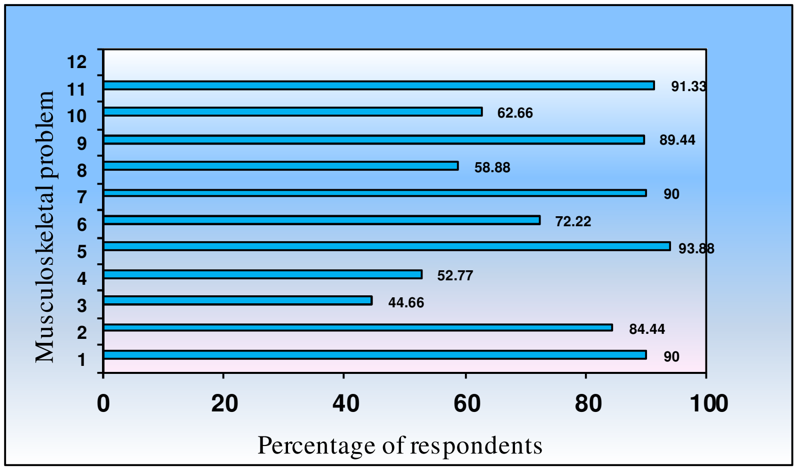


Fig.30: Prevalence of WRMSDS among the workers (n=180)

The analyses of data on work related musculoskeletal disorders faced by the workers revealed that the most commonly affected regions among the workers were low back pain (93.88%) and neck pain (90%) which was followed by finger pain (89.44%) and shoulder pain (84.44%).



1-Neck pain, 2-Shoulder pain, 3–Elbow pain, 4–Upper back pain, 5-Lower back pain, 6–Hand pain, 7–Wrist pain, 8–legs pain, 9–Finger pains, 10–Finger numbness, 11 – finger cuts

Fig. 31: Musculoskeletal Disorders faced by workers (n=180)

Finger cuts were found quite common among the workers i.e., 91.11 percent. Workers reported to have deep finger cuts, causing them difficulties in carrying out their daily activities (Fig.31). Wrist pain (73.88%) and hand pain (72.22%) were also observed commonly faced problems among the workers. This may be due to the repetitiveness in carrying out the operation along with application of force for a long duration in the daily basis and co-contraction in arm muscles.

Severity and frequency of MSDs faced

In order to assess the severity of work related body pains faced by the workers, incidence of pains were put into 3 point responses categories namely acute, less acute and negligible with scores 3, 2 and 1 respectively. The severity of MSDs was also categorized as acute, less acute and negligible based on the mean and standard deviation scores. The total score of each worker varied from 12 to 36.

From the data it was observed that 46 percent of the workers suffered from less acute incidences of body pains where as 33 percent of the workers had the acute incidences which was followed by negligible incidences i.e., 21 percent (Fig.32).

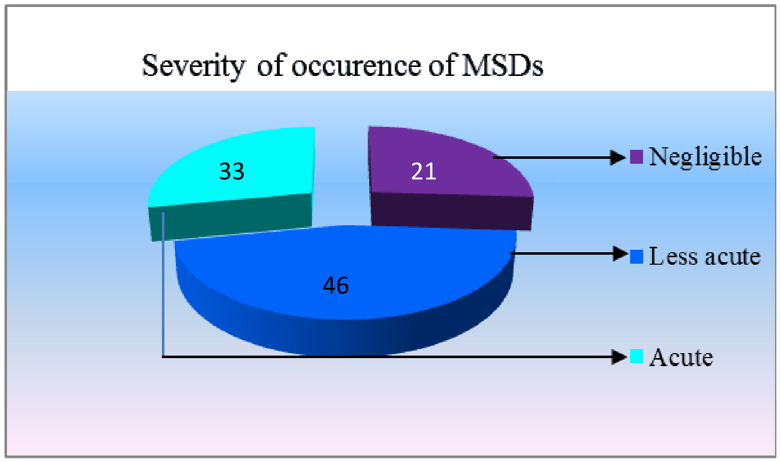


Fig. 32: Severity of MSDs faced by the workers

From further analyses of data it was observed that majority of the workers suffered from low back pain along with neck, shoulder and wrist in acute form. This may probably due to the reason that the plucking operation needs to maintain a forward bending posture and workers need to carry a heavy basket to keep the plucked leaves. Apart from this the activity is highly repetitive and performed for the entire shift.

As regards to frequency of occurrence of work related health problems, lower back pain (93.88%) and finger cuts (91.33 %) were observed as most frequently occurred problems among the workers which was followed by neck (90%) pain and finger pains (89.44).

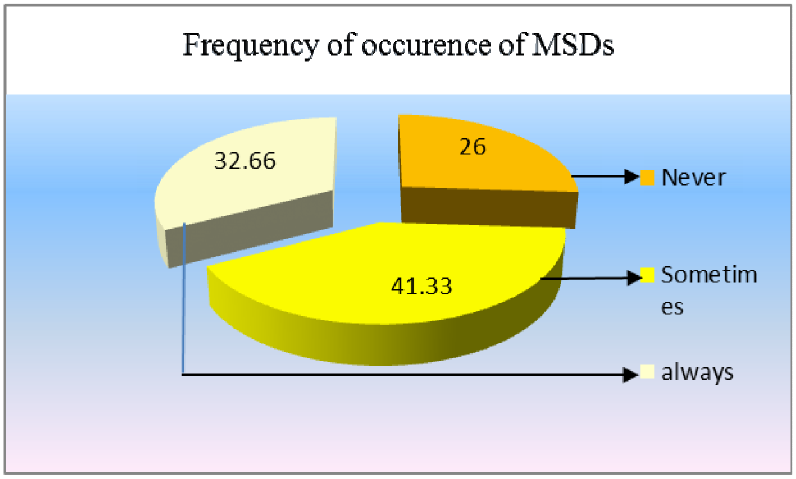


Fig. 33: Frequency of occurrence of MSDs faced by the workers, response in percentages

2.3.8 Risk factors in plucking

Complete risk factors analyses of plucking operation were carried out by using OWAS, RULA, QEC and OCRA methods. From the analyses presented in preceding figures and tables it was observed that considerable ergonomic risks were being reported by the workers associated with awkward postures, force and repetitiveness. Discomfort, or excessive fatigue in body parts, especially lower back, neck, shoulder and mostly in fingers were being reported by the workers. Parts of the body, especially the finger were seen damaged (Fig.34 a, b, c, d). This indicates that the plucking operation and working conditions were conducive for developing work related health hazards (body pains and injuries) among the workers.

a. Cuts in fingers by hard shoots during plucking

b. Deep finger cuts (Index and middle) during plucking

c. Palm injuries due to prolonged contact with hard shoots during plucking

d. Deep finger cuts during plucking

Fig. 34: Finger injuries among the workers engaged in tea leaf plucking operation

2.3.9 Relationship between Individual Characteristics and work related health problems

Work-related musculoskeletal disorders are common health problem and a major cause of disability (Bernard, 1997; Smith et al. 1997, European Agency for Safety and Health at Work, 1999) temporary and long term effects. A range of individual parameters, work method related, workplace related, organizational and psychosocial risk factors are associated with the development of these disorders. It is important to recognize these risk factors characteristics in work, work organization, and environment that are potential contributors to the health and well-being of individual workers, groups and the whole organisation. Relation among these factors leads to take clue to understand the appropriate selection of development criteria to be chosen.

From the collected data and due analyses of them, it was observed that as the age, years of experience increased, prevalence of work related musculoskeletal disorders among the workers were seen higher (Fig.35). Workers with Chronic Energy Deficiency (CED) problems were found more. Body Mass Index (BMI) is negatively correlated with work related musculoskeletal disorders. As the stress level (work related) increased, the severity of the problems was also seen to be increased, (Fig.35).

The notion of a link between the mind and body has existed throughout the history of management success users and this relationship between the mind and the body is studied extensively. The recognition of psychological factors as contributors of occupational health expanded along the development of the concept of the work-relatedness of occupational health since the early 1970's (Lee et al, 1995). Studies indicate a potential link between job stress and upper extremity cumulative trauma disorders (NIOSH, 1992). Hadler (1990) has stated that stress may be primary cause of the symptoms associated with many upper extremity musculoskeletal disorders. An understanding of how psychosocial factors at work can affect health, how to recognize these conditions and their effects, and how to control and intervene in any occupational setup is required in order to avoid their adverse effects and to promote health.

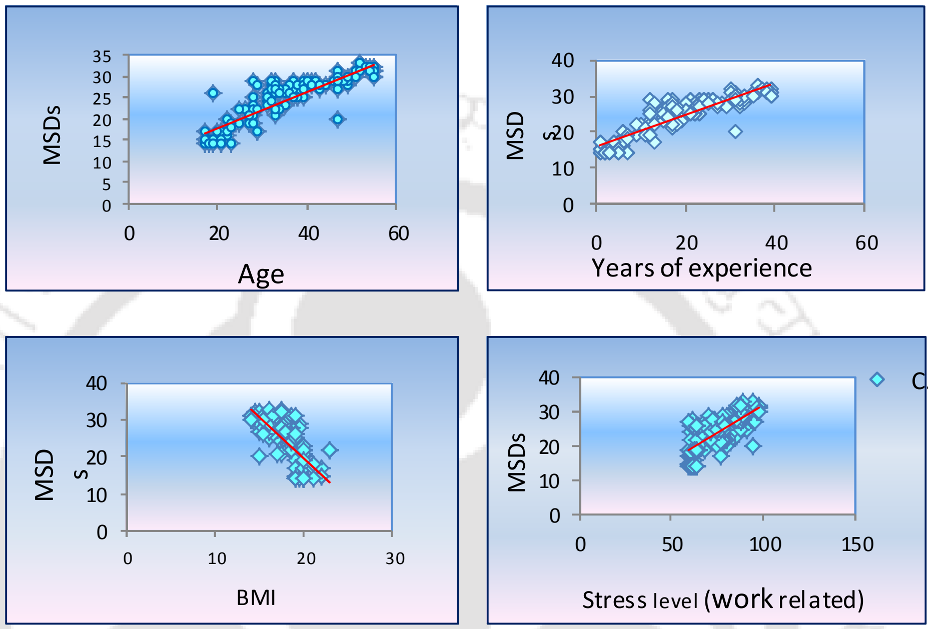


Fig. 35: Relationship between Individual Characteristics and work related health problems

In the present study, the results on occupational stress (organizational and psychosocial, familial and work related stress) demonstrate an association with the prevalence of musculoskeletal disorders (Fig.36 and 37). Organizational and psychosocial stress of workers increases with age. There does not exist any significant relationship of organizational and psychosocial stress, familial stress with Body Mass Index (BMI). (appendix M)

The analyses of data revealed that as the organizational and psychosocial stress increased the prevalence of WRMSDs also increased. The most obvious job characteristics found was workload or job demand. This describes both quantitative and qualitative aspects of the task. In tea-leaf plucking workers work under both the quantitative and qualitative job demand and they perform their activity under time pressure along with maintain quality plucking. Perceived stress was found to be associated with high level of workload resulting from amount of green leaves plucked and quality of leaves plucked.

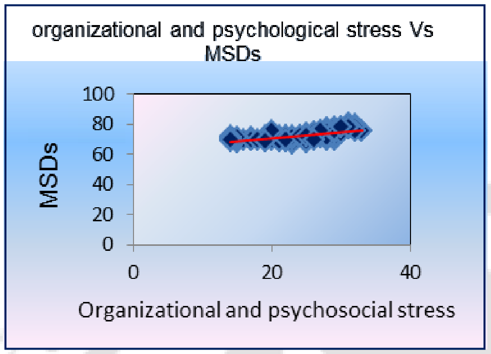


Fig.36: Association of WRMSDs with organizational and psychosocial stress

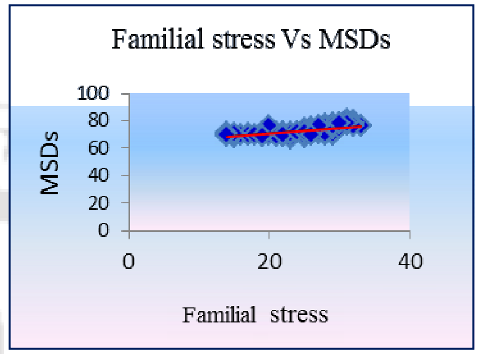


Fig.37:Association of MSDs with familial stress

There are familial factors that make a connection between stress and work related health problems plausible and likely. At the personal level, familial stress can lead to an increased physiological susceptibility to work related problems by affecting hormonal responses and circulatory responses that exaggerate the influences of the traditional risk factors (NIOSH, 2001). In addition, familial stress can affect workers' attitude, motivation and behavior that can lead to risky actions that increase work related health problem and it can affect the quality of production.

Workers, who are depressed due to poor familial factors are also seem to be dissatisfied at work and report more symptoms and disability than those who are content. In the present study the risk factors that found causing familial stress were family financial condition, relationship among the family members, household environment, children upbringing, alcohol consumption habits of husband and wife, etc.

The data from Nordic Questionnaire as used in the study showed ill symptoms from the musculoskeletal system and were found to be common among the tea leaf pluckers. The vast majority of the workers (91.33%) had experienced some forms of symptoms of musculoskeletal disorders, as reported occurrences during last 12 months.

The percentage of sick leave due to work related health problems in last 12 months (data collected from management record) was 40 percent. As shown in figure, (Fig.38) problems of the lower back (27%), neck pain (19%), finger pain (18%), shoulder pain (12%) and wrist (11%) pains were the causes of the highest rates of sick leaves.

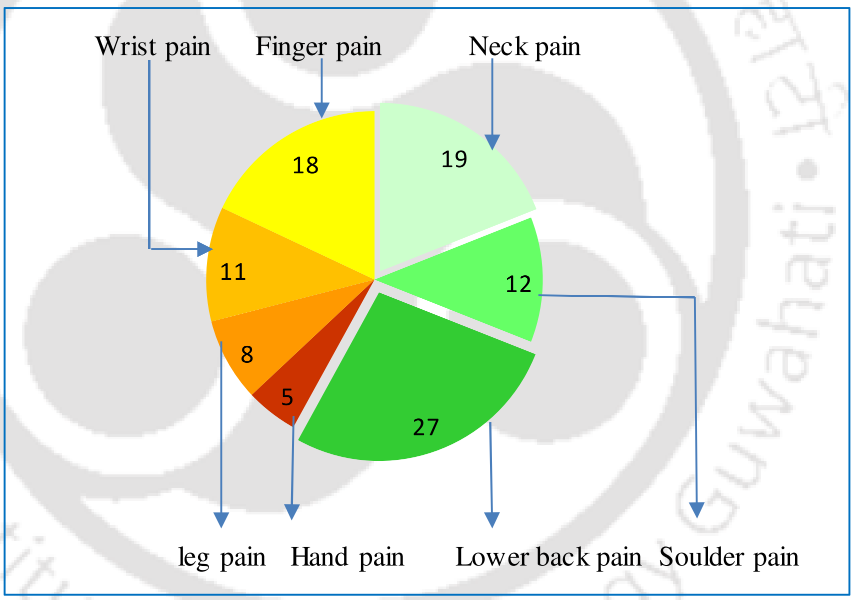


Fig.38: Trend in Sick leave due to MSDs leave.

This indicates that tea leaf plucking is a considerable high-risk activity for developing musculoskeletal disorders and appropriate attention is necessary to ease the upper arm activity.

Lower back pain, shoulder pain, neck pain and finger problems (pains, cuts numbness, etc.) were found to be the most prevalent among the workers studied. This could be attributed to awkward postures, highly repetitiveness and long duration. This implies that there is an urgent need of any interventional program for preventing or reducing physical exposure to MSD risk factors specifically focusing comfort of these regions.

2.4 Testing of Hypotheses

To find out the relationship between selected independent variables and dependent variables i.e. work related MSDs, occupational stress and individual characteristics, two null hypotheses were formulated.

The hypotheses were:

It was assumed that

- There is no significance of variance in severity of work related musculoskeletal disorders with variance of age, Body Mass Index, and years of experience; and
- There is no significance of variance in severity of work related musculoskeletal disorders with variance of work related stress, organizational and psychosocial stress and familial stress.

To test the hypotheses ANOVA was performed for a significance level of .05. From the results it was observed that there were significant differences in the musculoskeletal disorders with the variance of individual (age, years of experience and BMI) factors (i.e., F=18.028, p=0.000) and the occupational stress (organizational and psychosocial stress: F=41.178, P=0.000; familial stress: F=11.233, P=0.000; work related stress: F= 42.692, P=0.000).

Therefore it is concluded that there was

- A significance difference of work related musculoskeletal disorders with individual characteristics i.e., age, years of experience and BMI

- A significance difference of work related musculoskeletal disorders with occupational stress levels (work related, organizational and psychosocial, and familial issues concerned)

This led to think the possible way to address on what would be the immediate attention towards comfort working and productivity.

2.5 Conclusion

Tea-leaf plucking accounts for 70 per cent of the workdays and 40 per cent of the total cost of production. Analysis of plucking activity identified the risk factors for development of work related health hazards (musculoskeletal disorders, injuries) are: awkward front postures, force application to tear the shoots and repetitiveness in hand and finger movements. Injuries were being reported, workers reported discomfort, fatigue and pains in body parts e.g., lower back, neck, shoulder and mostly in fingers, abrasions in fore finger/middle finger were seen prominent. This indicates that the plucking operation and working conditions were conducive for developing work related musculoskeletal disorders specific to back, neck and upper arms among the workers.

This scopes the design development, specifically for plucking. Context specific design intervention improves the work performance and overall wellbeing of the workers.

2.6 Need justification of development of tools for the specific tasks

Hazards are best eliminated at the source; this is a fundamental principle of occupational health and safety. From the analyses of data it can be concluded that the women workers engaged in tea leaf plucking operation reported to have occupational stress. One of the indicating parameters of occupational stress among the workers studied was work related musculoskeletal disorders.

The observations revealed that the workers suffered from pains at back, neck, shoulder, hand, wrist, and numbness and tingling of fingers, skin abrasions and cuts in forefinger, thumb and middle finger were noticed. In the case of work related musculoskeletal disorders in tea leaf plucking, the prime source of hazard is the repetitiveness of work. The other components of work related musculoskeletal disorders were found to be applied force, holding of a body positions for a quite longer time (while plucking from the tea table), and the pace of work requiring repetition of the same movements over and over again.

Therefore the main effort to protect workers from work related musculoskeletal disorders should focus on minimizing such risk factors. For productivity in tea-leaf plucking activity, elimination of the repetitiveness of work, correcting the posture and the maintaining of slow pace of work may not be practical solutions. Focus on avoiding repetitive patterns of work can be done through job design which may include mechanisation, job rotation, job enlargement and enrichment or teamwork. One way to eliminate repetitive tasks is to mechanise the job intensity. In case where quality tea is concerned, selective tea-leaf plucking is essential. Therefore mechanisation is not technically feasible to go along with current practice.

As regards to job rotation workers are supposed to move between different tasks, at fixed or irregular periods of time. But it must be a rotation where workers do something completely different. Different tasks must engage different muscle groups in order to allow recovery for those already strained. In tea leaf plucking, skilled pluckers are required to perform a single job throughout; therefore job rotation is not possible. Other approaches like job enlargement and enrichment, team work, etc., are not the answer to the problem of repetition.

Therefore the prevention strategies involve designing a plucking device so that the risk factor of applied force can be addressed along with protecting the fingers from contact injuries. Designing a plucking device, that might provide selectivity along with improvement in productivity. In the present study efforts were made to design such a device, which would assist in selective tea-leaf plucking for quality tea production. In this regards it is to mention that management of few tea gardens opined to prefer to have mechanical harvesting if the mechanization provides selective plucking as done by hands.

Proper design of tools and equipment significantly decreases the force needed to complete the task. Providing the worker with the proper jigs or fixtures for tasks that require holding elements saves a lot of muscular effort in awkward positions.

The next stage of intervention is on developing a plucking aid that does not require additional skills to use as well as low cost and easy to use. Based on the severity of ergonomic risk factors (Fig.22) i.e., posture, force and frequency, the principle behind the plucking device is that if with the help of such device tearing off the shoots becomes easy and can avoid some false movements, that does not pluck but a habitual movement (Chakrabarti, 1987). Slective hand movements will lessen the false movements thus repetitiveness; thus contact time and force required for tearing the shoots, means force and duration of force application will be controlled; and the longer duration of holding a front bending posture will be eased out. With this, possibility of such a plucking aid device design was tried out and is presented in the next chapter.

Chapter-III

Design Development of a finger guard plucking aid

3.0 Introduction: Occupational Ergonomics and design intervention

Despite the technological advancement (though the effect of mechanisation has productive results as shown in chapter II), the tea-leaf harvesting remained a hand plucking task. Throughout the tea gardens of Assam, the women workers engaged in the operation of harvesting tea leaves manually for which mechanised harvest (with presently available machines in the market) is not technically feasible. For quality tea, selective plucking is essential. Moreover hand-plucked tea (facilitates selective plucking with two leaves and bud) is very rich in green-leaf biochemical precursors and have higher contents of made-tea quality constituents than mechanised/shear-plucked tea (Wijeratne, 1999). There are concerns expressed (Sen et al 1978) for a device suitable for hand plucking, but not effective attempt was made till date.

The tea-leaf pluckers are subjected to adverse working conditions inherent in the work process viz. adopting awkward postures reaching for the new shoots to be plucked which involve long hours of standing, reaching or bending, repetitive movements of fingers along with whole arms and carrying heavy loads on back, often under extreme weather conditions. There are evidences from the preceding chapters that work-related health hazards (body pains and injuries) and lost work time represent a significant health problem for women workers who are engaged in tea leaf plucking activity. Ergonomic interventions were deemed necessary to improve the working conditions and decrease the level of exposure to work-related health hazards (body pains and injuries) risks as mentioned in chapter II. Little effort is made for relieving the risk factors in plucking activity. Though few attempts were made to design leaves harvesting devices, e.g., shear device etc.; in Assam the effort was not found successful in practice for its requirements for selective plucking.

Identification of risk for work-related health hazards (body pains and injuries) and quantifying the level of risk by using relevant information on human capabilities is helpful to set priorities for which ergonomics issues should be addressed first in work situation. The ergonomics problem-solving technique leads the user through the identification of ergonomic risk factors effect on the body parts first. Next, each risk is evaluated looking into the root causes. This is repeated until common causes for the presence of risk factors are found. Accordingly strategies to reduce the risk are generated, and thus specific short-term and long-term solutions are developed. The preferred solution will usually be the one that reduces the risk for injury substantially at a relatively low price (Fig.39).

