Study on work posture and muscle load of cane and brass-metal artisans of Assam, intending to reduce occupational stress with relevant design solutions: An Ergonomics intervention

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This thesis material presented here in by Mr. Abhijit Das was undertaken under my guidance and supervision. The volume of work presented here in for the Degree of Doctor of Philosophy of Indian Institute of Technology Guwahati was not submitted by him earlier for any other degree of diploma.

He has undergone four specified courses and fulfilled all the requirements as mentioned in the rules and regulations for submitting the thesis for PhD degree of Indian Institute of Technology Guwahati.

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Preface

Occupational health and safety is one of the major concerns in any work settings. Poor workplace design, low work standards and lack of ergonomics considerations altogether imposes ill effect on performance and productivity which also causes potential health injuries, accidents and even death. This situation is very worse in unorganised production units, small scaled industries, crafts and cottage sectors. The workers in these sectors are working with prevailed occupational stressors, like awkward and static posture, poorly-designed hand tools, environmental stressors like heat, humidity, and noise, long work shift without proper rest which leads them to develop musculoskeletal and other relevant occupational disorders.

Ergonomics/human factors always works for human comfort, safety, and better productivity. Applications of ergonomics criteria and guidelines have always been found successful in reducing occupational hazards with appropriate design solutions. Greater success have been observed in large industrial sectors, corporate offices, semi and medium scaled industries in developed as well as in developing countries but it has failed to provide its impact to that extent in small scaled industries, crafts and cottage units, home-based production sectors specially in developing countries like India due to lack of systematic research investigations.

In India, the plentiful natural resources make it enable to set crafts, cottage, and home-based production units. North-eastern parts of this country specially Assam, Tripura, Arunachalpradesh and Manipur have abundant natural cane and bamboo, thus these regions are enriched with cane and bamboo based crafts units. Fine artistic sense of craft artisans of this region especially in Assam have got translated into décor and design of wood, brass metal, and pottery products.

Craft artisans in cane, bamboo, wood, brass metal, and other relevant sectors in Assam and other neighbouring sates of North-east India use traditional methods for