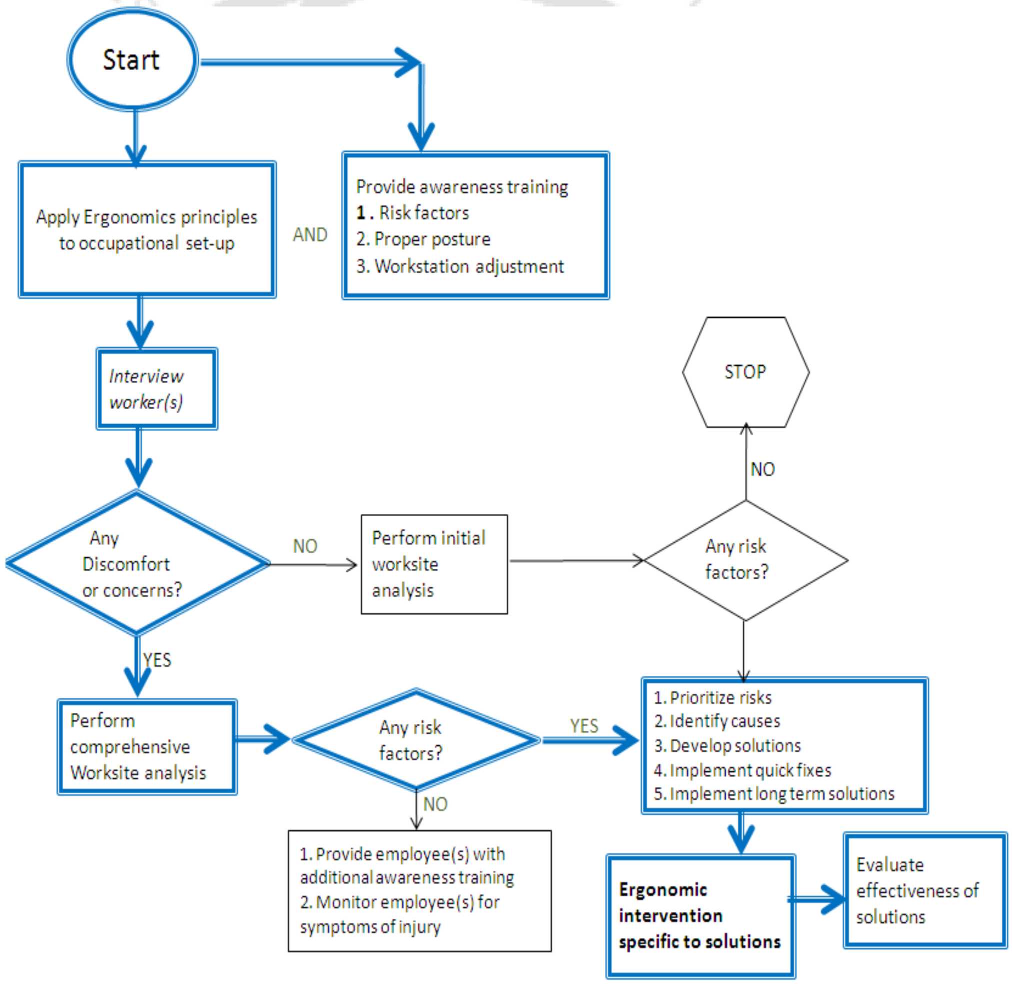


Fig.39: The flow chart for application of ergonomic principles in design development

Ergonomics contribute positively to the process of development of a best design/system to deliver the intended function to its user that operates successfully by ensuring a good fit between technology, its users and its operating environment. Flow chart presented in figure 39 briefly describes the application of ergonomics principles in design development.

Design is basically a creative endeavor with its history of origin as arts. The variety and complexity of design issues today, emphasize on more advanced ecological balance between human beings and their socio-cultural and natural environment. To qualify a development to be a good design ultimately the user has to feel comfort while using it. Usage of ergonomics in design provides a sound quantitative basis of human aspects of problems and possibilities of usability testing, and comfort of human product usage.

Although ergonomic research in hand-harvest labour all over world is increasing (Sakakibara et al. 1995; Miles and Steinke, 1996; Calisto et al. 1997; Baron et al. 2001), the health and safety hazards associated with harvesting work (especially in tea industry) have not been as thoroughly studied as in many other industries.

In spite of national importance of tea industry in Assam and its potential fruitful impact on overall economy of the country, there have been few ergonomics studies on the pluckers were done. In 1978 Calcutta University team reported the first of its kind of study that made, along with basic benchmark information, comments on requirements on plucking device design (Sen, et al 1981). The present study findings through chapter II material also recommends for a similar development.

The work related health problems of workers in tea leaf plucking can be prevented, if causes of problems can be identified and appropriate ergonomics principles are used in planning of design intervention. The design intervention should consider the elimination of ergonomics risk factors of posture, force and frequency (Fig.22). In the process of developing ergonomic design intervention, identification of need and finding of appropriate solution comes early, thus this part can be said reflecting the solution-focused nature component of design thinking. This solution inference is then subjected to analyses, evaluation and followed the trial feedback refinement becomes, ready for manufacture and use.

Purpose of the present study was to create awareness, analyse and categorise health related problems and injuries and offer proactive intervention to minimise chronic work-related health hazards (body pains and injuries) conditions among tea- leaf pluckers in tea industry. This finally led to a plucking device design that was conceptualised, designed, developed and evaluated by involving the users at all stages viz. tracing the problem, design and evaluation, and field trial.

3.1 Scope of design to improve occupational wellness: (Review) Indian other works

The complex man machine relationship and its surrounding environment are one of the most important potential areas of study towards improving occupational wellness in Indian industry. What we have seen for the last fifty years in Indian industry is suffering from the way the workers work in an uncomfortable work situation and environmental stresses, besides the incompatibility of man- machine interactions. International Ergonomics Association observation reveals show that in Indian industry, workers still spend 16 to 18 Kcal min^{-1} in their jobs, which is one of the highest from any countries' standard (Caple, 2005). We have also seen the loss of productivity at the tune of 30 percent due to poor work posture and poor work equipment design (Nag and Nag, 2007). The design of machinery and equipment has demonstrated to be a major cause of injury when it is not conceived along with the context specific needs and not used properly. It is very important to apply human factors issues to a product in its development phase.

Ergonomics has now been recognised undoubtedly as an effective tool for ensuring human comfort, health and safety as well as improving the production system as a whole. It helps to deliver appropriate methodologies, which can reduce the worker's workload and bring efficiency while doing work. We need to have the Indian work environmental set up in tune to the acceptable workload for men and women, Indianisation of complex machineries should be fitting to Indian requirements (Varghese, 1994); it may on developing work methods or design of work equipment.

In Indian industrial scenario women workers are sharing the jobs attended by man and has same work situation as far as machineries are concerned. Improved machineries and work tools have been developed primarily for men. Women have quite different technological needs than men due to different physical characteristics, skills, abilities etc. Therefore, a need was felt to develop technologies appropriate to the needs of women users (Nag, 1986; Chakrabarti, 1989; Iqbal and Ghosh, 2005); as well as to adapt a unisex strategy so that the development can fit both males and females.

Recently design developments of various work accessories to assist various tasks in the industries, where women are the major workforce have been started. Studies have been conducted viewing to increase productivity through design development to suit the working conditions and physical compatibility with women workers (Gandhi, et al 2009). During the Tenth Five Year Plan, emphasis was laid on technological empowerment of women. As a result efforts were made in this direction by various Research and Development institutions of the country namely, Central Institute of Agricultural Engineering, Bhopal; National Research Centre for Women in Agriculture, Bhubaneswar; All India Coordinated Research Project on Home Science in State Agricultural Universities and developed a number of technologies that are appropriate for women workers (Sen et al 1981; Bhattacharyya et al 2005;

Borah et al 2005; Gite et al 2007) etc., few to name with, there are many those who are making in this effect.

Researchers in India and abroad have worked consistently to develop a good numbers of design interventions considering the situation of work in tea industry. Shearing device used for tea plucking was designed aiming for Indian context in National Institute of Design, Ahmadabad (Chakrabarti, 1996). An improved tea plucking basket was designed under a project on 'ergonomic assessment of postures assumed by women workers in tea cultivation' at Assam Agricultural University (Bhattacharyya et al 2005). Design modifications were attempted for pruning knife, weeding and digging hoe in tea fields (Bhattacharyya et al 2008).

The empirical values of ergonomic assessment of plucking operation were found beyond the threshold of ergonomic risk as evident from analyses of data in the preceding chapter. A closer look into the results reveals that the force and frequency is the major contributor to the ergonomic risk along with awkward posture in plucking operation. Apart from that the workers were involved in performing the activity in the entire shift without enough breaks.

The analyses of data in the preceding chapter support the view that tea leaf plucking activity poses significant challenges to the musculoskeletal system particularly the low back, finger pain, shoulder pain and neck pain. One of the identified needs is to develop a system which will relieve at least one ergonomic risk factor contributing to operational easiness and increased productivity. This research work emphasised on some of the design development possibilities for women workers who are engaged in tea leaf plucking activity.

From the discussions with management, relevant experts in tea industry and specially the workers, it was felt necessary to have a design intervention so that the risk factors in plucking operation could be relieved. The design intervention was conceptualized to be focused on assisting plucking (for easing out force while performing tea leaf plucking operation) because changing of posture is not applicable as the workers need to stand in slight bending posture for reaching the periphery of tea table. Moreover repetitiveness of the activity cannot also be addressed as it has direct impact on productivity. Hence designing of a plucking device was felt required to assist traditional plucking practice in tune with smoothening selective plucking.

3.2 Design development strategies

A strong relationship exists between the comfort and productivity. Unfortunately, this fact has not been accepted by many industrial organisations, where the management expects the productivity of the organisation and quality of its products to be a function of pay rate only; very much prevails in tea industry. This is an indication of lack of understanding of the concepts of ergonomics and the roles of its principles for designing a realistic approach in improving productivity along with reducing the incidences of work related health problems among the workers.

While designing an approach below '6Ws and how' must be analysed (Chakrabarti, 1997)

Who- the individual or organization requiring design and their special corporate aim; in tea industry mostly decisions are made in corporate level.

Whom-the intended users: their basic limitations and the facilities available; the women leaf-tea pluckers.

Why- need of that product/ system; to design required assisting in tea leaf plucking so that force required for plucking the leaves will be minimised and quick plucking will be possible.

What- considerations to be taken- a thimble like device with a cutting blade

When- the context in which the design is to be used; to be used during tea leaf plucking

Where-the surrounding space and the relationship among the other articles to be used when performing the intended task; the plucking basket/bag, apron and a head cover to protect the workers from rain and Sun shine etc. used during plucking operation.

How-means to interlink the above six ‘W’s to arrive at a design solution with human compatibility. The design whatever its effect when implemented by the corporate decision and depending on larger user groups (the women pluckers) a great impact is expected.

A good ergonomic design creates a context for experience that fully respects user's all inbuilt capabilities and acquired skills, and understands users and their requirements. Design is the planning that lays the basis for making of every object or system for a specific purpose. It is an innovative, practical, reproducible solution to conceive various aids to human needs. It is a continuous problem solving process with conversion of ideas into reality, keeping in minds the user’s characteristics and limitations, art and aesthetics, material and process, and new technology. Application of principles of ergonomics in design establishes user-friendliness, and compatibility between man and his surroundings and articles for his use.

Ergonomics principles for good design comprises following (Chakrabarti, 2006)

1. A product should ensure the basic principles of human compatibility through:
   - A product user friendly relationship,
   - An anthropometric and behavioral match between the user and the product,
   - Ease of handling,

- Ease of decoding of messages, encoded with inbuilt features, and
- Proper semantic applications of recognising the functions and perceiving usability aspects,

2. A product conform reliability and safety through

- Designing the overall form, shape, size of the product and layout of the parts for operational ease,
- Removing unnecessary bad parts,
- Guarding unsafe things,
- Warning of probable hazards while using the same, and
- Training by specific instructions on how to use the product efficiently.

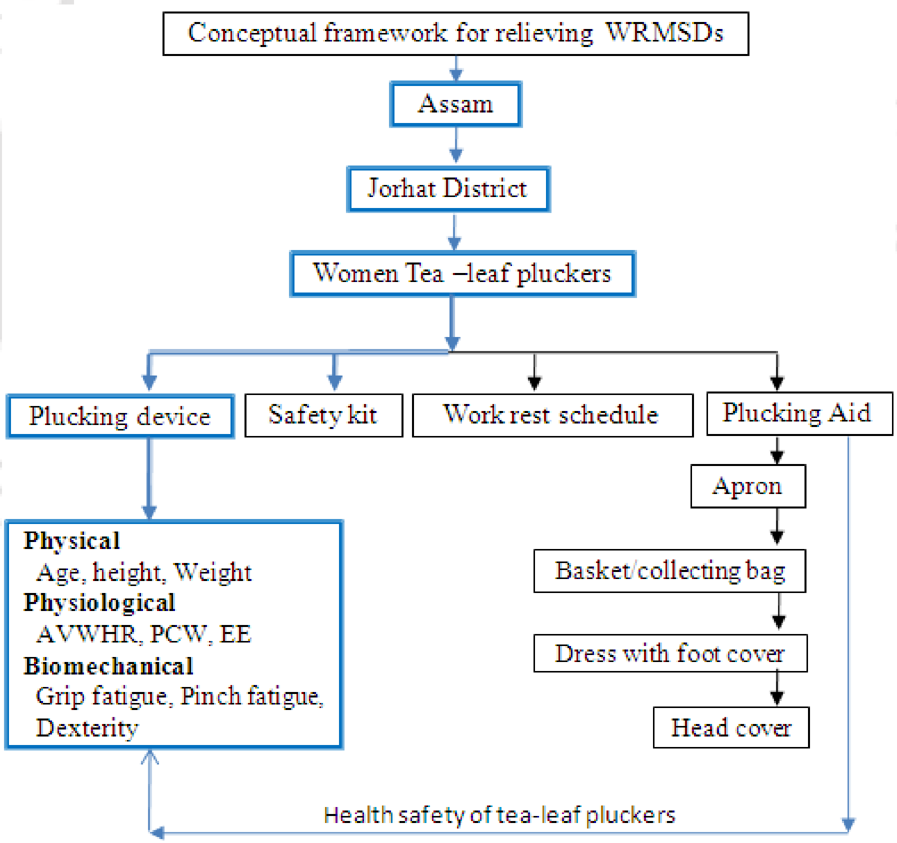


Fig.40 : Conceptual framework for relieving work related health problems

Design development in the present study consists in translating the need (for example, a device for the ease of plucking) into design characteristics i.e., type of device, kind of cutting edge, ease and comfort of using considering pressure restriction and free movement of fingers, and applying guarding features for safety, etc. Figure 40 provides a background comprehensive scheme followed in the present study.

3.3 Aim and Objective

Aim

The present study aims to attempt at developing a tea leaf plucking device for index finger or middle finger that can assist the task.

Objectives

The specific objectives of the design development were set

- To determine the design parameters and specific considerations,
- To conceptualise the design and to study its utility through preliminary trials, and
- To finalise the design support necessary for improving tea-leaf plucking comfort.

3.4 Materials and Methods

To address the research objectives, the study has been under taken as follows:

In this phase of the study, a plucking device was developed and was ergonomically tested on the workers and then suitable modifications were made. After the modifications, field trials were conducted to evaluate the device. The plucking device was designed to:

- reduce the ergonomic cost of plucking activity
- increase efficiency of worker
- improve productivity along with quality produces, and
- enhance the work comfort

Participatory approach was followed while designing the plucking device. Ease of comfort while using the device was studied by using Borg's scale (Borg, 1970).

3.4.1 Short description of the tea-leaf plucking process

The plucking activity is performed by the workers in standing (with a bend near lumber region for reaching the periphery of tea table) posture along with a load at back (plucking basket hanging from head with a belt, Fig. 29). While performing the operation arms are outstretched to reach the tea leaves and fingers i.e., index finger or middle finger with thumb move continuously. The workers pluck (pinching twist) young tea leaves with a bud (Fig. 41), holding the plucked leaves till the hand is full and throwing the plucked leaves to the plucking basket.

Fig.41(a): Wrist posture

Fig.41(b): Wrist movement during plucking operation

While plucking workers move within the bush with plucking basket and engaged in the operation for a total of 8 hours in 2 shifts (before and after lunch). To assist this hard plucking operation a plucking device was developed. The below mentioned tests were conducted at free hand plucking and using the new device to evaluate the effectiveness of the later over the previous method of plucking.

3.4.2 Experimental details (Design finalization)

In whole design development process participatory approach was adopted, starting from initiation of design theme to each and every concept generation steps. Selected workers were taken into confidence that the new device would help them better and comfort functioning. The below were considered:

No. of subjects	30 fast women tea pluckers, physical characteristics are presented in table: 10.
Replications	3
Trial duration	Two shifts i.e., before lunch and after lunch
No. of treatments	2 (With or without the new device)

Parameters for comparison to evaluate benefits of using new device::

Grip strength, Pinch strength Dexterity of the workers, Work related Musculoskeletal Disorders (pain feeling), Ease of comfort and Rating of perceived exertion and Electromyography (EMG)

The subjects

For the field trial of the plucking device, 30 physically fit women tea pluckers without having any physical disability and chronic ailments were selected purposively from three tea gardens of Jorhat district of Assam (Kakojan tea estate, Hunowal tea estate and experimental tea garden of Assam Agricultural University). All of the selected subjects were given practice with the device for 7days before starting the trials. The women workers who had experience of more than10 years belonging to the age group of 25-35 years were selected.

Body Mass Index (BMI), using their body height and weight, was calculated following the formula of Deurenberg (1991), and accordingly physical fitness and body types were categorized by following Garrow's scale (1985), to help selection of subjects for physical consistency. Relevant finger measurements of the workers were collected for designing the thimble for plucking (Chakrabarti, 1997).

Table 10: Physical characteristics of the respondents

Parameters	**Mean**	**± S.D.**
Age (Years)	34.00	8.2
Weight (Kg)	44.00	4.30
Height (cm)	153.76	2.8
BMI (scores)	19.1	2.40

3.4.2.1 Grip Strength

Grip strength, before the activity and after the completion of an activity is an indicator of fatigue of hand muscles. Grip dynamometer (Fig.42 a) was used to measure the grip strength of the workers. It was measured before and after the completion of activity separately for the right and left hand, without and with the new device. Fatigue of hand muscles was measured in percentage of grip fatigue.

3.4.2.2 Pinch strength:

Pinch strength, an indicator of fatigue of the hand muscles was measured with pinch gauge (fig. 42 b) before and after the completion of activity separately for the right and left hand, without and with the new device. Fatigued condition of hand muscles was measured in percentage of pinch fatigue.

3.4.2.3 Dexterity Test:

One of the important factors that influence the plucking average is the dexterity of the workers. The term dexterity is commonly used in application of motor skills of hands and fingers. For tea leaf plucking activity fine motor skills that involve a refined use of the small muscles controlling the hand, fingers and thumb, usually in coordination with the eyes are required (Venkatakrishnan *et al.,* 1999).

For dexterity test, the two-arm coordination test was used. The two-arm coordination test is intended as a measure of the ability to move both arms in a simultaneous and coordinated manner. The movement involved is that of the whole arm related to the ability of operating–controlling and driving–operating. Lateral movement is accomplished by simultaneously moving both handles to the left or to the right.

The equipment consists of a tracing board with a black star pattern, a stylus and an impulse counter (Fig.42 c). The test was composed of two operations i.e., tracing a star in a clockwise direction and in a counterclockwise direction. The stylus is manipulated by moving the handles in the apparatus and spreading the handles. Moving the handles makes the stylus move toward the top of the board, while bringing the handles together moves the stylus downward on the board. The objective of the test is to manipulate the handles in such a way as to keep the stylus on the black star pattern marked on the board. Every time the stylus leaves the black star pattern, an impulse counter connected to the stylus record one error. Both the time for task completion, which is recorded with a stop watch, and the number of errors made during the task performance, are collected during this test. Dexterity test was performed before and after the activity of the day with and without the plucking device.

3.4.2.4 Elecromyography

In order to observe the muscular activity/load benefit of new device in performance of tea leaf plucking, surface EMG study was used as an evaluation tool. Luttmann et al (1998) proposed surface EMG can be used as a valuable tool for the indication of muscle stress and fatigue in occupational field studies. They opined increase in EMG amplitude or a shift in the special distribution towards lower frequencies can be the fatigue induced change.

Laboratory experiment in design, EMG study was done in Ergonomics laboratory of IIT, Guwahati by simulating the work environment. Biopac systems (Fig.42 d) were used to perform the EMG studies and the results were calculated by using Acq-Knowledge software. Before placing the electrodes (Agcl electrodes) on the skin over selected muscles dead cell layers were removed by scraping by using the rectified spirit. Electrode gel was used while placing electrodes.

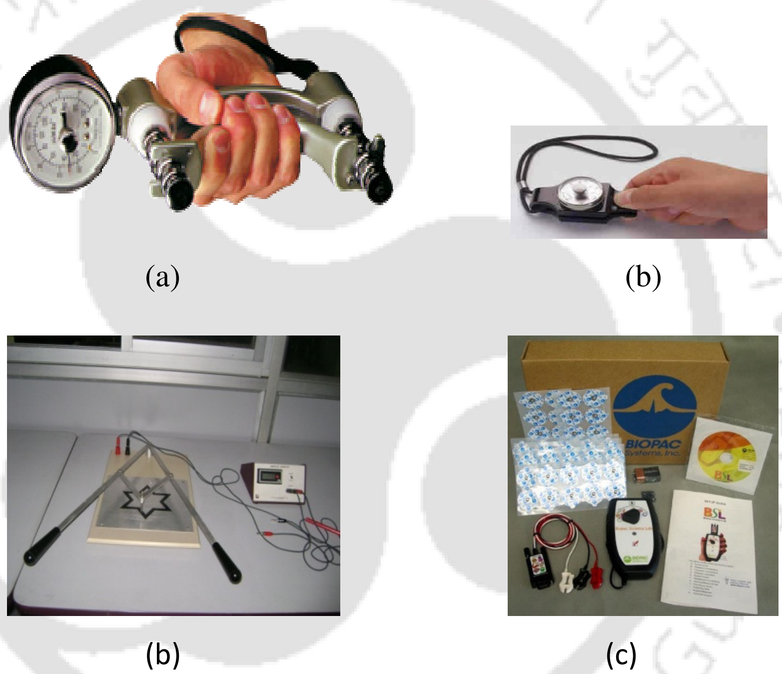


Fig. 42: Equiment (experimental setting used to evaluate the new plucking device

3.4.2.5 Work related Musculoskeletal Disordes

Body pain response of the workers (Appendix B) was studied at the end of the operation before lunch and after lunch, which lasts normally for more than three and half hour in each spell. The intensity of pain in different body parts were recorded with the help of a human body map by using three point rating scale i.e., just noticeable, moderate pain, intolerable pain while using and without using the new device.

3.4.2.6 Ease of comfort

Ease of comfort while using the new device was studied with a 3 point rating scale. Overall comfort/discomfort felt by the workers while performing plucking operation with and without the device, the rating scale numerically 1 being very uncomfortable, 2 being the comfortable and 3 being very comfortable was used.

3.5 Development of Ergonomic plucking device

From the discussions of preceding chapters it can be concluded that injuries were being reported by the tea leaf pluckers. Analysis of work area showed i.e., awkward postures, force and repetitiveness were the risk factors that are conducive for pains in different body parts, along with other work related problems. Workers reported discomfort, or excessive fatigue in different body parts, especially low back, neck, shoulder and mostly in fingers. Body parts were being damaged, especially the fingers cuts. With mechanisation quality problems along with reliability problems (machineries) exist. The design development attempt was focused on a plucking device if assist performance in tea-leaf pluckers in tea industry of Assam

To reduce the maximum voluntary contraction of finger muscles (mainly thumb and index finger) during the performance, a plucking device was conceptualised to assist tea-leaf plucking so that force application in tearing the shoots will be reduced and also will make the activity comfortable.

3.5.1 Design Conceptualisation: ideation

In the process of developing the plucking device to assist in plucking of tea leaf, relevant experts comprising of designers, faculties from the Department of Design, Indian Institute of Technology, Guwahati, the users (pluckers who volunteered in the study), and the management of the studied tea gardens were consulted. Based on their suggestions i.e., a thimble kind of device which fits the finger (no unnecessary rotation while in use) with a cutting blade was conceptualised. Figure 43 shows some of the initial sketches and wire model on which further development was based upon.

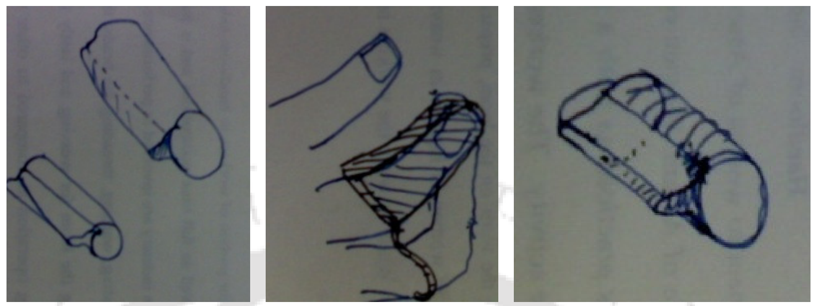


Fig.43: Design conceptualization- initial and basic thoughts

3.5.1.1 Mock-up model making: initial laboratory experiments

Based on the above concepts, some models trial was made with clay and wire to have the basic idea about the device (Fig 44).

Model making with clay Model making with wire

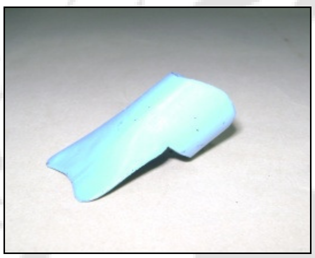
Giving shape like a cutting edge

Fig.44: Model Making, laboratory concepts

3.5.1.2 Interim Development:

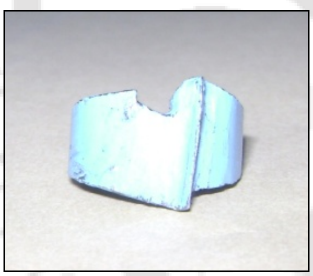
After the basic ideation, a few mockup models using various materials including PVC and metal alone, and in combination were developed. Figure 45 shows few such steps. . Field trials on the developed models were made to get the opinions of users and the relevant experts and workers.

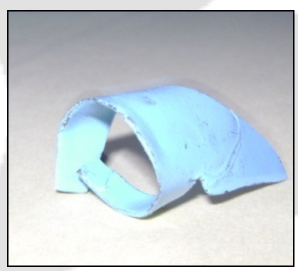
The feedbacks on first level of trials were: the workers did not feel the device comfortable as the device rotates with the force which is being applied during the activity. With the metal ring the device caused injuries to their fingers and they had to keep the fingers straight during the activity with the device on, for the entire shift. The feedbacks collected were considered while proceeding for second level of designing.


Ring with extended nail


Cutting blade is attached with two rings with


Two ringed blade with thumb guard


Single ring with extended mails


Single ring with extended nails

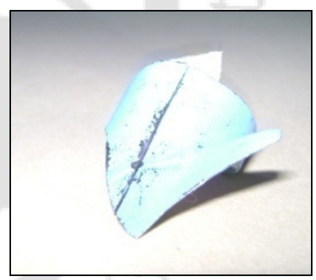

Single ring with a slanting blade

Fig.45: Interim design development

3.5.1.3 Trial confirmation of design features

1. The device may be a finger guard that should keep dorsal portion and up to second finger phalange joints with free finger movement,
2. The device should have a cutting edge, it may be made with the hardening of the same finger cover or a separate metal part can be fixed,
3. The finger guard must not rotate while in operation,

4. A non-slippery soft but unbreakable elastic material to be used for the basic structure with a cutting blade can face the medial side of the finger and pinch pressure of thumb if can assist in breaking the shoots.

Finally the design of the device was decided for a thimble type of finger guard along with a blade made of spring steel as cutting edge embedded on one side of the thimble to assist tea-leaf plucking operation. The device should have flexibility of finger movements. With this, a design as presented in figure 47 was considered and its trial prototype was made.

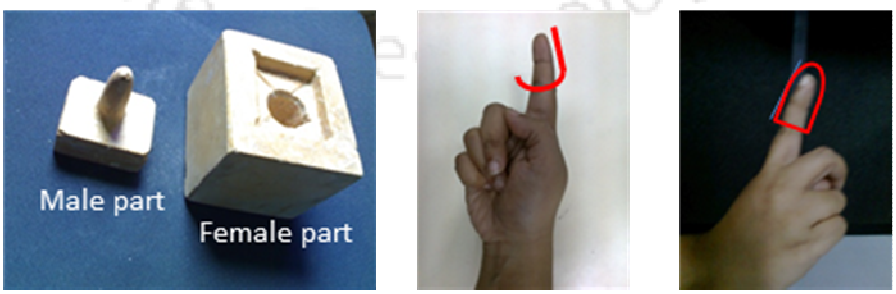
3.5.1.4 Final prototype making for trial

Selection of material

Silicon rubber was selected for making the thimble due to its ease of shaping. Silicone rubber is a rubber-like material, generally non-reactive, stable, and resistant to extreme environments and temperatures. For the blade spring steel was used.

Preparation of Dye

For making the device a dye was prepared with casting plaster. The dye consists of two parts: the male part and the female part (Fig. 46 a). To make the thimble, anthropometric measurement of index finger up to second phalanges (Fig. 46 b) and finger circumferences were taken (Chakrabarti, 1997).



(a) (b) (c)

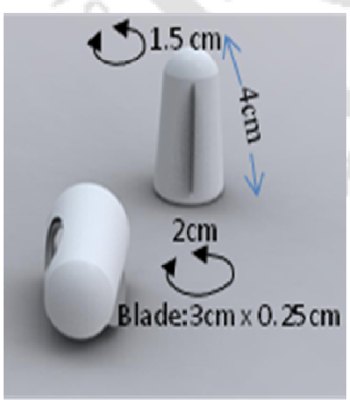
Fig. 46: Preparation of dye

3.5.2 Design finalization

Field trials for newly developed design were carried out. Utility study of designed device was conducted through participatory approach (Fig. 48). Again comments were collected and accordingly modifications were incorporated. Comments from the users after the field trials on the newly designed plucking devices were gathered. The workers suggested that the device should provide air circulation inside for comfort in using it. Based on the requirements as suggested by the workers design modifications were made. Accordingly a hole was made in the opposite side of the device.

The newly designed plucking device is a thimble like device which is to be worn either in index finger or in middle finger based on the workers' preferences (the finger used for plucking operation) with a thumb guard, (Fig.47). Material used is Silicon rubber with spring still blade. In the thimble there is a hole in just opposite side of the blade to facilitate easy bending of the finger.

Dimensions details and different functional parts of new plucking device are shown in the following figure 47 is a concept prototype that was evaluated against analyses of productivity, usability and cost efficiency.



Material-
Silicon rubber
Metal blade

Sizes-

Thimble
Length: 4cm
Circumferences:2cm
5cm
Blade: 3cm x 0.25cm
Weight: 9 gm

Fig. 47 Dimensions details of the plucking device

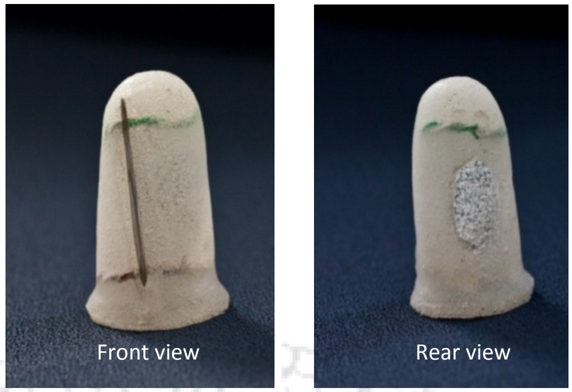


Fig.48: The final design of the Plucking Device

Fig.49: Field trials of improved thimble plucking device
(Conducted in experimental tea garden of Assam Agricultural University)

3.5.3 Evaluation of the new device for plucking operation

3.5.3.1 Grip strength

Grip fatigue (the amount of muscle strength loss) was found more when the activity was performed without the new device i.e., 21.6 percent for right hand and 18.4 percent for left hand as compared to with plucking device (14.97 % for right hand and 12.5 % for left hand) which is presented in figure 50.

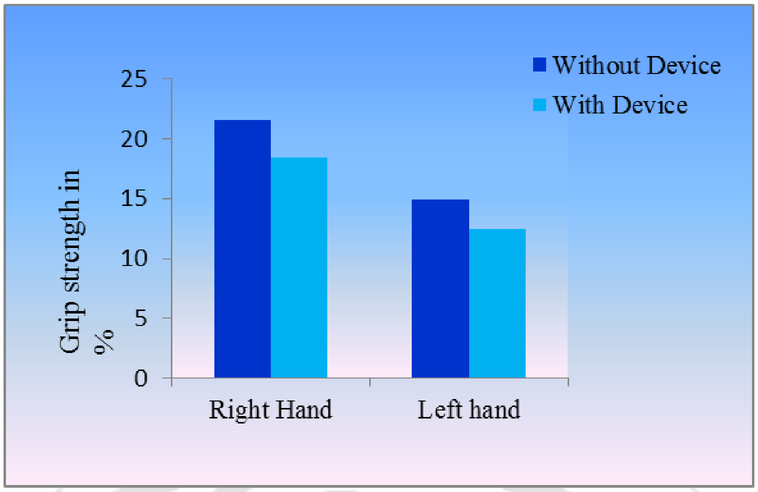


Fig.50: Comparision of Grip strength with and without new device

3.5.3.2 Pinch Strength

Significant difference in pinch strength was observed with test positions. Decrease in pinch strength (the amount of muscle strength loss) was found more in plucking operation when performed without the plucking device i.e., 7.37 percent for right hand and 6.39 percent for left hand as compared to with the plucking device (6.49 % for right hand and 5.22 % for left hand).

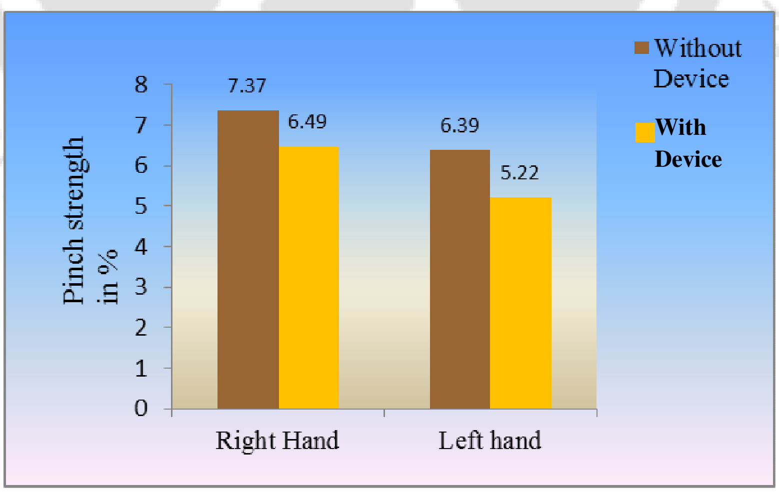


Fig.51 Comparision of pinch strength with and without the new device

3.5.3.3 Dexterity test of hands and arms

Dexterity tests are generally used to assess performance decrease due to performance of repetitive activities for a long duration. In plucking operation significant differences were found in dexterity of the workers before and after the activity (without and with the new device), which was measured in terms of errors and time required in performing the tests.

Analyses of data revealed that:

- Average errors found were:
  - Without the new device :15
  - With the new device :7
- Average time taken for the experimental activity was measured to be as followed:
  - Without the new device :200 Sec
  - With the new device : 110 Sec

From the above observation it can be concluded that due to the dynamic load for repetitive movements in the fingers and static load in arms, decrease in finer and arm muscles coordination were observed when the plucking was done without the new device. It was assessed in terms of numbers of errors and time requirements.

3.5.3.4 Comparison of muscle's electrical activity during plucking with and without blade

Measuring EMG allowed knowing the effectiveness of the new device through the electrical activity of respective muscles involved during the plucking activity. To record the electrical activity of muscles while performing the plucking operation with and without the new device surface electromyography was done with BIOPAC EMG system.

Surface EMG electrodes were placed on the skin (after cleaning the skin) over the surface of 1st *lumbricalis* (responsible for index finger flexion) and over the surface of *abductor pollicis brevis* (responsible for thumb abduction). (the electronic text book of hand surgery)

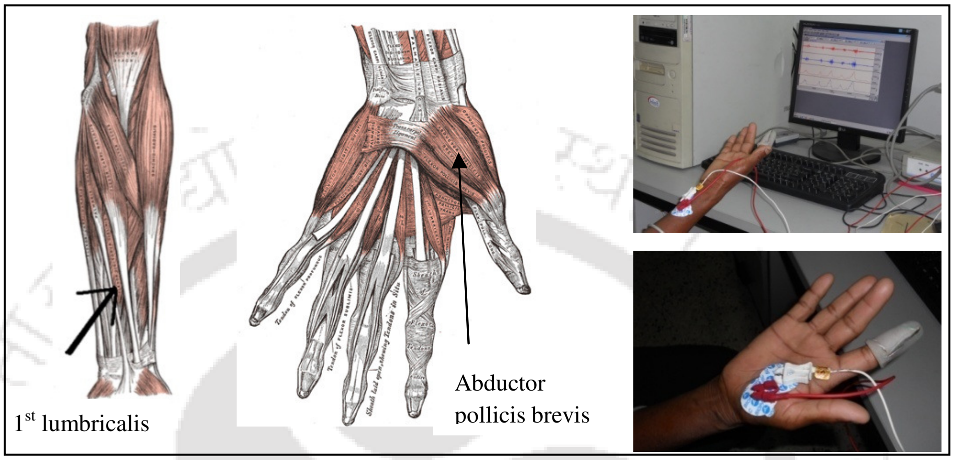


Fig.52: Muscles selected for EMG and placement of electrodes

The preparation of the skin and the location of the different electrodes placements (Fig. 52), were done according to the recommendations of Basmajian and De Luca (1985).

The anatomical localization of the muscles i.e., 1st *lumricalis and abductor pollicis brevis* was done by feel as the subject put them in isometric contraction. The recorded EMG (RMS) values for both the muscles with and without the new device are compared and are presented in figure 53.

From EMG study of *abductor pollicis brevis* (responsible for thumb abduction), it is observed that there is not much difference in EMG values while performing plucking activity with and without the new device. But in case of *1st lumbricalis muscle,* which is responsible for flexion of index finger, shows an obvious decrease in EMG values while performing the activity of tea-leaf plucking with the new device.

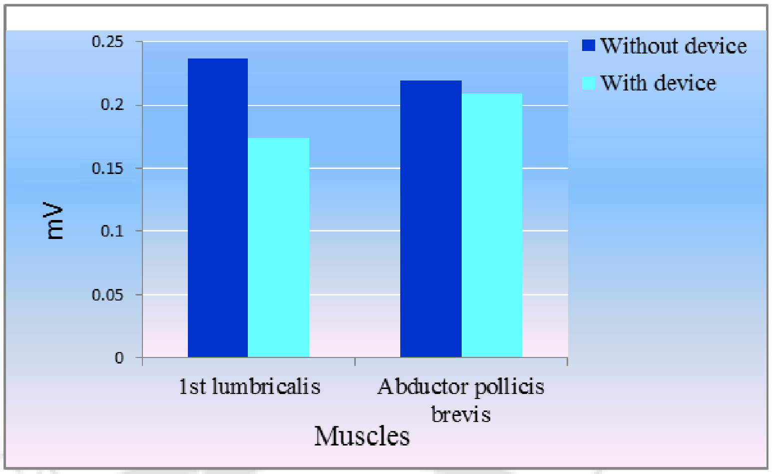


Fig.53: Comparison of muscle activities with and without new device

The higher value of EMG indicated that the muscle strain is higher due to task characteristics. Frequent, long term muscle strain led to quick fatigue and may lead to muscle injury. The new design show visible benefits (Fig.53).

3.5.3.5 Ease of Comfort

As regards to ease of comfort, as an overall opinion expressed by the workers and garden managers, it was found that plucking operation with newly designed device has been considered as comfortable as compared to plucking operation carried out with bare hands. The ease of comfort score was found with the new device was 2.1 i.e., comfortable.

3. 5.3.6 Subjective response of body pain

On the basis of human body map, musculoskeletal problems were determined at three point scale ranging from just noticeable pain, moderate pain and intolerable pain: 1, 2 and 3.

Working with the new device brought about significant reduction in pain relating to finger pain (17.39%) followed by wrist (13.45%), hand pain (10.00%) and elbow pain (10.62%). There was significant reductions in finger cuts were observed while plucking was performed with the new device. In case of finger numbness it was found more i.e. 7.10%. Possible reason for increase in numbness may be workers were habituated to work bare handed and the device initially restricts free finger movements and moreover for day long it tightly covers the finger.

Table 11: Percent reduction in musculoskeletal problems while performing plucking operation with and without using thimble

Body parts	Without plucking device	With plucking device	Significant reduction (%)
Neck pain	2.40	2.40	0
Shoulder pain	2.26	2.13	-5.75
Elbow pain	1.60	1.43	-10.62
Upper back pain	2.06	2.03	-1.45
Lower back pain	2.53	2.53	0
Hand pain	2.00	1.80	**-10.00**
Wrist pain	2.23	1.93	**-13.45**
Leg pain	1.73	1.73	0
Finger pain	2.30	1.9	**-17.39**
Finger numbness	1.83	1.96	+7.10
Finger cuts	2.5	1.83	**26.08**

3.6 Workers overall response on the new device

The final word of design concepts, effectiveness and acceptance comes from the end-user, the workers; their overall views must be brought into confidence. Most tea-leaf pluckers in tea industries are women. The workers volunteered for the study were initially wary of venturing into this unconventional form of work tool. During the study period they participated in the whole developmental process and their suggestions were put in the design concept finalisation. They soon come to value its positive attributes. Higher earnings apart, on the use of a tool also give them a sense of job enrichment and have favorably responded to the new device. The workers found the new device comfortable as it eased out their application of force during plucking along with finger injuries. They felt some kind of finger numbness that they opined it will go away in time.

3.7 Salient features of the design

After the field trials and the evaluation following conclusions were drawn:

1. It satisfies human comfort and safety features,
2. The device was found comfortable by workers,
3. The design of the device was welcomed by the management,
4. Low cost,
5. Light in weight,
6. Acts as an integral part of finger,
7. The device does not impose additional workload on the workers, but it helps in enhancing productivity.

3.8 The final CAD drawing of the new plucking device (Thimble cutter)

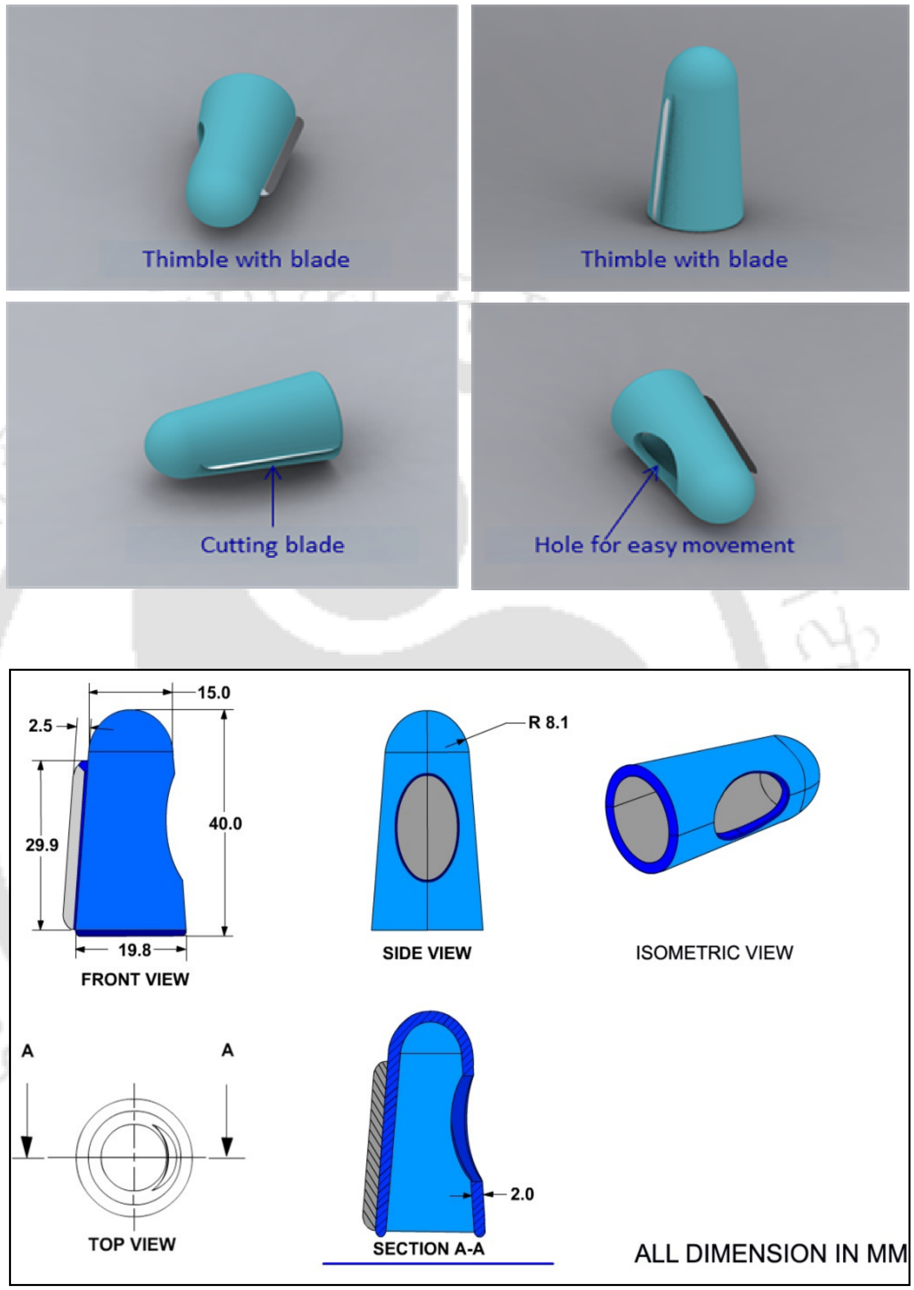


Fig.54: Different parts of plucking device with measurements, 3-D model

In conclusion, design intervention for tea-leaf pluckers studies revealed that the plucking tool was helpful in reducing work related problems among the women workers. The new device has potential in enhancing work performance of the workers without hampering the production efficiency. It is light in weight i.e. approximately 9gm, acting as an integral part of the hand by fitting the fore finger tightly with the guard in thumb, it can also be used on middle finger those who prefer. The results reveal that the device has a significant usage in tea plucking operation (an evident from the above trials results as well as from the management and supervisors collective opinion expressed), however further detailed research is needed to exploit its potential as mass production for industrial use.

Chapter IV

Discussions and Conclusions

4.0 Discussions

The below are the summarised discussions of the study presented in earlier chapter materials:

4.1 Work and occupational risk factors

The inclement of work environment (e.g., primitive work accessories, extreme weather conditions, ergonomic risk factors) occupational stress, accidents, particularly in agro-based industries, there are concerns related to workers' health problems, slow pace of work and other issues of work environment, where ergonomics can bring solution by contributing human compatibility to the work efficiency and productivity justified factors. Ergonomics principles and its application attempt to harmonise work and working environment to promote individual as well as organisational well-being through optimising the effort of the workers. The role of Occupational Ergonomics in the management of occupational stress is to look into measures and methods of prevention of occupational stress.

Work related musculoskeletal disorders mostly expressed through body pain, as a major indicating parameter of occupational stress amongst the workers in industries, are the result of multiple exposures to a combination of risk factors. Controlling of these problems are accomplished by matching workers characteristics and workplaces/work tools/machineries details in a manner that improves worker's efficiency and productivity while decreasing the worker's risk of injury and discomfort.

Therefore, in practice, studying the risk factors in occupational setting in organised way is the correct approach. This is achieved through a combination of employee and supervisor interviews, onsite observation, videotaping while performing the task. Components of the job that involve identified risk factors should be evaluated and quantified wherever possible. The information should then be analysed and modifications of the tasks, methods of performing can be developed. Identification of risk for injury or illness or for musculoskeletal fatigue and quantifying the level of risk by using data on human capabilities is helpful to set priorities for which ergonomics issues should be addressed in work situation.

4.2 Participatory approach of finding betterment

One of the realistic approaches to solve the mentioned problems is participatory approach, in this likely to be beneficiaries take part in the whole developmental process with direct involvement as well as providing feedback strategy. Studies have recently been conducted viewing to increase productivity through participatory approach for design development to suit the working conditions and physical compatibility with women workers (Gandhi, 2009).

Practicing occupational ergonomics in Indian industry is still off the rhythm in spite of its close association with productivity, safety, health and well-being of employees. Possibly because of the defense and academic dominance of ergonomics in the past decades, there have been very few attempts at an organised approach to apply ergonomics in Indian occupational settings, specifically in North East India. There always exits a fundamental difference between practicing ergonomics and academic research.

4.3 Current status: Tea leaf harvesting in Assam and workers

Solution for every problem is unique and varies from shop to shop and industry to industry. Tea industry of Assam is the second largest agro based industry of Assam where women workers are integral part. To increase the productivity in tea leaf plucking, semi-mechanisation and automation has been tried out in the tea growing states of India other than Assam. The tea gardens of Assam do not feel appropriate to go for mechanisation and automation because of compromising quality harvest in comparison to hand plucked method; followed traditionally till today employing women pluckers.

The hand plucking activities performed by workers are subjected to ergonomic risk factors i.e., awkward posture, force, and frequency of action along with inclement of environmental issues. Specifically in tea-leaf plucking operation, handling of low loads at high frequency (repetitive work) is required for the entire shift by the workers. Risk factors in repetitive work in tea-leaf plucking include the frequency of actions; the exposure duration; the postures and movement of body segments; the forces associated with the work, work organisation; job control; demands on work output (e.g. quality, quantity, task precision); level of training/skill. Additional factors include: environmental factors (extreme weather conditions i.e., bright sunshine, rain etc.). Good ergonomic design of work accessories and proper organisation of work are basic requirements to avoid the adverse effects mentioned, the occupational stress.

Based on the symptoms report determined from garden record as well as workers interviews, this study identified a high prevalence of work related musculoskeletal disorders among the tea-leaf pluckers; more than 80% of the studied subjects met the criteria for the condition; shoulder, back, neck and fingers were the most frequently affected body regions. The risk factors associated with the occurrence of these problems were mostly related to work related (awkward work posture, repetitiveness and duration), psychosocial and organizational factors (time pressure, work load, job insecurity, poor social environment) and familial factors (family financial conditions, alcohol consumption habit of both the spouses, and conflict with family members).

The stress results from work environments and family demands may produce increased muscle tension and exacerbate task- related biomechanical strain. This may be due to the fact that work place and family are the two most important aspects in working women's lives, imposing dual load. They deal with home and family issues as well as job stress on a daily basis. Balancing work and family roles has become a key personal and family issue. There are many facets in women worker's lives that subject to stresses. Various factors appear to strengthen the brunt of pressure on women.

4.4 Tea-leaf pluckers' work load analyses

Using correlation and ANOVA analyses as mentioned in chapter III, results suggested that there were significant positive relationship between levels of work related musculoskeletal disorders and family difficulties, psychosocial and organisational demands and work relatedness in workers. There also found statistically significant association between physical and demographic characteristics of the studied subjects i.e., age, BMI, years of experience and the occurrence of symptoms of work related musculoskeletal disorders. These results are consistent with literature on work related musculoskeletal disorders in professionals who also had musculoskeletal and psychosocial demands, familial demands, work demands during work activities (Aptel M, et al 2002), but unfortunately, no studies specifically looking at pluckers were found for comparison.

A substantial body of credible epidemiologic research provides strong evidence of an association between work related musculoskeletal disorders and certain work-related physical factors; when there are high levels of exposure and especially in combination with exposure to more than one physical factor (e.g., repetitiveness for more than two hours, carrying/lifting loads, awkward postures and duration) (Frymoyer and Mooney, 1986; Waters, 1993; Crawford el al., 2008). Available exposure-response data show that work related problems may occur even when workers are exposed to an occupational risk factor on an occasional basis or for a 25 percent or less of the day. In a review of work related health problems prevalence among telecommunications sector workers, reported that the most common body areas affected by discomfort were the neck, shoulders, hand and wrists. Exposures of high frequency for long duration increase the risk of these problems.

In tea-leaf plucking workers engaged in the operation are exposed to the adverse working conditions for the entire shift. As a result in the present study it was found that the workers felt pains in different parts of the body (back pain, finger pain, and arm and shoulder pains) due to constant forward bending posture along with repetitive finger and arm movements. These results are in agreement with Gangopadhyay et al (2003) that musculoskeletal disorders have been positively associated with constant awkward bending postures and repetitive work for prolonged period of time.

Moreover while plucking tea-leaf the workers carry load at back. This may be responsible for their discomfort feeling mainly affecting low back, shoulder and arms. This result was supported by Kivi and Mattila (1991); Wells et al (1997); National Research Council, (2001) and Mathiassen, (2006). According to them forceful exertions, awkward postures, static postures, repetition are associated with the development of work related musculoskeletal disorders.

Ergonomic assessment of work and workplace is one of the starting points to address the problem of work related body pains. Researchers proposed different methods for ergonomic assessment of activities and quantification of ergonomic risk factors. Westgaard (1988) noted that empirical indices serve useful purpose in identification of critical exposures to ergonomic risk factors. In this present study, ergonomic assessment of plucking operation was carried out by quantifying using OWAS, RULA, QEC and Strain Index (OCRA index and OCRA. checklist)

The video-based documentation for the OWAS analysis offered a reliable basis for work environment improvements. The OWAS method was used to identify the action level that needed immediate corrective attention. The poor working postures identified in plucking operation can be avoided by better work tool design.

The RULA score found goes beyond the threshold of ergonomic risk. A closer look into the results reveals that repetitiveness and force handling are the major contributors to the ergonomic risk. Moreover the information on prevalence of work related health problems among the studied workers shows strong evidences of reported symptoms of discomfort in fingers, wrist, shoulder and neck. The QEC scores confirm the results obtained by RULA. However, advantages of using QEC is that QEC gives individual risk scores considering the perception of task demand of a worker working on that task.

Tea-leaf plucking is a highly repetitive activity and workers perform the activity for the entire shift of 440 min^{-day} (starting from 8 a.m. to 5 p.m. with one hour lunch break and 10min break for drinking water). Moreover, the workers are supposed to meet the deadlines of plucked leaves i.e., minimum 23 kg per^{-day}. According to Bongers et al (1993) there is evidence for a causal relationship between highly repetitive work and neck and neck/shoulder pains. In many workplaces, the time to complete a specific unit or cycle of work is less than a few minutes. If the cycle is repeated continuously for 2 or more hours, the work is considered repetitive. Although the energy demands are usually low, the repetitive use of small muscle groups may cause muscle fatigue, and the repeated application of tension in the muscle tendon group and the repeated motion around a joint may cause soreness and inflammation. The repetitive work causes pain and fatigue, which may lead to musculoskeletal disorders, reduced productivity, and deteriorated posture and movement co-ordination. The latter can increase the risk of errors and may result in reduced quality and productivity. When ignored, other disorders may emerge, such as chronic pains.

Most of the epidemiologic study reviews defined “repetitive work” for the neck as work activities which involve continuous arm or hand movements which affect the neck/shoulder musculature and generate loads on the neck/shoulder area (Wells et al 1997, Saiyed and Tiwari, 2004); the tea-leaf pluckers in the present study reported to suffer from neck pain and it was also observed that while performing the plucking operation there involve static loads on arms and shoulders and dynamic loads on fingers and wrist. In the present study repetitive finger and arm movements were measured by using OCRA (using frequency and duration of movements) fulfilled the most stringent epidemiologic criteria, showing strong associations with neck/shoulder/finger MSDs (NIOSH, 2001).

The Strain Index is a tool used to evaluate a job's level of risk for developing a disorder of the hand, wrist, forearm, or elbow. In the present study Strain Index was studied in terms of OCRA Index and checklists.

The average Strain Index (SI) i.e., the OCRA score obtained through video analyses and self-reported SI score of plucking operation was 11 for right hand and 9 for left hand. The majority of the workers were found with high Strain Index. It was very clear from the SI scores that workers engaged in tea-leaf plucking operation is highly exposed to distal upper extremities strain with high repetitiveness for a beyond permissible duration i.e., less than 30 seconds per cycle, or more than 1000 per shift, (Kohn, 1998). This was also seen that as per strain Index the plucking of tea leaf operation was on the need to be improved based on ergonomic considerations. The implementation of Strain Index method showed that the risk of work related health problems may be reduced if the amount of exertion of fingers during the plucking operation could be reduced.

The plucking of tea leaves is a repetitive task having a bad posture along with carrying load at back for the entire shift. It was expected to have fore arm/shoulder/neck, back and finger disorders. Almost every worker studied reported to suffer from back pain and finger injuries. It was found that they feel little or severe discomfort in neck, shoulder, finger and wrist during working hours but they told it remains for short period. The reason for not reporting these disorders could be dominance of back pain and finger injuries/pains over these types of pains.

4.5 Design intervention

It was therefore felt that if plucking twist and pinch force required for individual shoot breaking is reduced it would control other risk factors. Thus designing a plucking device (aid) to assist the plucking operation for lowering the possibility of work related pains of upper limbs was conceived. Assisting the activity with a blade fixed in a thimble like index or middle finger cover can prove to be one of the effective design options. This option would particularly be useful to the existing plucking skills, and improve awkward posture, repetitiveness and duration of activity i.e., plucking time of each shoots.

Design solution has been implemented using participatory approach, taking study volunteer workers in confidence from initiation of concept to trial feedback refinement of the design. Field trials and lab-based testing methods have been used to see the efficacy of new plucking device. Field trials were done in three tea gardens of Jorhat District of Assam, namely Kakojan tea estate, Honuwal tea estate and experimental tea garden of Assam agricultural University. Laboratory experiment in design evaluation, EMG study was done in Ergonomics laboratory of IIT, Guwahati by simulating the work environment.

From the field trials of the new plucking device it was revealed that use of work tools to assist plucking of tea leaves is beneficial. Results from grip strength test, pinch strength test, dexterity test and EMG studies confirmed that with design intervention work related stress in plucking operation can be reduced. It was seen from the field trials that after completion of plucking with the new device there was less reduction of grip strength and pinch strength of the workers (which can be parameters to study the fatigued condition of muscles, Peng-Cheng, 2009) than without the new device. This may be due to the fact that plucking with the new device reduces the efforts required for plucking. Hence, there is less impaired maximum grip strength and pinch strength after completion of activity with the new device while plucking. From the EMG values it was revealed that while plucking, index finger flexes more than that of thumb due to the efforts required. Therefore with a plucking device attached to index finger can reduce the required effort while plucking. That is why, the results show more differences in electrical activity of 1st lumbricalis (flexes index finger) than the abductor pollicis brevis (abducts thumb) while plucking of tea leaves with and without the newly ventured plucking device

5.0 Findings of the present study

In a state like Assam, because of her large population size and low general economic status, the use of manpower may likely to persist on a larger scale in the coming decades. The large work force employed in industries and many other occupations comprises of majority of women (Behal, 1992). To develop economy and social wellbeing in Assam, women workforce should specifically be considered. In this regard women involvement prevalent and promising industry, involves repetitive tasks was looked into and hence tea gardens where women workers are the main workforce was selected as study area. Special attention to women workforce was stressed for developing work tools.

The below are summarized as the salient findings of this research work

5.1 Tea leaf plucking strategy-women intensive:

- In Tea industry of Assam though both male and females are involved at every stages of production, mostly women are involved in tea leaf plucking activity in the tea fields. It was revealed that plucking requires patience and dexterity which is possible by women workers only. The tea planters prefer more women workers than men, because the male workers, who are engaged in plucking during busy season, handle the tea bush roughly and thus harm the plants physically. There is a fall in the quality and quantity of leaves plucked by men. The quality of tea is the summation of the desirable attributes comprising internal and external i.e., aroma, flavor, strength, colour and briskness.

- The tea leaf plucking remains as women preferred task in tea industry.

- It was found that for best quality tea, fine plucking is required which is possible with selective plucking i.e., only two leaves and a bud. It is an artistic job and in tea parlance, is overwhelmingly labour-intensive, relies completely on manual labour. For selective plucking of tea leaves mechanised harvest (with the available machines in the market so far) is not technically feasible. Throughout the tea gardens of Assam, the workers engaged in the operation of harvesting tea leaves manually. Moreover hand-plucked tea (facilitates selective plucking) are very rich in green-leaf biochemical precursors and have higher contents of made-tea quality constituents than mechanised/shear-plucked tea.

- Two leaf and a bud plucking means qualities.

- It is implicit that tea-leaf pluckers engaged in tea fields are exposed to prolonged, static/dynamic working postures involving hand extension, frequent wrist pronation and supination. During plucking, maintaining awkward wrist and elbow postures for extended periods and frequent movements of wrist creates static and dynamic loads on the exposed parts of the body.

- Long duration shoot breaking is painful, force required and repetitive task aggravates the job risk; a plucking device development may be looked into.

* It was noticed that tea plucking is a strenuous work, as the plucker has to carry a basket into which she would collect the leaf. When the basket gets full and heavy, the leaves are weighed and collected and taken to the factory for processing. Women have to pluck the tea bushes in steep terrain, and find their way through rows of tea bushes. Moreover tea plucking is a single task job, involves repetitive movements of whole arm along with an awkward posture. While performing the activity, workers stand in bending position (near neck and back regions) with load at back and arms outstretched to pluck young tea leaves.

- Basket design must fit the body assist smooth movement inside the garden and provide ease of colleting plucked shoots and dislodging.

* Ergonomic risk factors identified in tea plucking operation were awkward posture, long duration (in the entire shift of more than 400 minutes per day workers are involved in monotonous activity), repetitiveness and frequency.

- Intermittent rest-pause facility may be introduced

5.2 Occupational issues and relevant observations

* Occupational load while performing the tea leaf plucking has been assessed by quantifying the ergonomic risk factors by using few ergonomics measuring techniques: OWAS scores, RULA scores, QEC scores, and OCRA index. It was observed that OWAS (maximum 3)and

QEC (above 70%) scores indicated high ergonomic risk factors. RULA score was observed beyond ergonomic risk threshold (Li and Buckle 1998; McAtamney and Corlett, 1993; Moussavi Najarkola, 2005) that was 7. OCRA index. (11 for right hand and 9 for left hand) indicated high risk involvement in plucking operation as the activity is highly repetitive.

- Occupational stress was found prevalent among the workers in terms of psychosocial and organisational stress, familial stress and work related stress. The stressors found were biomechanical (uncomfortable posture at work, repetitiveness and duration), psychosocial factors (time pressure, work load, job insecurity, poor social environment) and familial factors (family financial conditions, alcohol consumption habit of both the spouses, and conflict with family members), etc.
- Injuries were being reported among the workers. Nearly 94 percent of respondents were found to suffer from back pain. Finger and wrist pains were found common among majority of the respondents. Analysis of work area showed i.e., awkward postures, force and repetitiveness which were conducive for development of physical discomfort. More over the workers reported discomfort, or excessive fatigue in body parts, especially low back, neck, shoulder and mostly in fingers.
- Almost every worker studied reported to suffer from back pain and finger injuries. It was found that the workers suffer from severe discomfort in neck, shoulder, finger and wrist. The Nordice questionnaire used to study the prevalence of work related health problems showed that symptoms from the upper limbs were common among the pluckers. High percent of pluckers had experienced some kind of symptoms from the upper limbs during the last 12 months.

- Analysis of Variance (ANOVA) was performed on the data for a significance level of .05 and the results indicated that a significance difference of work related health problems with occupational stress levels (work related, organizational and psychosocial, familial) was observed. From the results it was observed that there were significant differences in the musculoskeletal disorders with the variance of individual (age, years of experience and BMI) factors (i.e., F=18. 028, p=0.000) and the occupational stress(organizational and psychosocial stress: F=41.178, P=0.000; familial stress: F=11.233, P=0.000; work related stress: F= 42.692, P=0.000).

- Ergonomic interventions were deemed necessary to improve working conditions and decrease the level of exposure to health problems risks. This led to see the design development specifically for plucking. Plucking device serves good for tea pluckers.

5.3 Design development

- Newly designed plucking device appeared to be beneficial for assisting the plucking operation. There was reduction in electrical activity of muscles involved in tea plucking (abductor pollocis brevis and 1st lumbricalis) was observed with the new device. There was also less reduction of impaired maximum grip and pinch strength of the workers when plucking operation was accomplished with the new device. Moreover the workers found the tool comfortable as it eased out the exertion during plucking and the device reduces finger injuries.

- Subjective and performance level evaluation indicates future productivity increment as the workers get well acquainted with the new plucking device.

6.0 Conclusion

Work related discomfort and pains are a major occupational health problem amongst the workers in industries. Controlling these problems by using ergonomics begins with identifying exposure to the known risk factors through an on-site assessment of the work being performed. The ergonomics problem-solving technique leads the user through the identification of ergonomic risk factors by body parts first. By generating multiple reasons, each risk is evaluated by asking why it is present. Strategies are generated to reduce the risk; specific short-term and long-term solutions are developed. The preferred solution may be the one that improves the ergonomics of the job and reduces the risk for injury substantially at a relatively low price.

In tea-leaf plucking operation it was essential to develop a new system consisting of work method redesign, work accessories design, and rescheduling of activity.

The newly developed plucking device provides the tea pluckers ease in plucking operation by assisting the activity. It helps in preventing finger injuries. It is evident from ergonomic parameters i.e. grip strength, pinch strength, dexterity and EMG analyses that the new device ensures comfort, safety and productivity.

The study concludes that work related risk factors in development of work related body pains can be reduced, even be avoided with ergonomic interventions. This can be achieved by identifying the risk factors in the activity and finding the proper solution with design intervention. For user friendly design, if participatory ergonomics approach is taken into consideration for design development process, the results become fruitful.

As a concluding statement, this thesis set out to outline an ergonomic approach to harmonise work and working environment to raise productivity and work efficiency and promote individual well-being through optimising the effort of the worker or user. Further it can be concluded that Identification of ergonomic risk factors in occupational settings would help in developments of various contexts specific solutions. With ergonomic solutions work related stressors can be reduced.

The tea-leaf plucking device appears to improve the ergonomic risk factors as well as productivity. Unlike unorganised agro based sector (Ref. chapter I) where design of work accessories are different context and purpose driven; the tea sector being corporate, a corporate decision will implant the design and with a mass use a thorough uplift of productivity increase is expected as well as workers' overall occupational wellbeing would be ensured.

7.0 Suggestions and Recommendations

7.1 Expansion suitability: Lab to land scope

The study was carried out with sample tea gardens and experimentation was done basically in laboratory and final field trials were given on limited number of subjects. The design i.e. thimble like plucking device was carried out to the working model. Mass scale production details and manufacturing requires to be explored. The ergonomic new cutting blade containing thimble like plucking device is filed for patent through Indian Institute of Technology, Guwahati. Now the tea gardens used for this study are being approached for processing and using in their gardens on a technology transfer (from lab to land) point of view.

7.2 Suggestions for further scope of studies including limitations

In North East India women workers are engaged in varied traditional occupations, especially in agro-based industries, namely fruit processing industries, beetle-nut processing industry, *agarbati* industries, craft and cottage industries etc. which are mostly unorganised. Women workers working in these industries are subjected to adverse working conditions due to in availability of proper work accessories/machineries, etc. Moreover whenever technological advancement takes place, men working forces are considered. Therefore initiatives should be taken in considering women workforce while planning context specific design solutions for occupational settings. Therefore prior to planning for design solutions, identification of risk factors where women workers are engaged required to be studied.

Similar studies can be carried out in other areas as garment industries, agriculture, small scale industries, weaving industries where women are the main work force.

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APPENDICES

APPENDIX-A

Questionnaire for field study

Name of the tea garden

Type of organization

a. Private – Proprietor-……… Corporate …….

b. Public- Assam Tea Corporation…………

c. Tea Trading Corporation of India………………

Wage structure for pluckers: …………………

Availability of medical facilities:……………..

Type of plucking:

Hand plucking Yes ……… No……….

Shears plucking Yes ……… No………

Use of machine in plucking Yes……….. No…………

Number of pluckers you have Male Female

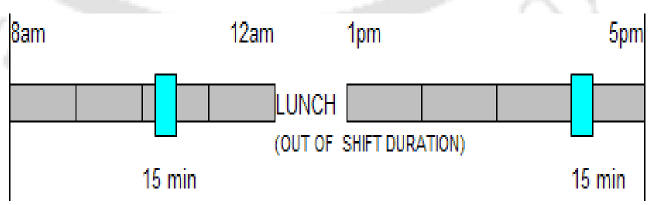
Type of industry: Private ……. Public………. Large………. Small…………

Do you set target: Yes………. No…………..

1. Shift Duration

Workplace	Description	Minutes
Shift Duration	Official	
	Real	
Official Breaks	Official	
Other Breaks	Real	
Lunch Break	Official	
	Real	
Work time considered as recovery	Official	
	Real	
Non repetitive tasks	Official	
	Real	
Net duration of repetitive task		
No. of units per shift	Official	
	Real	
Net duration of cycle time (sec)		
Observed duration of cycle time (Sec)		
% of difference		

How many days a week do you work? ………………..



PAUSE (10 MIN) PAUSE (10 MIN.)

1°h. 2°h. 3°h. 4°h. 5°h. 6°h. 7°h. 8°h. 9°h.

A A A A Lunch A A A A A

Questionnaire and Checklists

Part I Personal Details

1. Name:________________________
2. Age:___________
3. Height: _________ Weight:_________
4. Year of joining in the present job:____________
5. Did you discontinue your job in between these years? Yes__ No__
6. Income of the family:_______________
7. Salary:________
8. Type of family: joint/nuclear/extended
9. No. of family members:______
10. Literacy level: No education/Primary school/Up to high school or above
11. Do you smoke? Yes__ No__
12. Do you consume alcohol? Yes__ No__
13. Days

Part II Medical background

14. Have you ever been told by a physician that you had any of the following?

    Diabetes Yes__ No__ Gout Yes__ No__

    Hypothyroidism/underactive thyroid: Yes__ No__

    Ruptured disc in the neck: Yes__ No__

    Ruptured disc in the back: Yes__ No__

    Rheumatoid arthritis: Yes__ No__

    Carpel Tunnel syndrome: Yes__ No__

15. While performing the activity do you have trouble with pains in different parts of the body?

    Yes ………. No………

    If yes, tick the following:

    Low back pain ……….. Upper back pain………, Neck pain………., Shoulder pain……….

    Elbow pain …………… Finger pain……….. Wrist pain…………, Hand pain …………Leg pain

16. Frequency of occurrence of pains

a) How often you feel pains?

Sl. No.	Pains in body part	Always	Sometimes	Rarely
	Low back pain			
	Upper back pain			
	Neck pain			
	Shoulder pain			
	Elbow pain			
	Finger pain			
	Wrist pain			
	Hand pain			
	Leg pain			
	Finger Numbness			
	Finger injuries			

b) Severity of pains

Sl. No.	Pains in body part	Acute	Less acute	Negligible
	Low back pain			
	Upper back pain			
	Neck pain			
	Shoulder pain			
	Elbow pain			
	Finger pain			
	Wrist pain			
	Hand pain			
	Leg pain			
	Finger Numbness			
	Finger injuries			

17. The General Standardized Nordic Questionnaire perceived symptoms of MSD (Kourinka et al., 1987)

Ache, pain and Discomfort in the musculoskeletal system	Have you experienced ache, pain or discomfort during the preceding 12 months?	Have you during the preceding 12 month been unable to do your daily work because of the ache, pain and discomfort?	Have you experienced ache, pain or discomfort during the preceding 7 days?
	To be answered by all!	To be answered if you have answered Yes in the first column!	
Neck	_ Yes _ No	_ Yes _ No	_ Yes _ No
Shoulders	_ Yes _ No	_ Yes _ No	_ Yes _ No
Elbow	_ Yes _ No	_ Yes _ No	_ Yes _ No
Hands/wrists	_ Yes _ No	_ Yes _ No	_ Yes _ No
The upper back_	_ Yes _ No	_ Yes _ No	_ Yes _ No
The lower back	_ Yes _ No	_ Yes _ No	_ Yes _ No
Hips	_ Yes _ No	_ Yes _ No	_ Yes _ No
Knees	_ Yes _ No	_ Yes _ No	_ Yes _ No
Feet	_ Yes _ No	_ Yes _ No	_ Yes _ No

a) <u>Neck trouble</u>

Have you ever had any neck troubles (ache, pains, numbness, discomfort) Yes ……… No……….

If yes, have you ever hurt neck in an accident? Yes ………No………

If yes, was the accident at work? Yes ………No………..

What was the approximate date of the accident?

Have you ever had to change duties or jobs because of neck trouble?

Yes………. No………..

What do you think brought on this problem with your neck?

Accident………..Sporting activity…………Activity at home

Activity at work………… & other, specify……………………………………..

What year did you first have neck trouble?.........................

How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………

Have you ever been absent from work because of neck trouble? Yes………. No…………………

If yes, how many times? …………………

How many days have you been absent from work with neck trouble in total? ………………….

How many days have you been absent from work with neck trouble in last 12 months ……………….

How often do you get or have had neck trouble?

Daily………., one or more times a week…………,, one or more times a month……………..

one or more times a year …………, one episode of trouble only……………….

What is the total length of time that you have had neck trouble during the last 12 months?

0 day…………1-7 days ………… 8-30 days………… every day …………

Has neck trouble caused you to reduce your activity during the last 12 months? Yes………….... No…………..

What is the total length of time that neck trouble prevented you from doing your normal work? ....

Days………………

Have you been seen by a doctor because of neck trouble during the last 12 months

Yes……………. No……………….

b) <u>Shoulder trouble</u>

Have you ever had any shoulder troubles (ache, pains, numbness, discomfort) Yes ……… No……….

If yes, have you ever hurt shoulder in an accident? Yes ………No………

If yes, was the accident at work? Yes ………No………..

What was the approximate date of the accident?

Have you ever had to change duties or jobs because of shoulder trouble?

Yes………. No………..

What do you think brought on this problem with your shoulder?

Accident………..Sporting activity…………Activity at home

Activity at work………… & other, specify……………………………………..

What year did you first have shoulder trouble ?.........................

How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………

Have you ever been absent from work because of shoulder trouble? Yes………. No…………………

If yes, how many times? …………………

How many days have you been absent from work with shoulder trouble in total? ………………….
How many days have you been absent from work with shoulder trouble in last 12 months ……………….
How often do you get or have had shoulder trouble?
Daily………., one or more times a week…………,, one or more times a month……………..
one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had shoulder trouble during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day …………
Has shoulder trouble caused you to reduce your activity during the last 12 months? Yes…………... No…………..
What is the total length of time that shoulder trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of shoulder trouble during the last 12 months
Yes……………. No……………….

c) <u>Low back trouble</u>

Have you ever had any low back troubles (ache, pains, numbness, discomfort) Yes ……… No……….
If yes, have you ever hurt low back in an accident? Yes ………No………
If yes, was the accident at work? Yes ………No………..
What was the approximate date of the accident?
Have you ever had to change duties or jobs because of low back trouble?
Yes………. No………..
What do you think brought on this problem with your low back?
Accident………..Sporting activity…………Activity at home
Activity at work………… & other, specify……………………………………..
What year did you first have low back trouble?..........................
How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………
Have you ever been absent from work because of low back trouble? Yes………. No…………………
If yes, how many times? …………………
How many days have you been absent from work with low back trouble in total? ………………….
How many days have you been absent from work with low back trouble in last 12 months ……………….
How often do you get or have had low back trouble?
Daily………., one or more times a week…………,, one or more times a month……………..
one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had low back trouble during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day …………
Has low back trouble caused you to reduce your activity during the last 12 months? Yes…………... No…………..
What is the total length of time that low back trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of low back trouble during the last 12 months
Yes……………. No……………….

d) <u>Wrist and hand trouble</u>

Have you ever had any wrist and hand troubles (ache, pains, numbness, discomfort) Yes ……… No……….
If yes, have you ever hurt wrist and hand troubles in an accident? Yes ………No………
If yes, was the accident at work? Yes ………No………..
What was the approximate date of the accident?
Have you ever had to change duties or jobs because of wrist and hand troubles trouble?
Yes………. No………..
What do you think brought on this problem with your wrist and hand troubles?
Accident………..Sporting activity…………Activity at home
Activity at work………… & other, specify……………………………………..
What year did you first have wrist and hand troubles trouble?..........................
How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………
Have you ever been absent from work because of wrist and hand troubles trouble? Yes………. No………………
If yes, how many times? …………………
How many days have you been absent from work with wrist and hand troubles in total? ………………….
How many days have you been absent from work with wrist and hand troubles in last 12 months ……………….
How often do you get or have had wrist and hand troubles?
Daily………., one or more times a week…………,, one or more times a month……………..

one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had wrist and hand troubles during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day …………
Has wrist and hand troubles trouble caused you to reduce your activity during the last 12 months? Yes……….. No………
What is the total length of time that wrist and hand troubles trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of wrist and hand troubles trouble during the last 12 months
Yes……………. No……………….

e) <u>Finger trouble</u>

Have you ever had any finger troubles (ache, pains, numbness, discomfort) Yes ……… No……….
If yes, have you ever hurt finger in an accident? Yes ………No………
If yes, was the accident at work? Yes ………No………..
What was the approximate date of the accident?
Have you ever had to change duties or jobs because of finger trouble?
Yes………. No………..
What do you think brought on this problem with your finger?
Accident………..Sporting activity…………Activity at home
Activity at work………… & other, specify……………………………………..
What year did you first have finger trouble ?.........................
How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………
Have you ever been absent from work because of finger trouble? Yes………. No…………………
If yes, how many times? …………………
How many days have you been absent from work with finger trouble in total? ………………….
How many days have you been absent from work with finger trouble in last 12 months ……………….
How often do you get or have had finger trouble?
Daily………., one or more times a week…………,, one or more times a month……………..
one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had finger trouble during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day ………….
Has finger trouble caused you to reduce your activity during the last 12 months? Yes………….. No…………..
What is the total length of time that finger trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of finger trouble during the last 12 months
Yes……………. No……………….

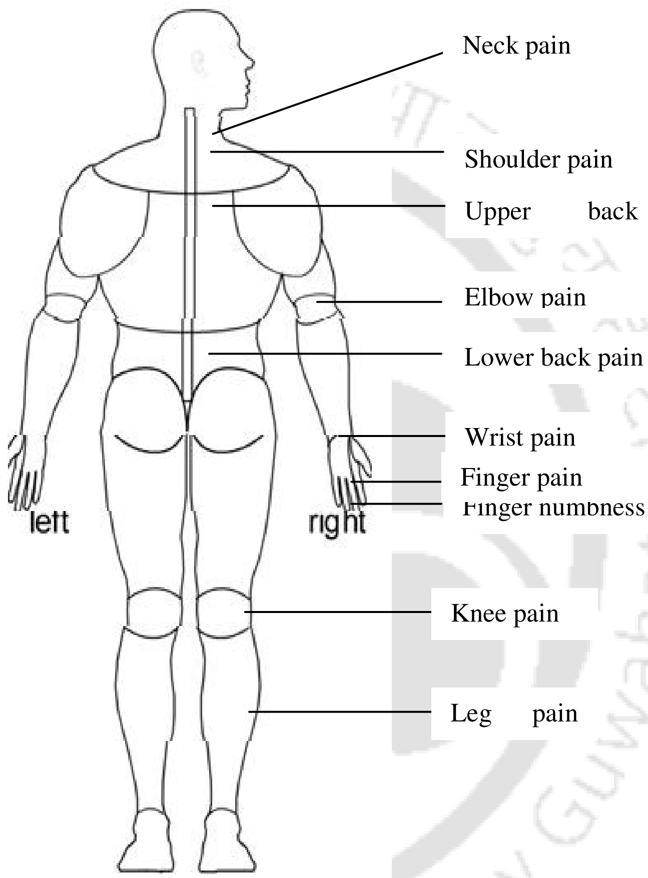
Part IV Occupational stress factors

Sl.No.	Statements	Always 5	Often 4	Sometimes 3	Rarely 2	Never 1
I	**<u>Organizational and psychosocial factors</u>**					
1	We get reward (bonus) in completion of our stated task in time					
2	Poor social environment					
3	Availability of adequate health facilities					
4	Criticism from supervisor makes me upset					
5	My relations with my superiors cause me a great deal of anxiety					
6	Risk of accidents/ snake bite keeps me tense					
7	Fed up by keeping myself busy all the time to meet deadlines					
8	I am fed up to follow the same routine day in and day out					
9	I manage to cope up well with the demands from my work					
10	I wait for the day to come when I can relax					
11	People in the organizations can understand my priorities					
12	Fear of losing the job/job insecurity keeps me tense					

13	My inability to cope with the deadlines leaves me nervous					
14	In able to complete work in time'					
15	My relations with my coworkers cause me a great deal of anxiety					
16	Advice from colleagues when faced with a problem is a rarity in my life					
17	My superiors understand my personal problems with sympathy					
18	My coworkers go out of the way to help me					
19	Satisfaction with recognition you get for good work					
20	Satisfaction with your remuneration					
21	I feel full of energy while at work					
II	**Work related factors/demands**					
1	Monotonous work					
2	Prolonged periods of work without a break					
3	Carrying heavy loads on a repeated basis					
4	Unpleasant physical work condition					
5	An overuse of the muscles on a continued repetitive basis					
6	Poor posture or a badly organised work area that is not ergonomically sound					
7	My workload is unevenly distributed, creating a backlog of work					
8	I must keep my mind on my work at all the time					
9	I need to work very fast					
10	At the end of the day I feel exhausted					
11	Day long working in hot/rainy season is stressful					
12	Fed up of working long hours at my task					
13	Very less rest breaks					
14	There is no flexibility in my job during the shift					
15	Need to follow continual repetition of movements					
16	Need to apply force concentrated on small parts of the body, such as the hand or wrist					
17	A pace of work that does not allow sufficient recovery between movements					
18	Fixed or constrained body positions					
19	Forceful activities					
20	Difficulty in keeping up with the pace of the task during peak season					
III	**Familial factors**					
1	Most of the time I have to force myself to start work					
2	My familial problems come in way of my wok in the industry					
3	Care for ill family member/mother creates constant stress in work					
4	My job often interferes with my family and social obligations or personal n					
5	Looking after household chores along with duty is painful					
6	No cooperation from other family members in household chores					
7	Family financial condition put me in stressful conditions					
8	Conflicts between family members put me in stress					
9	Alcohol consumption habit of family members creates problems					
10	Children do not listen					

APPENDIX - B

Body map used to find out the areas having MSDs



APPENDIX- C

ANLYSIS OF BODY MASS INDEXOF THE RESPONDENTS ACCORDING TO THEIR AGE-GROUPS

N=180

Age groups	Body Mass Index (BMI)					
	Upto 16.0 CED Gr III (Severe)	16.0-17.0 CED Gr II (Moderate)	17.0-18.0 CED GrI (Mild)	18.0-20.0 Weight Normal	20.0-25.0 Gr.I (Obese)	25.0-and above Gr.II (Obese)
Below25 N=30 (16.66)	-	4 (13.33)	13 (43.33)	11 (36.66)	2 (06.66)	-
26-35 N=61 (33.88)	1 (01.63)	21 (34.42)	24 (39.34)	13 (21.31)	2 ()03.27)	-
36-45 N=38 (21.11)	3 (07.89)	6 (15.78)	14 (36.84)	14 (36.84)	1 (02.63)	-
46-55 N=39 (21.66)	4 (10.25)	8 (20.51)	15 (38.46)	12 (30.76)	-	-
Above 55 N=12 (6.66)	3 (25.00)	5 (41.66)	3 (25.00)	1 (08.33)	-	-
Total	11	44	69	51	5	-

APPENDIX - D

ANALYSIS OF MUSCULOSKELETAL PROBLEMS OF THE WOMEN WORKERS ACCORDING TO THEIR AGE

N-180

Age Groups	Musculoskeletal Problems faced (MSDs)										
	Neck pain	Shoulder pain	Upper back pain	Low back pain	Elbow pain	Wrist pain	Hand pain	Finger pain	Finger numbness	Leg pain	Finger cuts
Below25 N=30 (16.66)	26 (86.66)	24 (80.00)	10 (33.33)	27 (90.00)	10 (33.33)	21 (70.00)	18 (60.00)	25 (83.33)	15 (50.00)	10 (33.33)	24 (80.00)
26-35 N=61 (33.88)	52 (85.25)	49 (80.32)	36 (59.01)	55 (90.16)	26 (42.62)	44 (72.13)	46 (75.40)	55 (90.16)	44 (72.13)	33 (54.09)	57 (93.44)
36-45 N=38 (21.11)	36 (94.73)	33 (86.84)	17 (44.73)	36 (94.73)	18 (47.36)	30 (78.94)	28 (73.68)	35 (92.10)	22 (57.89)	25 (65.78)	37 (97.36)
46-55 N=39 (21.66)	37 (94.87)	35 (89.74)	25 (64.10)	39 (100.00)	22 (56.41)	32 (82.05)	33 (84.61)	36 (92.30)	25 (64.10)	29 (74.35)	36 (92.30)
Above 55 N=12 (6.66)	11 (91.66)	11 (91.66)	7 (58.33)	12 (100.00)	4 (33.33)	8 (66.66)	5 (41.66)	10 (83.33)	7 (58.33)	9 (75.00)	10 (83.33)
Total	162	152	95	169	80	135	130	161	113	106	164

APPENDIX-E

ANALYSIS OF MUSCULOSKELETAL PROBLEMS OF THE WOMEN WORKERS ACCORDING TO THEIR YEARS OF EXPERIENCE

N-180

Years of experience (Yr)	Musculoskeletal Problems faced (MSDs)										
	Neck pain	Shoulder pain	Upper back pain	Low back pain	Elbow pain	Wrist pain	Hand pain	Finger pain	Finger numbness	Leg pain	Finger cuts
Below 5 N=24 (13.33)	20 (83.33)	17 (70.83)	11 (45.83)	21 (87.50)	4 (16.66)	18 (75.00)	17 (70.83)	19 (79.16)	11 (45.83)	9 (37.50)	19 (79.16)
5-10 N=32 (17.77)	28 (87.50)	28 (87.50)	16 (50.00)	29 (90.62)	12 (37.50)	23 (71.87)	21 (65.62)	28 (87.50)	16 (50.00)	18 (56.25)	28 (87.50)
10-15 N=59 (32.77)	56 (94.91)	52 (88.13)	33 (55.93)	55 (93.22)	29 (49.15)	42 (71.18)	41 (69.49)	54 (91.52)	39 (66.10)	36 (61.01)	55 (93.22)
15-20 N=34 (18.88)	31 (91.17)	28 (82.35)	24 (70.58)	33 (97.05)	17 (50.00)	26 (76.47)	25 (73.52)	31 (91.17)	24 (70.58)	22 (64.70)	32 (94.11)
Above 20 N=31 (17.22)	27 (87.09)	27 (87.09)	21 (67.74)	31 (100.00)	18 (58.06)	26 (83.87)	26 (83.87)	29 (93.54)	23 (74.19)	21 (67.74)	30 (96.77)
Total	162	152	95	169	80	135	130	161	113	106	164

APPENDIX - F

RISK FACTORS IN WORK RELATED STRESS

N=180

Risk Factors	No. of workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Awkward posture	180	112 (62.22)	48 (26.66)	20 (11.11)	452	2.51	I
Forceful action	180	55 (30.55)	83 (46.11)	42 (23.33)	373	2.07	III
Duration	180	57 (31.66)	79 (43.88)	44 (24.44)	373	2.07	III
Frequency	180	65 (36.11)	72 (40.00)	43 (23.88)	382	2.12	II
Exertion	180	48 (26.66)	77 (42.77)	55 (30.55)	353	1.96	IV
Repetitiveness	180	70	62	48	382	2.12	II

APPENDIX - G

STRESSORS OF ORGANIZATIONAL AND PSYCHOSOCIAL STRESS

Stressors	No. of Workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Job/ task design(Work pressure)	180	121 (67.22)	34 (18.88)	25 (13.88)	456	2.53	I
Work organization	180	73 (40.55)	72 (40.00)	35 (19.44)	398	2.21	III
Technology	180	70 (38.88)	78 (43.33)	32 (17.77)	398	2.21	III
Overload	180	98 (54.44)	74 (41.11)	8 (04.44)	450	2.50	II
Work environment	180	99 (55.00)	72 (40.00)	9 (05.00)	450	2.50	II
Social environment	180	40 (22.22)	82 (45.55)	58 (32.22)	342	1.90	IV
Job insecurity	180	112 (62.22)	46 (25.55)	22 (12.22)	450	2.50	II

APPENDIX - H

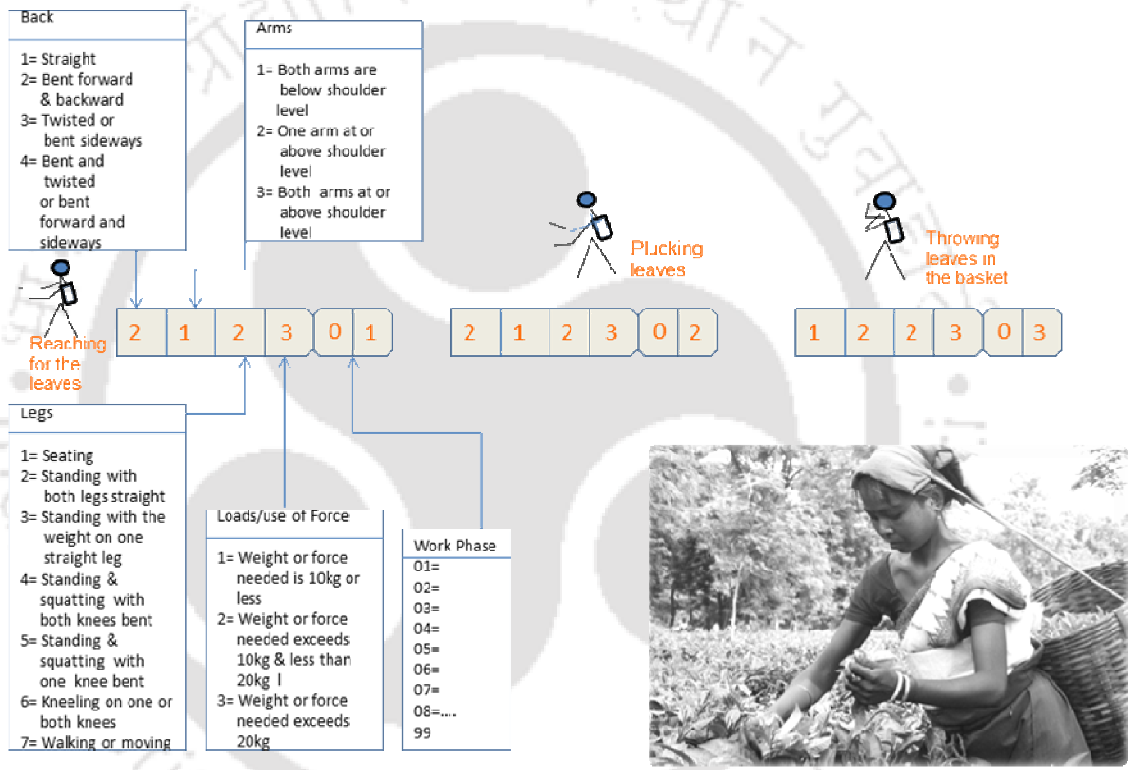
STRESSORS CAUSING FAMILIAL STRESS

N=180

Stressors	No. of workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Financial problems	180	125 (69.44)	38 (21.11)	17 (09.44)	468	2.60	I
No help in household chores	180	23 (12.77)	130 (72.22)	27 (15.00)	356	1.97	III
Conflict with family members	180	63 (35.00)	85 (47.22)	32 (17.77)	391	2.17	II
family environment	180	32 (17.77)	71 (39.44)	77 (42.77)	315	1.75	IV
Alcohol consumption habit	180	61 (33.88)	89 (49.44)	30 (16.66)	391	2.17	II
Cooperation among the family members	180	48 (26.66)	80 (44.44)	52 (28.88)	356	1.97	III

APPENDIX - I

The OWAS code



APPENDIX - J

Scoring table for OWAS

Back	Arms	Leg 1			2			3			4			5			6			7		
	Use of Force	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
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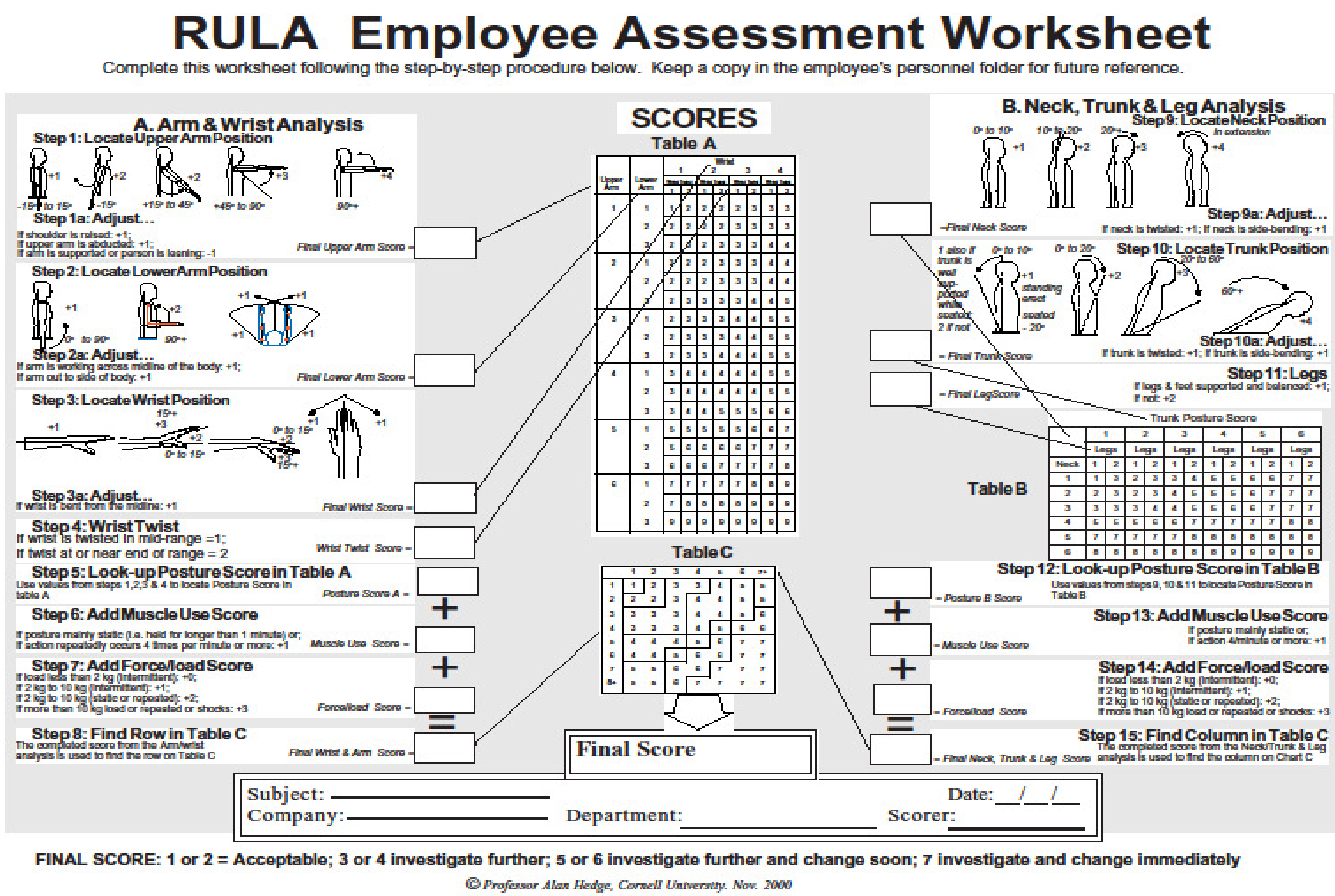
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

APPENDIX - K

Score sheet for RULA



APPENDIX - L

The OCRA check list

APPENDIX - M

Protocol for Quick Exposure Check

Quick Exposure Check (QEC)

QEC has been designed to:

- assess the changes in exposure to musculoskeletal risk factors of the back, shoulders and arms, hands and wrists, and neck before and after an ergonomic intervention
- involve the practitioner (i.e. the observer) who conducts the assessment, and the worker who has direct experience of the task
- indicate change in exposure scores following an intervention

The QEC Guide gives more detailed information about each question and the background to QEC.

Worker's name: ____________________

Worker's job title: ____________________

Task: ____________________

Assessment conducted by: ____________________

Date: __________ Time: __________

Action(s) required: ____________________

For more information on the Quick Exposure Check contact:
The Robens Centre for Health Ergonomics
European Institute of Health and Medical Sciences
University of Surrey, Guildford GU2 7TE
Telephone 01483 689 213
www.surrey.ac.uk/robens/erg

Worker's name ______________________ Date ____________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Exposure Scores Worker's name ____________________ Date __________

Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4 ☐

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5 ☐

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6 ☐

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ________

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4 ☐

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5 ☐

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ________

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1 ☐

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3 ☐

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4 ☐

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5 ☐

Total score for Wrist/Hand
Sum of Scores 1 to 5 ________

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1 ☐

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2 ☐

Total score for Neck
Sum of Scores 1 to 2 ________

Driving

M1	M2	M3
1	4	9

Total for Driving ________

Vibration

N1	N2	N3
1	4	9

Total for Vibration ________

Work pace

P1	P2	P3
1	4	9

Total for Work pace ________

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ________

APPENDIX – N

SPSS output table for Co-efficient Correlation between dependent variables and independent variables

Correlations

		Age values	BMI values	Years of Involvement	MSDs	Stress level values (Organizational)	Stress level values (Familial)	Stress level categories (Phy)	
Age values	Pearson Correlation	1.000	-.801	.955	.296	.862	.656	.314	
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	
	N	180	180	180	180	180	180	180	
BMI values	Pearson Correlation	-.801	1.000	-.772	-.211	-.719	-.483	-.217	
	Sig. (2-tailed)	.000	.	.000	.004	.000	.000	.003	
	N	180	180	180	180	180	180	180	
Years of Involvement	Pearson Correlation	.955	-.772	1.000	.278	.820	.634	.325	
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	
	N	180	180	180	180	180	180	180	
MSDs	Pearson Correlation	.296	-.211	.278	1.000	.290	.312	.050	
	Sig. (2-tailed)	.000	.004	.000	.	.000	.000	.509	
	N	180	180	180	180	180	180	180	
Stress level values (Organizational)	Pearson Correlation	.862	-.719	.820	.290	1.000	.585	.233	
	Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.002	
	N	180	180	180	180	180	180	180	
Stress level values (Familial)	Pearson Correlation	.656	-.483	.634	.312	.585	1.000	.253	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.001	
	N	180	180	180	180	180	180	180	
Stress level categories (Phy)	Pearson Correlation	.314	-.217	.325	.050	.233	.253	1.000	
	Sig. (2-tailed)	.000	.003	.000	.509	.002	.001	.	
	N	180	180	180	180	180	180	180	

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX – N

List of Publications
based on thesis material

International publication

1. **Bhattacharyya, N.** and Chakrabarti, D., Design development scope on women's occupational aspect: Specific reference to local agro based food processing industries in NE India, Work: A journal of prevention, assessment and rehabilitation, Accepted for publication for special issue on Humanizing the work and work environment.(In press).

International Conference publication

2. **Bhattacharyya, N.**, Baruah, M., Pathak, M., Ali N. F., (2008): Physiological stress of women workers engaged in handloom industry, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
3. **Bhattacharyya, N.**, Baruah, S.C., Chakrabarti, D., (2008) Ergonomic Intervention to reduce physiological stress of tea pluckers, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
4. **Bhattacharyya, N.** and Chakrabarti, D., (communicated 2011): Ergonomic basket design to reduce cumulative trauma disorders in tea leaf plucking operation, Paper ID 130, accepted for IEA congress, Brazil February 2012.
5. Chakrabarti, D; **Bhattacharyya, N.**, (communicated 2011): Ergonomic work tools design development strategy for women agro based workers in Northeast India, Paper ID 127, accepted for IEA congress, Brazil February 2012.

National Conference publication

6. **Bhattacharyya, N.** and Chakrabarti, D.,(2008): Design development scope on women occupational aspect-specific reference to different activities in tea industry, Indian Science Congress held in Shillong from Jan. 2008.
7. **Bhattacharyya, N.**, Pandit, S., Chakrabarti, D. (2010): Work related upper limb disorders among the women workers engaged in fruit processing industries of Assam and design development scope, Section XI: Medical Sciences (Including Physiology), Indian Science Congress, Chennai.
8. Pandit, S., **Bhattacharyya, N.,** Chakrabarti, D. (2010): An ergonomics study on women weaver's performance: Design an doccupational assessment in the handloom industries in Assam, Section XI: Medical sciences (Including Physiology), Indian Science Congress, Chennai.

Patent Filed

1. The new plucking device is under process for Indian patent through Research and Development section of Indian Institute of Technology Guwahati (which was filed during the research work in 2010).

APPENDICES

APPENDIX-A

Questionnaire for field study

Name of the tea garden
Type of organization

a. Private – Proprietor-……… Corporate …….
b. Public- Assam Tea Corporation…………
c. Tea Trading Corporation of India………………

Wage structure for pluckers: …………………
Availability of medical facilities:……………..
Type of plucking:

Hand plucking Yes ……… No……….
Shears plucking Yes ……… No………
Use of machine in plucking Yes……….. No…………

Number of pluckers you have Male Female

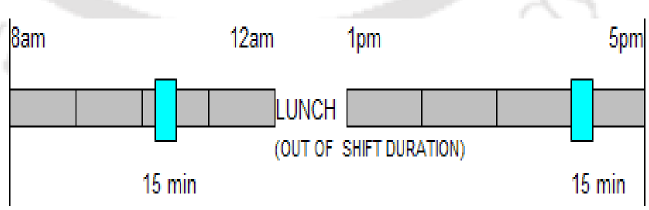
Type of industry: Private ……. Public………. Large………. Small…………

Do you set target: Yes………. No…………..

1. Shift Duration

Workplace	Description	Minutes
Shift Duration	Official	
	Real	
Official Breaks	Official	
Other Breaks	Real	
Lunch Break	Official	
	Real	
Work time considered as recovery	Official	
	Real	
Non repetitive tasks	Official	
	Real	
Net duration of repetitive task		
No. of units per shift	Official	
	Real	
Net duration of cycle time (sec)		
Observed duration of cycle time (Sec)		
% of difference		

How many days a week do you work? ………………..



PAUSE (10 MIN) PAUSE (10 MIN.)

1°h. 2°h. 3°h. 4°h. 5°h. 6°h. 7°h. 8°h. 9°h.
A A A A Lunch A A A A A

Questionnaire and Checklists

Part I Personal Details

1. Name:________________________
2. Age:___________
3. Height: _________ Weight:_________
4. Year of joining in the present job:____________
5. Did you discontinue your job in between these years? Yes__ No__
6. Income of the family:_______________
7. Salary:________
8. Type of family: joint/nuclear/extended
9. No. of family members:______
10. Literacy level: No education/Primary school/Up to high school or above
11. Do you smoke? Yes__ No__
12. Do you consume alcohol? Yes__ No__
13. Days

Part II Medical background

14. Have you ever been told by a physician that you had any of the following?

    Diabetes Yes__ No__ Gout Yes__ No__

    Hypothyroidism/underactive thyroid: Yes__ No__

    Ruptured disc in the neck: Yes__ No__

    Ruptured disc in the back: Yes__ No__

    Rheumatoid arthritis: Yes__ No__

    Carpel Tunnel syndrome: Yes__ No__

15. While performing the activity do you have trouble with pains in different parts of the body?

    Yes ………. No………

    If yes, tick the following:

    Low back pain ……….. Upper back pain………, Neck pain………., Shoulder pain……….

    Elbow pain …………… Finger pain……….. Wrist pain…………, Hand pain …………Leg pain

16. Frequency of occurrence of pains

a) How often you feel pains?

Sl. No.	Pains in body part	Always	Sometimes	Rarely
	Low back pain Upper back pain Neck pain Shoulder pain Elbow pain Finger pain Wrist pain Hand pain Leg pain Finger Numbness Finger injuries			

b) Severity of pains

Sl. No.	Pains in body part	Acute	Less acute	Negligible
	Low back pain Upper back pain Neck pain Shoulder pain Elbow pain Finger pain Wrist pain Hand pain Leg pain Finger Numbness Finger injuries			

17. The General Standardized Nordic Questionnaire perceived symptoms of MSD (Kourinka et al., 1987)

Ache, pain and Discomfort in the musculoskeletal system	Have you experienced ache, pain or discomfort during the preceding 12 months?	Have you during the preceding 12 month been unable to do your daily work because of the ache, pain and discomfort?	Have you experienced ache, pain or discomfort during the preceding 7 days?
	To be answered by all!	To be answered if you have answered Yes in the first column!	
Neck	_ Yes _ No	_ Yes _ No	_ Yes _ No
Shoulders	_ Yes _ No	_ Yes _ No	_ Yes _ No
Elbow	_ Yes _ No	_ Yes _ No	_ Yes _ No
Hands/wrists	_ Yes _ No	_ Yes _ No	_ Yes _ No
The upper back_	_ Yes _ No	_ Yes _ No	_ Yes _ No
The lower back	_ Yes _ No	_ Yes _ No	_ Yes _ No
Hips	_ Yes _ No	_ Yes _ No	_ Yes _ No
Knees	_ Yes _ No	_ Yes _ No	_ Yes _ No
Feet	_ Yes _ No	_ Yes _ No	_ Yes _ No

a) Neck trouble

Have you ever had any neck troubles (ache, pains, numbness, discomfort) Yes ……… No……….

If yes, have you ever hurt neck in an accident? Yes ………No………

If yes, was the accident at work? Yes ………No………..

What was the approximate date of the accident?

Have you ever had to change duties or jobs because of neck trouble?

Yes………. No………..

What do you think brought on this problem with your neck?

Accident………..Sporting activity…………Activity at home

Activity at work………… & other, specify……………………………………..

What year did you first have neck trouble?.........................

How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………

Have you ever been absent from work because of neck trouble? Yes………. No…………………

If yes, how many times? …………………

How many days have you been absent from work with neck trouble in total? ………………….

How many days have you been absent from work with neck trouble in last 12 months ………………

How often do you get or have had neck trouble?

Daily………., one or more times a week…………„ one or more times a month……………..

one or more times a year …………, one episode of trouble only……………….

What is the total length of time that you have had neck trouble during the last 12 months?

0 day…………1-7 days ………… 8-30 days………… every day …………

Has neck trouble caused you to reduce your activity during the last 12 months? Yes…………... No…………..

What is the total length of time that neck trouble prevented you from doing your normal work? ....

Days………………

Have you been seen by a doctor because of neck trouble during the last 12 months

Yes……………. No……………….

b) Shoulder trouble

Have you ever had any shoulder troubles (ache, pains, numbness, discomfort) Yes ……… No……….

If yes, have you ever hurt shoulder in an accident? Yes ………No………

If yes, was the accident at work? Yes ………No………..

What was the approximate date of the accident?

Have you ever had to change duties or jobs because of shoulder trouble?

Yes………. No………..

What do you think brought on this problem with your shoulder?

Accident………..Sporting activity…………Activity at home

Activity at work………… & other, specify……………………………………..

What year did you first have shoulder trouble ?.........................

How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………

Have you ever been absent from work because of shoulder trouble? Yes………. No…………………

If yes, how many times? …………………

How many days have you been absent from work with shoulder trouble in total? ………………….
How many days have you been absent from work with shoulder trouble in last 12 months ……………….
How often do you get or have had shoulder trouble?
Daily………, one or more times a week…………,, one or more times a month……………..
one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had shoulder trouble during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day …………
Has shoulder trouble caused you to reduce your activity during the last 12 months? Yes………….. No…………..
What is the total length of time that shoulder trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of shoulder trouble during the last 12 months
Yes……………. No……………….

c) **Low back trouble**

Have you ever had any low back troubles (ache, pains, numbness, discomfort) Yes ……… No……….
If yes, have you ever hurt low back in an accident? Yes ………No………
If yes, was the accident at work? Yes ………No………..
What was the approximate date of the accident?
Have you ever had to change duties or jobs because of low back trouble?
Yes………. No………..
What do you think brought on this problem with your low back?
Accident………..Sporting activity…………Activity at home
Activity at work………… & other, specify……………………………………..
What year did you first have low back trouble?.........................
How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………
Have you ever been absent from work because of low back trouble? Yes………. No…………………
If yes, how many times? …………………
How many days have you been absent from work with low back trouble in total? ………………….
How many days have you been absent from work with low back trouble in last 12 months ……………….
How often do you get or have had low back trouble?
Daily………, one or more times a week…………,, one or more times a month……………..
one or more times a year …………, one episode of trouble only……………….
What is the total length of time that you have had low back trouble during the last 12 months?
0 day…………1-7 days ………… 8-30 days………… every day …………
Has low back trouble caused you to reduce your activity during the last 12 months? Yes………….. No…………..
What is the total length of time that low back trouble prevented you from doing your normal work? ....
Days………………
Have you been seen by a doctor because of low back trouble during the last 12 months
Yes……………. No……………….

d) **Wrist and hand trouble**

Have you ever had any wrist and hand troubles (ache, pains, numbness, discomfort) Yes ……… No……….
If yes, have you ever hurt wrist and hand troubles in an accident? Yes ………No………
If yes, was the accident at work? Yes ………No………..
What was the approximate date of the accident?
Have you ever had to change duties or jobs because of wrist and hand troubles trouble?
Yes………. No………..
What do you think brought on this problem with your wrist and hand troubles?
Accident………..Sporting activity…………Activity at home
Activity at work………… & other, specify……………………………………..
What year did you first have wrist and hand troubles trouble?.........................
How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………
Have you ever been absent from work because of wrist and hand troubles trouble? Yes………. No………………
If yes, how many times? …………………
How many days have you been absent from work with wrist and hand troubles in total? ………………….
How many days have you been absent from work with wrist and hand troubles in last 12 months ……………….
How often do you get or have had wrist and hand troubles?
Daily………, one or more times a week…………,, one or more times a month……………..

one or more times a year …………, one episode of trouble only……………….

What is the total length of time that you have had wrist and hand troubles during the last 12 months?

0 day…………1-7 days ………… 8-30 days………… every day ………….

Has wrist and hand troubles trouble caused you to reduce your activity during the last 12 months? Yes……….. No………

What is the total length of time that wrist and hand troubles trouble prevented you from doing your normal work? ....

Days………………

Have you been seen by a doctor because of wrist and hand troubles trouble during the last 12 months

Yes……………. No……………….

e) Finger trouble

Have you ever had any finger troubles (ache, pains, numbness, discomfort) Yes ……… No……….

If yes, have you ever hurt finger in an accident? Yes ………No………

If yes, was the accident at work? Yes ………No………..

What was the approximate date of the accident?

Have you ever had to change duties or jobs because of finger trouble?

Yes………. No………..

What do you think brought on this problem with your finger?

Accident………..Sporting activity…………Activity at home

Activity at work………… & other, specify……………………………………..

What year did you first have finger trouble ?..........................

How bad was the pain during the worst episode? Mild …….. Severe ……….very, very severe…………

Have you ever been absent from work because of finger trouble? Yes………. No…………………

If yes, how many times? …………………

How many days have you been absent from work with finger trouble in total? ………………….

How many days have you been absent from work with finger trouble in last 12 months ……………….

How often do you get or have had finger trouble?

Daily………., one or more times a week…………,, one or more times a month……………..

one or more times a year …………, one episode of trouble only……………….

What is the total length of time that you have had finger trouble during the last 12 months?

0 day…………1-7 days ………… 8-30 days………… every day ………….

Has finger trouble caused you to reduce your activity during the last 12 months? Yes………….. No…………..

What is the total length of time that finger trouble prevented you from doing your normal work? ....

Days………………

Have you been seen by a doctor because of finger trouble during the last 12 months

Yes……………. No……………….

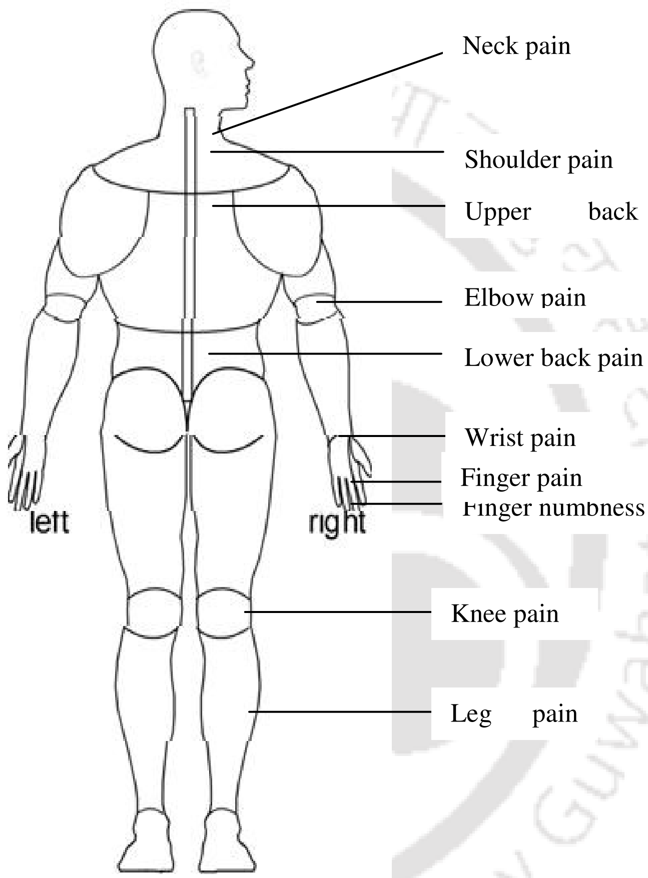
Part IV Occupational stress factors

Sl.No.	Statements	Always 5	Often 4	Sometimes 3	Rarely 2	Never 1
I	**Organizational and psychosocial factors**					
1	We get reward (bonus) in completion of our stated task in time					
2	Poor social environment					
3	Availability of adequate health facilities					
4	Criticism from supervisor makes me upset					
5	My relations with my superiors cause me a great deal of anxiety					
6	Risk of accidents/ snake bite keeps me tense					
7	Fed up by keeping myself busy all the time to meet deadlines					
8	I am fed up to follow the same routine day in and day out					
9	I manage to cope up well with the demands from my work					
10	I wait for the day to come when I can relax					
11	People in the organizations can understand my priorities					
12	Fear of losing the job/job insecurity keeps me tense					

13	My inability to cope with the deadlines leaves me nervous					
14	In able to complete work in time’					
15	My relations with my coworkers cause me a great deal of anxiety					
16	Advice from colleagues when faced with a problem is a rarity in my life					
17	My superiors understand my personal problems with sympathy					
18	My coworkers go out of the way to help me					
19	Satisfaction with recognition you get for good work					
20	Satisfaction with your remuneration					
21	I feel full of energy while at work					
II	**Work related factors/demands**					
1	Monotonous work					
2	Prolonged periods of work without a break					
3	Carrying heavy loads on a repeated basis					
4	Unpleasant physical work condition					
5	An overuse of the muscles on a continued repetitive basis					
6	Poor posture or a badly organised work area that is not ergonomically sound					
7	My workload is unevenly distributed, creating a backlog of work					
8	I must keep my mind on my work at all the time					
9	I need to work very fast					
10	At the end of the day I feel exhausted					
11	Day long working in hot/rainy season is stressful					
12	Fed up of working long hours at my task					
13	Very less rest breaks					
14	There is no flexibility in my job during the shift					
15	Need to follow continual repetition of movements					
16	Need to apply force concentrated on small parts of the body, such as the hand or wrist					
17	A pace of work that does not allow sufficient recovery between movements					
18	Fixed or constrained body positions					
19	Forceful activities					
20	Difficulty in keeping up with the pace of the task during peak season					
III	**Familial factors**					
1	Most of the time I have to force myself to start work					
2	My familial problems come in way of my wok in the industry					
3	Care for ill family member/mother creates constant stress in work					
4	My job often interferes with my family and social obligations or personal n					
5	Looking after household chores along with duty is painful					
6	No cooperation from other family members in household chores					
7	Family financial condition put me in stressful conditions					
8	Conflicts between family members put me in stress					
9	Alcohol consumption habit of family members creates problems					
10	Children do not listen					

APPENDIX - B

Body map used to find out the areas having MSDs



APPENDIX- C

ANLYSIS OF BODY MASS INDEXOF THE RESPONDENTS ACCORDING TO THEIR AGE-GROUPS

N=180

Age groups	Body Mass Index (BMI)					
	Upto 16.0 CED Gr III (Severe)	16.0-17.0 CED Gr II (Moderate)	17.0-18.0 CED GrI (Mild)	18.0-20.0 Weight Normal	20.0-25.0 Gr.I (Obese)	25.0-and above Gr.II (Obese)
Below25 N=30 (16.66)	-	4 (13.33)	13 (43.33)	11 (36.66)	2 (06.66)	-
26-35 N=61 (33.88)	1 (01.63)	21 (34.42)	24 (39.34)	13 (21.31)	2 ()03.27)	-
36-45 N=38 (21.11)	3 (07.89)	6 (15.78)	14 (36.84)	14 (36.84)	1 (02.63)	-
46-55 N=39 (21.66)	4 (10.25)	8 (20.51)	15 (38.46)	12 (30.76)	-	-
Above 55 N=12 (6.66)	3 (25.00)	5 (41.66)	3 (25.00)	1 (08.33)	-	-
Total	11	44	69	51	5	-

APPENDIX - D

ANALYSIS OF MUSCULOSKELETAL PROBLEMS OF THE WOMEN WORKERS ACCORDING TO THEIR AGE

N-180

Age Groups	Musculoskeletal Problems faced (MSDs)										
	Neck pain	Shoulder pain	Upper back pain	Low back pain	Elbow pain	Wrist pain	Hand pain	Finger pain	Finger numbness	Leg pain	Finger cuts
Below25 N=30 (16.66)	26 (86.66)	24 (80.00)	10 (33.33)	27 (90.00)	10 (33.33)	21 (70.00)	18 (60.00)	25 (83.33)	15 (50.00)	10 (33.33)	24 (80.00)
26-35 N=61 (33.88)	52 (85.25)	49 (80.32)	36 (59.01)	55 (90.16)	26 (42.62)	44 (72.13)	46 (75.40)	55 (90.16)	44 (72.13)	33 (54.09)	57 (93.44)
36-45 N=38 (21.11)	36 (94.73)	33 (86.84)	17 (44.73)	36 (94.73)	18 (47.36)	30 (78.94)	28 (73.68)	35 (92.10)	22 (57.89)	25 (65.78)	37 (97.36)
46-55 N=39 (21.66)	37 (94.87)	35 (89.74)	25 (64.10)	39 (100.00)	22 (56.41)	32 (82.05)	33 (84.61)	36 (92.30)	25 (64.10)	29 (74.35)	36 (92.30)
Above 55 N=12 (6.66)	11 (91.66)	11 (91.66)	7 (58.33)	12 (100.00)	4 (33.33)	8 (66.66)	5 (41.66)	10 (83.33)	7 (58.33)	9 (75.00)	10 (83.33)
Total	162	152	95	169	80	135	130	161	113	106	164

APPENDIX-E

ANALYSIS OF MUSCULOSKELETAL PROBLEMS OF THE WOMEN WORKERS ACCORDING TO THEIR YEARS OF EXPERIENCE

N-180

Years of experience (Yr)	Musculoskeletal Problems faced (MSDs)										
	Neck pain	Shoulder pain	Upper back pain	Low back pain	Elbow pain	Wrist pain	Hand pain	Finger pain	Finger numbness	Leg pain	Finger cuts
Below 5 N=24 (13.33)	20 (83.33)	17 (70.83)	11 (45.83)	21 (87.50)	4 (16.66)	18 (75.00)	17 (70.83)	19 (79.16)	11 (45.83)	9 (37.50)	19 (79.16)
5-10 N=32 (17.77)	28 (87.50)	28 (87.50)	16 (50.00)	29 (90.62)	12 (37.50)	23 (71.87)	21 (65.62)	28 (87.50)	16 (50.00)	18 (56.25)	28 (87.50)
10-15 N=59 (32.77)	56 (94.91)	52 (88.13)	33 (55.93)	55 (93.22)	29 (49.15)	42 (71.18)	41 (69.49)	54 (91.52)	39 (66.10)	36 (61.01)	55 (93.22)
15-20 N=34 (18.88)	31 (91.17)	28 (82.35)	24 (70.58)	33 (97.05)	17 (50.00)	26 (76.47)	25 (73.52)	31 (91.17)	24 (70.58)	22 (64.70)	32 (94.11)
Above 20 N=31 (17.22)	27 (87.09)	27 (87.09)	21 (67.74)	31 (100.00)	18 (58.06)	26 (83.87)	26 (83.87)	29 (93.54)	23 (74.19)	21 (67.74)	30 (96.77)
Total	162	152	95	169	80	135	130	161	113	106	164

APPENDIX - F

RISK FACTORS IN WORK RELATED STRESS

N=180

Risk Factors	No. of workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Awkward posture	180	112 (62.22)	48 (26.66)	20 (11.11)	452	2.51	I
Forceful action	180	55 (30.55)	83 (46.11)	42 (23.33)	373	2.07	III
Duration	180	57 (31.66)	79 (43.88)	44 (24.44)	373	2.07	III
Frequency	180	65 (36.11)	72 (40.00)	43 (23.88)	382	2.12	II
Exertion	180	48 (26.66)	77 (42.77)	55 (30.55)	353	1.96	IV
Repetitiveness	180	70	62	48	382	2.12	II

APPENDIX - G

STRESSORS OF ORGANIZATIONAL AND PSYCHOSOCIAL STRESS

Stressors	No. of Workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Job/ task design(Work pressure)	180	121 (67.22)	34 (18.88)	25 (13.88)	456	2.53	I
Work organization	180	73 (40.55)	72 (40.00)	35 (19.44)	398	2.21	III
Technology	180	70 (38.88)	78 (43.33)	32 (17.77)	398	2.21	III
Overload	180	98 (54.44)	74 (41.11)	8 (04.44)	450	2.50	II
Work environment	180	99 (55.00)	72 (40.00)	9 (05.00)	450	2.50	II
Social environment	180	40 (22.22)	82 (45.55)	58 (32.22)	342	1.90	IV
Job insecurity	180	112 (62.22)	46 (25.55)	22 (12.22)	450	2.50	II

APPENDIX - H

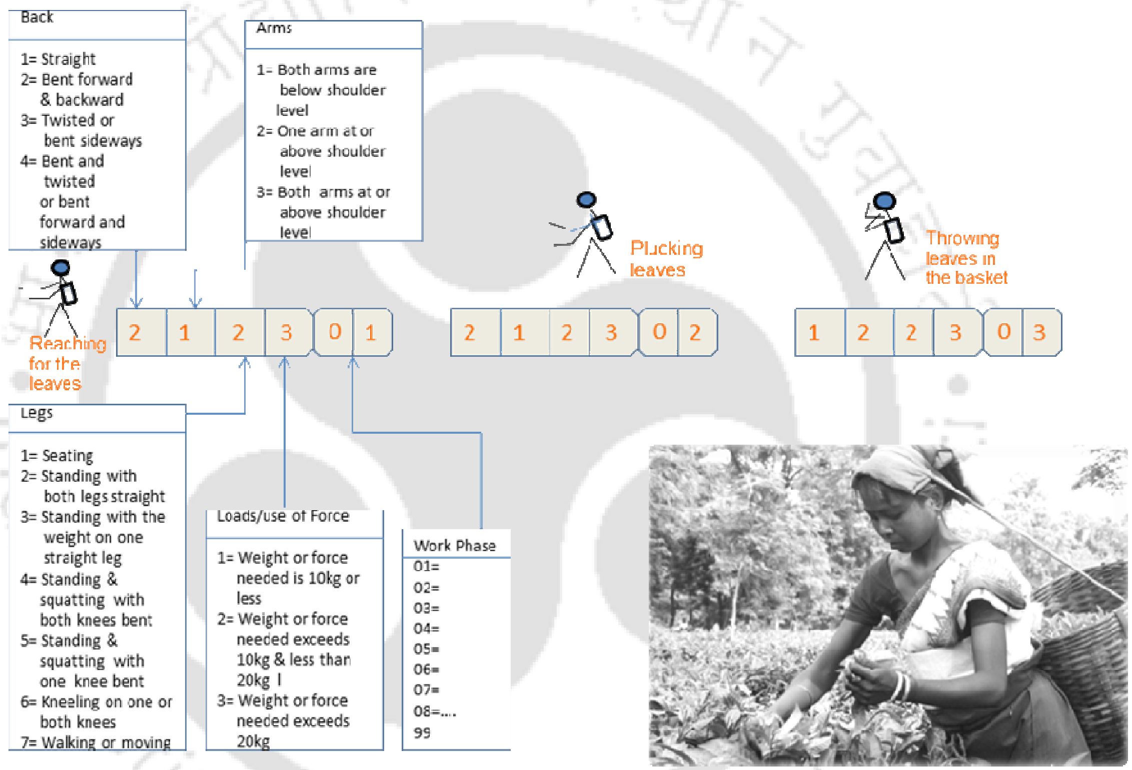
STRESSORS CAUSING FAMILIAL STRESS

N=180

Stressors	No. of workers	Frequency			Wt. Score	Mean Score	Rank
		Always	Sometimes	Never			
Financial problems	180	125 (69.44)	38 (21.11)	17 (09.44)	468	2.60	I
No help in household chores	180	23 (12.77)	130 (72.22)	27 (15.00)	356	1.97	III
Conflict with family members	180	63 (35.00)	85 (47.22)	32 (17.77)	391	2.17	II
family environment	180	32 (17.77)	71 (39.44)	77 (42.77)	315	1.75	IV
Alcohol consumption habit	180	61 (33.88)	89 (49.44)	30 (16.66)	391	2.17	II
Cooperation among the family members	180	48 (26.66)	80 (44.44)	52 (28.88)	356	1.97	III

APPENDIX - I

The OWAS code



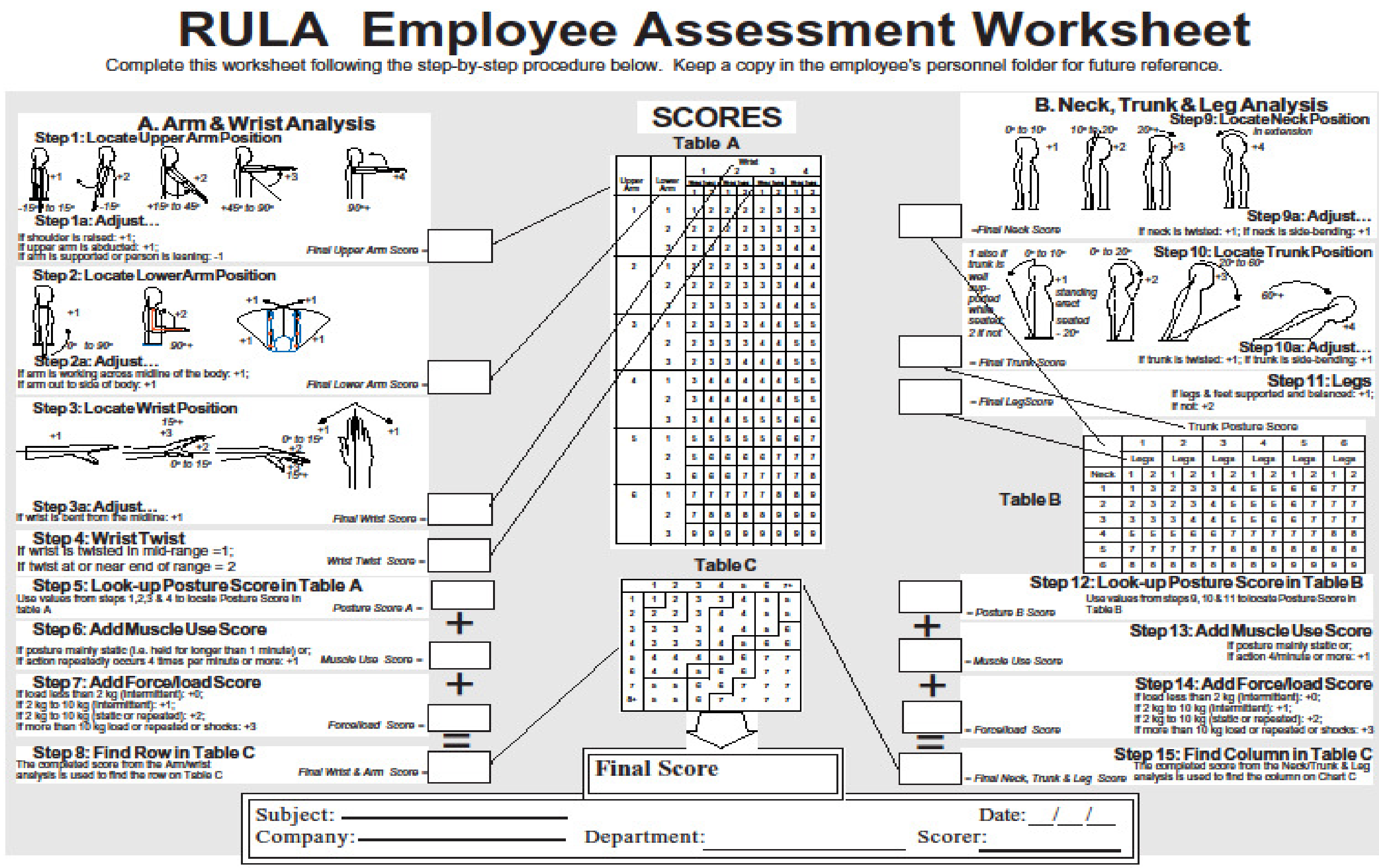
APPENDIX - J

Scoring table for OWAS

Back	Arms	1			2			3			4			5			6			7			Leg
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Use of Force
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1	
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

APPENDIX - K

Score sheet for RULA



FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediately

© Professor Alan Hedge, Cornell University. Nov. 2000

APPENDIX - L

The OCRA check list

APPENDIX - M

Protocol for Quick Exposure Check

Quick Exposure Check (QEC)

QEC has been designed to:

- assess the changes in exposure to musculoskeletal risk factors of the back, shoulders and arms, hands and wrists, and neck before and after an ergonomic intervention
- involve the practitioner (i.e. the observer) who conducts the assessment, and the worker who has direct experience of the task
- indicate change in exposure scores following an intervention

The QEC Guide gives more detailed information about each question and the background to QEC.

Worker's name: ____________________

Worker's job title: ____________________

Task: ____________________

Assessment conducted by: ____________________

Date: __________ Time: __________

Action(s) required: ____________________

____

____

For more information on the Quick Exposure Check contact:
The Robens Centre for Health Ergonomics
European Institute of Health and Medical Sciences
University of Surrey, Guildford GU2 7TE
Telephone 01483 689 213
www.surrey.ac.uk/robens/erg

Robens UniS

Worker's name ______________________ Date ____________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

***L**

***P**

***Q**

Exposure Scores Worker's name ____________ Date ________

Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4 ☐

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5 ☐

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6 ☐

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ________

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4 ☐

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5 ☐

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ________

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1 ☐

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3 ☐

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4 ☐

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5 ☐

Total score for Wrist/Hand
Sum of Scores 1 to 5 ________

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1 ☐

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2 ☐

Total score for Neck
Sum of Scores 1 to 2 ________

Driving

M1	M2	M3
1	4	9

Total for Driving ________

Vibration

N1	N2	N3
1	4	9

Total for Vibration ________

Work pace

P1	P2	P3
1	4	9

Total for Work pace ________

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ________

APPENDIX – N

SPSS output table for Co-efficient Correlation between dependent variables and independent variables

Correlations

		Age values	BMI values	Years of Involvement	MSDs	Stress level values (Organizational)	Stress level values (Familial)	Stress level categories (Phy)	
Age values	Pearson Correlation	1.000	-.801	.955	.296	.862	.656	.314	
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	
	N	180	180	180	180	180	180	180	
BMI values	Pearson Correlation	-.801	1.000	-.772	-.211	-.719	-.483	-.217	
	Sig. (2-tailed)	.000	.	.000	.004	.000	.000	.003	
	N	180	180	180	180	180	180	180	
Years of Involvement	Pearson Correlation	.955	-.772	1.000	.278	.820	.634	.325	
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	
	N	180	180	180	180	180	180	180	
MSDs	Pearson Correlation	.296	-.211	.278	1.000	.290	.312	.050	
	Sig. (2-tailed)	.000	.004	.000	.	.000	.000	.509	
	N	180	180	180	180	180	180	180	
Stress level values (Organizational)	Pearson Correlation	.862	-.719	.820	.290	1.000	.585	.233	
	Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.002	
	N	180	180	180	180	180	180	180	
Stress level values (Familial)	Pearson Correlation	.656	-.483	.634	.312	.585	1.000	.253	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.001	
	N	180	180	180	180	180	180	180	
Stress level categories (Phy)	Pearson Correlation	.314	-.217	.325	.050	.233	.253	1.000	
	Sig. (2-tailed)	.000	.003	.000	.509	.002	.001	.	
	N	180	180	180	180	180	180	180	

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX – N

List of Publications
based on thesis material

International publication

1. **Bhattacharyya, N.** and Chakrabarti, D., Design development scope on women's occupational aspect: Specific reference to local agro based food processing industries in NE India, Work: A journal of prevention, assessment and rehabilitation, Accepted for publication for special issue on Humanizing the work and work environment.(In press).

International Conference publication

2. **Bhattacharyya, N.**, Baruah, M., Pathak, M., Ali N. F., (2008): Physiological stress of women workers engaged in handloom industry, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
3. **Bhattacharyya, N.**, Baruah, S.C., Chakrabarti, D., (2008) Ergonomic Intervention to reduce physiological stress of tea pluckers, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
4. **Bhattacharyya, N.** and Chakrabarti, D., (communicated 2011): Ergonomic basket design to reduce cumulative trauma disorders in tea leaf plucking operation, Paper ID 130, accepted for IEA congress, Brazil February 2012.
5. Chakrabarti, D; **Bhattacharyya, N.**, (communicated 2011): Ergonomic work tools design development strategy for women agro based workers in Northeast India, Paper ID 127, accepted for IEA congress, Brazil February 2012.

National Conference publication

6. **Bhattacharyya, N.** and Chakrabarti, D.,(2008): Design development scope on women occupational aspect-specific reference to different activities in tea industry, Indian Science Congress held in Shillong from Jan. 2008.
7. **Bhattacharyya, N.**, Pandit, S., Chakrabarti, D. (2010): Work related upper limb disorders among the women workers engaged in fruit processing industries of Assam and design development scope, Section XI: Medical Sciences (Including Physiology), Indian Science Congress, Chennai.
8. Pandit, S., **Bhattacharyya, N.,** Chakrabarti, D. (2010): An ergonomics study on women weaver's performance: Design an doccupational assessment in the handloom industries in Assam, Section XI: Medical sciences (Including Physiology), Indian Science Congress, Chennai.

Patent Filed

1. The new plucking device is under process for Indian patent through Research and Development section of Indian Institute of Technology Guwahati (which was filed during the research work in 2010).

SYNOPSIS OF

Ergonomically Designed Intervention towards Occupational Wellness of Women Tea Leaf Pluckers in Assam

A thesis submitted in
partial fulfillment of the
requirement for the degree of

Doctor of Philosophy

By:
Nandita Bhattacharyya
Roll No. 08610502

Under the Supervision of
Prof. Debkumar Chakrabarti

Department of Design
Indian Institute of Technology, Guwahati

September, 2011

Abstract

The Tea Industry is one of the largest employers of women amongst organised agro based industries in North east India, particularly in Assam. Women constitute nearly 51% of the total workforce in Assam. Many of the activities, especially the plucking activity (40 per cent of the total cost of production of tea leaves) performed by the workers in tea plantation demand a high degree of physical effort because of repetitiveness and assuming static awkward posture, leading to early fatigue and work related musculoskeletal problems. To make best way of work performance and increasing overall productivity of the workers an ergonomic interventions study in easing out the ergonomic risk factors in tea garden leaf plucking was carried out that can reduce work related hazards and improve work comfort and productivity.

In order to maintain the quality, the tea garden managements still prefer selective plucking of two leaves and a bud through hand plucking instead of any mechanical development in the process. Thus the present study aims at assessing the current working condition and feasibility of introducing low-cost ergonomic design of work tools that to improve occupational health and the work performance so that finally productivity of the workers can be enhanced with comfort.

Followed by the study of occupational load, the design development of work accessories was identified as a priority area; and the attempt was made to see the feasibility of a tea leaf plucking aid that can be used by individual workers in the tea garden. The new plucking device consists of a cutting blade imbedded on a thimble type finger (index / middle finger) guard. Evaluation of effectiveness of the new device was carried out with subjective opinion, discomfort ratings, selected physiological parameters, productivity and comfort in use. If the breaking of tea shoots (two leaves and a bud) from the tea table can be made easy, the force required and frequency of hand movements can be controlled (new device lessens false hand movements) will ultimately reduce holding of the awkward posture longer; this would facilitate dynamic movement. Thus the new device addresses the ergonomics risk factors responsible for occupational stress as well as productivity and work comfort. Such small development, looking into implementation possibility with the corporate decision, for a vast end users group i.e., women tea-leaf pluckers would result in an effective way.

1. Introduction

A strong relationship exists between the comfort of workers and their productivity. In reality it should be practiced. The main objective of ergonomics is to achieve an optimal relationship between people and their work environment. The conflicting factors in this optimisation process are workers' productivity and physical wellbeing. The physical wellbeing of workers refers to freeing the work related health problems during work. Work related health problems range discomfort, minor aches and pains to more serious medical conditions requiring time off from work and even medical treatment. In more chronic cases, treatment and recovery are often unsatisfactory; the result could be permanent disability and loss of employment.

The ergonomic risk factors, related to work load, are mostly inappropriate design of work method/work tools that quite often refers to specific to health issues such as musculoskeletal disorders (MSDs) and inadequate relationship between workers and their tasks. Specifically it aggravates when women workers are concerned. Among the work force, women workers share income generation work load as well as house hold activities, thus wellbeing in women work force would give a mileage to the society at large. Context specific design intervention improves work performance and overall well being. For design ergonomics, studying the risk factors in occupational setting in organised way could be the correct approach.

This thesis work was based on an assumption that in organized sector many people are engaged in performance of repetitive activity for a considerable duration, causing the workers work related health problems where a specific design development may produce a good result. In this, women dominated work area, specifically tea plucking as representative of organised sector has been taken. Effort was made to see design scope in assisting performance of tea leaf pluckers in tea industry of Assam. The task comprises of two leaves and a bud from the apex tip of tea bushes are plucked by hand and stored in a basket carried during the whole operation.

2. Literature review

Women workers constitute one of the most vulnerable segments of the country's labour force. They often face different workplace health challenges than men do, partly because men and women tend to have different kinds of jobs. They are engaged in a range of work that extends from heavy and inherent psych physical differences to monotonous, repetitive jobs, which are in many times experienced with low-paid and involves in long hours of work. Because of this, men and women experience different job-related problems. In terms of health, women generally have more work-related cases of carpal tunnel syndrome, tendonitis, respiratory diseases, infectious and parasitic diseases, and anxiety and stress disorders compared to men (NIOSH, 2010; Srivastava and Bihari, 2000). Women's workplace healths problems are frequently compounded by getting more of the same at home - the "double jeopardy" of domestic work (Ghoshal, and Chakrabarti, 1987). Due to their double role, they are more exposed to stressful conditions.

All work is designed ideally to improve productivity with efficiency and comfort; most of the health problems and accidents are caused due to unplanned events, and are hence avoidable with appropriate planning and design of work. Study conducted by Brouha (1967), demonstrated a considerable improvement in recovery heart rate responses by partial mechanization of a job requiring human effort. Several ergonomics approaches have been attempted to tackle the occupational health problems in specific work settings in India. Occupational health study is concerned with safety and well being of the workers. As per NIOSH (National Institute of Safety and Health, Ahmadabad), occupational stress is the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources or the needs of the worker (Niedhammer, et al ,1998). In examining the job demand fitness compatibility by Sawkar, Varghese and Saha (2008), it was evident that the relative load (%) on Indian female agricultural labourers was above acceptable limits of workload. With these evidences it is clear that ergonomic research needs to be carried out to ensure job demand-fitness-compatibility in order to make the activities more humane in various jobs context to Indian requirements. Specific stressors parameters, e.g. musculoskeletal disorder may be chosen as a measurement.

Musculoskeletal disorder is one of the indicating parameters of occupational stress, (Halim, Rahman, Omar, Saad, 2004). The term of Musculoskeletal disorder is referred to conditions where the worker experiences discomforts of neck, shoulder, low back, and elbow, hand, hip and knee, as well as multiple joints manifesting ache, tingle, swelling and pains. The economic loss due to those disorders affects not only the individual but also the organization and the society as a whole (NIOSH, 2010). At present, work related musculoskeletal disorder is one of the most important problems ergonomists encounter in the workplace around the world. In many countries, preventing work-related musculoskeletal disorders is considered even as a national priority. Indian studies (as reported in HWWE proceedings under Indian Society of Ergonomics, 2005, 2008, 2009) have shown good progress which is reported in many forum from time to time.

Ergonomists over the years found out a casual relationship between some specific MSDs and the jobs (Van Willy, 1970; Smith, et al 1981). Some of the common MSDs are Carpel Tunnel Syndrome (CTS), thoracic outlet syndrome, tendinitis, cumulative trauma disorders (CTD), Repetitive strain injuries (Putz-Anderson, 1993).Work-related musculoskeletal disorders (WMSDs), the resultant effect of consequences of interaction between different factors/demands are recognized as leading causes of significant human suffering, loss of productivity, and economic burdens on society. WMSDs are a common health problem and a major cause of disability (Bernard, 1997; European Agency for Safety and Health at Work, 1999; Smith et al., 2006

In contrast to many occupational diseases that have their origin in exposure to particular hazardous agents, most musculoskeletal disorders (MSDs) are characterized as multi-factorial that a number of risk factors contribute to causing the problems (WHO, 1991). Findings of scientific research have identified different groups of factors may contribute to MSDs, including workplace related (physical and biomechanical), organisational and psychosocial factors, individual and personal factors, these may act uniquely or in combination (Hagberg et al., 1995; Nordander et al., 1999). On the basis of a number of recent critical reviews of the literature (Burdorf, 1992; Winkel and Mathiassen, 1994; Hagberg, et al., 1995; NIOSH, 1997; Punnett and Bergqvist, 1997), many types of musculoskeletal disorders have substantial work-related component. Many industrial operations are being carried out in awkward postures, repetitive movements and repetitive bending that triggers various MSDs (Mallory and Bradford, 1989; Genaidy, 1995). Ijadunola et.al (2003) observed that, poorly designed workstation and work equipment promote unnecessary physical efforts, which reduce performance efficiency and there by productivity loss also. This is especially true where there is a high level of exposure and where there are combinations of adverse conditions (Hoogendoorn et al., 1999; Ariens et al., 2001; National Research Council and Institute of Medicine, 2001; Riihimaki and Hiihimaki, 2005; Ganguli, 2007), e.g. carrying loads on back, hanging from head with the arms outstretched moving frequently is stressful for the shoulder region, neck and arms (posture assumed by workers during plucking of tea leaves). Epidemiological studies suggested that factors such as job demands, time pressure, and stimulus from work activities are also significantly associated with WMSD development (Bongers, de Winter, Kompier, & Hildebrandt, 1993; Ariëns, van Mechelen, Bongers, Bouter, & van der Wal, 2001; Buckle, 2002; NIOSH, 2002).

Humanizing work and working environment are two of the significant catchwords in today's world of occupational work load and productivity. Safe working conditions are considered as vital contributor to ideal occupational health in most industries. Through ideal occupational health, the productivity and quality of industries can be increased. It can be hypothesised that musculoskeletal problems can be reduced by optimising the biomechanical and psychosocial load at work. In recent years that some workers, trade unions, employers, manufacturers, and researchers have begun to give attention to how workplace/work/work tool design can improve the health of worker and ensure safe working aiming at improved productivity.

Despite high prevalence rates of work-related musculoskeletal disorders, the causes and pathways of development are not fully understood. Multiple factors (physical, psychosocial, and individual) have been associated with WMSD development, but causal inferences are not available due to lack of experimental designs.

Health hazards of women workers have been traditionally under-estimated because occupational safety and health standards and exposure limits to hazardous substances are mostly based on male populations and laboratory tests. The design of machinery and equipment has demonstrated to be a major cause of work related musculoskeletal disorders when is not conceived or not used properly, particularly in the industries, where the operation, requires more of repetitive work and exertions. In the design of equipment and work tools the anthropometric data used do not always reflect the characteristics of the working population who will use it. Most of the personal protective equipment and tools used worldwide are designed based on male populations (Silverstein, Fine, and Armstrong, 1986) that does not appear compatible to the women workers.

Moreover women's issues are often absent from health and safety policies, the hazards involved are either unknown or underestimated, and priorities are defined in male-dominated sectors and occupations. This failure to take account of women's health issues in the workplace constitutes a barrier to frame effective policies on occupational health and equal opportunities specifically in case of Indian workforce scenario where entry of women workers in the erstwhile male dominated and specifically women intensive working is relatively new.

Thus, long term success in controlling these occupational problems depends on understanding their causation. A clear understanding and establishment of the mechanism of problem causation has been somehow elusive. Therefore, an appropriate starting point is required to examine and construct theories of musculoskeletal disorder causation. Ergonomics is relatively young to Indian society compared to its development in the west. In India, ergonomics started in1970s in terms of awareness mainly through academic interests but gained its acceptance as a productive tool has come very recently. It is still an emerging area with heterogeneous nature of research and practices in different spheres of technological needs. The major focus started with analyses, evaluation and optimization of workplace, work methods and tools in agriculture, including informal sectors and mining (Sen, 1984; Nag, 1986). Though many of the work environment studies and work place modifications were made on an ad-hoc basis, these strongly reflected an increasing trend of ergonomics practices (Ramanathan and Nag, 1982) suitable to our country.

The work-related portion of the injuries and resulting disability is potentially preventable and it is important to identify ergonomic interventions that are effective in reducing both the incidence of initial work-related musculoskeletal disorders (WMSD) and/or reducing disability from injuries, their personal costs and the monetary costs associated with them (Frank et al., 1997).

The purpose of the present study was to examine the epidemiologic evidence that associates the prevalent work related problems such as musculoskeletal disorders (MSDs) of the upper extremity and the low back with exposure to different work related factors (physical, work organizational, psychosocial, individual, and socio-cultural factors) at work. The goal of epidemiologic studies is to identify the relevant factors that are associated with the development or recurrence of adverse medical conditions. Understanding these associations and relating them to problem etiology is critical in identifying workplace exposures that can be reduced or prevented.

3. Motivation, objective and scope

An approach of primary prevention will be more appropriate to attack the root of the problems. Understanding of the mechanism of causation of occupational injuries and accidents will put us in a better position to design effective strategies of control and prevention. Ergonomic design of work, machine, tools and equipment and work environment with due consideration of humane capabilities and limitations from the physical (anthropometric), physiological and psychosocial (socio-cognitive issues) points has been recognised as necessary, not only for ensuring health, comfort, and safety of workers, is improving also for effectiveness of the production system.

Workers in different economic sectors generally have work related health hazards which are characteristics of those sectors. People in forestry, construction, and manufacturing have a higher proportion of back injuries. Those working in office type jobs involving key boarding have cumulative trauma disorders (also called repetitive strain injuries). Since it does not happen the other way round, i.e. the heavy physical workers developing cumulative trauma disorder and the office workers injuring their backs, this offers credence to the argument that the nature of the physical stress and the region enduring the load largely determine the affected area and probably the nature of injury (Kumar, 1998). If, therefore, one is able to delineate the mechanism of injuries and the quantitative details of the relevant variables one may be able to develop a more effective intervention. An effective intervention will result in a better control of injuries which clearly has a significant pay-off.

Most designers of agricultural equipment concentrate to improve efficiency and durability, but none seem to give importance to the operator's comfort. The ergo refined tools and implements minimized the drudgery of the workers and also increase the productivity at reduced expenditure levels. In several studies carried out on farm machineries, the available agricultural hand tools/equipment viz., direct paddy seeder, groundnut striper, fertilizer broadcaster, sugar cane harvesting knife, etc. were critically analysed for their ergonomics in order to improve man-machine system efficiency without sacrificing performance, which are still in documentation stage (Gite, et al, 2005; Kathrivel, K. 2009). In North East India such studies in tea fields would provide a development base.

The women workers engaged in highly labour intensive sectors perform both single-task job (single task or combinations of task involving repetitive movements for the entire job timing) and multiple-task jobs (job rotations in between) along with their homemaking responsibilities. They are therefore prone to suffer from work-related diseases, which are further complicated by social, psychological and physiological issues. It is noticed in common, 1 out of 300 female is suffering from some kind of occupation related diseases. It cannot be specifically found in any form of medical record. Shyness, cost of treatment and the fear of losing the job by disclosure of disease retrain them from reporting.

Vast population of women workforce in NE India with varied traditional occupations remained unexplored. The emerging approach for intervention focused on, a pro-active response to stress, with emphasis on preventive measures & elimination **o**f causes of stress, her than on the treatment of its effects. The need of the hour is to study ergonomics principles & context specific criteria & apply in work situations for compatible effective interface between the material resource & human resource & developmental approaches.

The present study was conducted among women workers engaged in repetitive activities, i.e., tea plucking operation to determine WMSD prevalence rate among women workers and to assess the level of exposure to work discomfort and lowered work performance and finally lowered productivity risks. Under the study to support the data on consequential effects of repetitive activity, some other industrial activities (with repetitive movement) i.e. peeling of pineapple and pickle making was also studied. Efforts were also made to study the scope for development of design interventions in both the selected areas. The interaction with the management as well as the workers in tea, the organized sector revealed that a substantial number of workers are engaged in a single task job for considerable shift duration.

A specific design development may produce a good result through a corporate decision. Where as in small unorganized sector workers are engaged in multi-task jobs depending on availability of materials and skill in an unpredictable supply-demand production scenario, the design development may needs context specific approach and the developmental efforts may be participatory. Thus to see the effect of design (work tool) intervention applicable for a large working group with corporate decision tea leaf plucking operation was considered for in depth enquiry.

The goal of the study was to identify factors (such as physical, organizational, psychosocial, and work related factors) that are associated with the development or recurrence work-related problems and the remedial measures through assessing work tool development without affecting normally practiced work method.

3.1 Hypotheses

01 It is assumed that: There is a proportionate relationship between work performance and occupational stressors specific to the work context.

02 Development strategy assumes that there is no significance of variance in terms of severity of MSDs with the variance of age, body mass index (BMI), and years of experience but the method of task performed imposing varied levels of physical stress.

03 Proper work equipment and work tool design improves work performance and occupational wellbeing in terms of work comfort and operational easiness.

3.2 Aim and objectives

Aim:

The study aims at looking into Ergonomic Design Intervention towards occupational wellness of Women tea pluckers and productivity in Assam

Objectives of the study are:

1. To examine the ergonomic risk factors prevailed among women workers in agro based industries specific to tea-leaf plucking activity that influences the work performance and relevant health issues; with reference to work related musculoskeletal disorders (WRMSDs) through body pain and strain feeling in order to select the appropriate methods for development in the present set up.

2. To assess the occupational loads on women workers engaged in tea-leaf plucking activity to identify specific design development of work tools and accessories that suits the specific nature of task requirement.

3. To demonstrate the possible design support viewing to improve tea leaf plucking comfort and easy operation without changing the present method of work culture followed in the tea gardens of Assam.

4. Summary of the research work

In a state like Assam, because of her large population size and low general economic status, the use of manpower may likely to persist on a larger scale in the coming decades. The large work force employed in industries and many other occupations comprises of majority of women (Behal, 1992). To develop economy and social wellbeing in Assam, women workforce should specifically be considered. In this regard women involvement prevalent and promising industry, involves repetitive tasks was looked into and hence tea gardens where women workers are the main workforce was selected as study area. Special attention to women workforce was stressed for developing work tools.

The below are summarized as the salient findings of this research work

4.1 Tea leaf plucking strategy-women intensive

- In Tea industry of Assam though both male and females are involved at every stages of production, mostly women are involved in tea leaf plucking activity in the tea fields. It was revealed that plucking requires patience and dexterity which is possible by women workers only. The tea planters prefer more women workers than men, because the male workers, who are engaged in plucking during busy season, handle the tea bush roughly and thus harm the plants physically. There is a fall in the quality and quantity of leaves plucked by men. The quality of tea is the summation of the desirable attributes comprising internal and external i.e., aroma, flavor, strength, colour and briskness.
  - The tea leaf plucking remains as women preferred task in tea industry.
- It was found that for best quality tea, fine plucking is required which is possible with selective plucking i.e., only two leaves and a bud. It is an artistic job and in tea parlance, is overwhelmingly labour-intensive, relies completely on manual labour. For selective plucking of tea leaves mechanised harvest is not technically feasible as opined by managements in tea gardens of Assam. Throughout the tea gardens of Assam, the workers engaged in the operation of harvesting tea leaves manually.

Moreover hand-plucked tea (facilitates selective plucking) are very rich in green-leaf biochemical precursors and have higher contents of made-tea quality constituents than mechanized/shear-plucked tea.

- Two leaf and a bud plucking means qualities.

- It is implicit that pluckers engaged in tea fields are exposed to prolonged, static/dynamic working postures involving hand extension, frequent wrist pronation and supination. During plucking, maintaining awkward wrist and elbow postures for extended periods and frequent movements of wrist creates static and dynamic loads on the exposed parts of the body.

a) Tearing the shoots by bending with thumb and index/midle finger

b) Plucking by garsping the shoots followed by some matching motion

c) Tearing by bending the shoot, holding from top

Fig. 1: Plucking of tea leaves

- Long duration shoot breaking is painful, force required and repetitive task aggravates the job risk; a plucking device development may be looked into.

- It was noticed that tea plucking is a strenuous work, as the plucker has to carry a basket into which she would collect the leaf. When the basket gets full and heavy, the leaf is weighed and collected and taken to the factory for processing. Women have to pluck the tea bushes in steep terrain, and find their way through rows of tea bushes. Moreover tea plucking is a single task job, involves repetitive movements of whole arm along with an awkward posture. While performing the activity, workers stand in bending position (near neck and back regions) with load at back and arms outstretched to pluck young tea leaves.

- Basket design must fit the body assist smooth movement inside the garden and provide ease of colleting plucked shoots and dislodging.

- Ergonomic risk factors identified in tea plucking operation were awkward posture, long duration (in the entire shift of more than 400 minutes per day workers are involved in monotonous activity), repetitiveness and frequency

  - Intermittent rest-pause facility may be introduced

4. 2 Occupational Issues and relevant observations

- Occupational load while performing the tea leaf plucking has been assessed by quantifying the ergonomic risk factors by using few ergonomics measuring techniques: OCRA index, QEC scores, RULA scores, and OWAS scores. It was observed that OCRA index (11 for right hand and 9 for left hand) indicated high risk involvement in plucking operation as the activity is highly repetitive. RULA score was observed beyond ergonomic risk threshold(Li and Buckle 1998; McAtamney and Corlett, 1993; Moussavi Najarkola, 2005), that was 7. OWAS and QEC (above 70%) scores indicated high ergonomic risk factors.

- Occupational stress was found prevalent among the workers in terms of psychosocial and organisational stress, familial stress and work related stress as the respondents (n=180) expressed during the survey. The stressors found were biomechanical (uncomfortable posture at work, repetitiveness and duration), psychosocial factors (time pressure, work load, job insecurity, poor interpersonal relationship among the fellow workers social environment) and familial factors (family financial conditions, alcohol consumption habit of both the spouses, and conflict with family members), etc.

- Injuries were being reported among the workers. Above 94 percent of respondents were found to suffer from back pain. Finger pain, wrist pain were found common among more than 80 percent of the respondents. Analysis of work area showed i.e., awkward postures, force and repetitiveness which were conducive for development of physical discomfort. More over the workers reported discomfort, or excessive fatigue in body parts, especially low back, neck, shoulder and mostly in fingers.

- Almost every worker studied reported to suffer from back pain and finger injuries. It was found that the workers suffer from severe discomfort in neck, shoulder, finger and wrist. The Nordice questionnaire used to study the prevalence of work related musculoskeletal disorders showed that symptoms from the upper limbs were common among the pluckers. High percent of pluckers had experienced some kind of symptoms from the upper limbs during the last 12 months.

- Analysis of Variance (ANOVA) was performed on the data for a significance level of 0.05 and the results indicated that the two tailed significance of the ANOVA test was 0.000. A significance difference of occupational stress levels (work related, psychosocial and organizational, familial) was observed with age, Body Mass Index(BMI), years of experience of the studied workers engaged in tea plucking operation. A significance difference of WMSDs with occupational stress levels (work related, organizational and psychosocial, familial) was observed.

- Ergonomic interventions were deemed necessary to improve working conditions and decrease the level of exposure to WMSDs risks. This led to see the design development specifically for plucking. Tea basket, plucking device and some methodical improvement together serves good for tea workers.

4.3 Design development

The design development attempt was focused on:

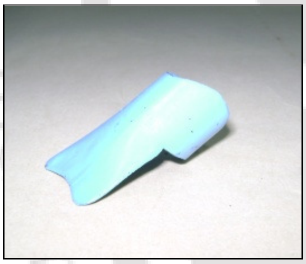
1. Plucking device
2. Basket to collect the plucked leaves.

4.3.1 The Plucking Device

- Ergonomic interventions were deemed necessary to improve working conditions and decrease the level of exposure to health problems. This led to see the design development specifically for tea-leaf plucking operation.

- Traditionally the activity of tea leaf plucking is carried out with bare hands which bruise the fingers of pluckers badly. The activity of tea leaf plucking is highly a repetitive activity involving repetitive muscle contraction for long duration along with an unnatural posture and carrying load at back. To reduce the maximum voluntary contraction of finger muscles (mainly thumb and index finger) during the performance, a plucking device was conceptualized to assist plucking which will not only reduce the MVC but also makes the activity faster. Trials were made. Based on the trials and opinions of the workers new design was developed.

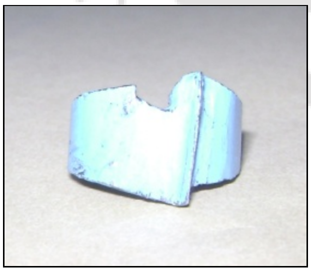
Fig.2: Design conceptualization



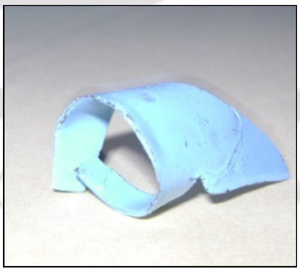
Ring with extended nail

Cutting blade is attached with two rings with

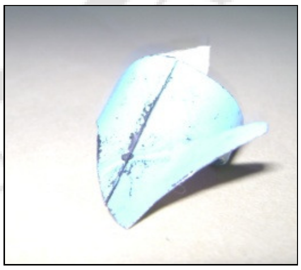
Two ringed blade with thumb guard



Single ring with extended mails



Single ring with extended mails



Single ring with a slanting blade

Fig.3: Interim design development

- The finally designed plucking device is a thimble type of device made out of silicon rubber with a cutting blade embedded facing towards thumb. The device was meant for either forefinger or for middle finger. A thumb guard was also designed. The new device appeared to be beneficial for assisting the plucking operation. There was reduction in electrical activity of muscles involved in tea plucking (adbuctor pollocis brevis and 1st lumbricalis) was observed with the new device. There was also less reduction of impaired maximum grip and pinch strength of the workers when plucking operation was accomplished with the new device. Moreover the workers found the tool comfortable as it eased out the exertion during plucking and the device reduces finger injuries.

- Subjective and performance level evaluation indicates future productivity increment as the workers get well acquainted with the new plucking device.

Salient features of thimble design

- No special training is required
- Easy to make and supply by corporate decision
- Low cost (Approx. Rs. 15.00; calculated against the prototype development)
- Easy to maintain
- Development is along with traditional practice of tea leaf plucking. So special training etc. are not necessary.

Fig.4: The Design details; front and rear views of the Plucking Device

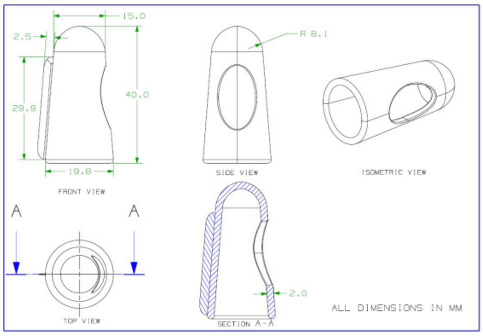


Fig 5: The CAD drawing

Fig. 6. The design trial in field

4.3.2 Improved basket

A modified tea leaf plucking basket, designed under a project on 'ergonomic assessment of postures assumed by women workers in tea cultivation', sponsored by National Tea Research Foundation, Tea Board of India (Bhattacharyya et al, 2003) was used along with the newly designed plucking device. The results of the field trials confirmed that with design intervention in tea leaf plucking operation work related health problems can be reduced along with worker's work performance could be improved.

5. Conclusion

Long hours, unnatural postures, repetitive action and carrying load throughout the shift impose major occupational health problems amongst the women tea leaf pluckers. Controlling work related musculoskeletal disorders by using ergonomics begins with identifying exposure to the risk factors through an on-site assessment of the work being performed. The ergonomics problem-solving technique leads the user through the identification of ergonomic risk factors by body parts first. By understanding multiple reasons, each risk is evaluated by asking what could be the reasons/causes. Strategies are generated to reduce the risk; specific short-term and long-term solutions are developed. The preferred solution may be the one that improves the ergonomics of the job quality and reduces the risk for injury substantially at a relatively low price.

In tea leaf plucking operation it was essential to look into a new system consisting of work method redesign, work accessories design, and rescheduling of activity. The newly developed plucking device provides the tea-leaf pluckers ease in plucking operation by assisting the activity. It helps in preventing finger injuries. It is evident from ergonomic parameters i.e. grip strength, pinch strength, dexterity and EMG analyses that the new device ensure comfort, safety and productivity.

The study concludes that work related risk factors in development of WRMSDs can be reduced, even be avoided with ergonomic interventions. This can be achieved by identifying the risk factors in the activity and finding the proper solution with design intervention. For user friendly design, if participatory ergonomics approach is taken into consideration for design development process, the results become fruitful.

As a concluding statement, this thesis set out to outline an ergonomic approach to harmonize work and working environment to raise productivity and work efficiency and promote individual well-being through optimising the effort of the worker or user. Further it can be concluded that Identification of ergonomic risk factors in occupational settings would help in developments of various contexts specific solutions. With ergonomic solutions work related stressors can be reduced.

The plucking device reduces the ergonomic risk factors as well as improves productivity and comfort. The tea sector being corporate, a corporate decision will implant the design and with a mass use a thorough uplift of productivity increase is expected as well as workers' overall occupational wellbeing would be ensured.

6. Contents/ chapter distribution of the thesis

The outline of thesis is as follows:

1.0 Introduction - Occupational ergonomics in India

1.0.1 Priorities of Ergonomics research, North East specific

1.1 Participation of women workers in economic activities- special reference to Assam

1.1.1 Cases of North East and Assam

4.1 Findings of the present study

4.1.1 Tea leaf plucking strategy-women intensive

4.1.2 Occupational Issues

4.1.3 Design development

4.1.3.1 Salient features of thimble design

4.1.3.2 Salient features of improved basket

4.2 Conclusions

4.3 Expansion suitability: Lab to land scope

4.3 Suggestions for further scope of studies including limitations

7. Publications

7.1 International publication

1. Bhattacharyya, N. and Chakrabarti, D., Design development scope on women's occupational aspect: Specific reference to local agro based food processing industries in NE India, Work: A journal of prevention, assessment and rehabilitation, Accepted for publication for special issue on Humanizing the work and work environment. (In press)

7.2 International Conference publication

2. Bhattacharyya, N., Baruah, M., Pathak, M., Ali N. F., (2008): Physiological stress of women workers engaged in handloom industry, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
3. Bhattacharyya, N., Baruah, S.C., Chakrabarti, D., (2008) Ergonomic Intervention to reduce physiological stress of tea pluckers, International conference on Humanizing Work and Work Environment, 2008, VIT, Pune, December, 2008.
4. Bhattacharyya, N. and Chakrabarti, D. : Ergonomic basket design to reduce cumulative trauma disorders in tea leaf plucking operation, IEA 2012 (abstract accepted, full paper communicated).
5. Chakrabarti, D. and Bhattacharyya, N.: Ergonomic design intervention strategy for work tools development for women agro based workers in North-east India, IEA 2012 (abstract accepted, full paper communicated).

7.3 National Conference publication

6. Bhattacharyya, N. and Chakrabarti, D., (2008): Design development scope on women occupational aspect-specific reference to different activities in tea industry, Indian Science Congress held in Shillong from Jan 2008.
7. Bhattacharyya, N , Pandit, S., Chakrabarti, D. (2009): Work related upper limb disorders among the women workers engaged in fruit processing industries of Assam and design development scope, Indian Science Congress, held in Chennai
8. Pandit, S., Bhattacharyya, N., Chakrabarti, D. (2009), an ergonomic study on women weaver's performance: design and occupational assessment in the handloom industries in Assam, Indian Science Congress, held in Chennai.

Applied for patent for the thimble device through R & D, IITG.

Nandita Bhattacharyya, 26.8.2011

Document for the synopsis to be presented before DC on 2nd September 2011.

Declaration Certificate **October 2011**

I hereby declare that the thesis, entitled “Ergonomically Designed Intervention towards Occupational Wellness of Women Tea Leaf Pluckers in Assam” is being submitted in the partial fulfillment for the award of Ph.D. degree, is an authentic work of my research work carried out during the period from July 2008 to October 2011in the Department of Design, Indian Institute of Technology Guwahati under the supervision of Prof. Debkumar Chakrabarti. The matter presented in this thesis has not been submitted by me earlier for any other degree or diploma.

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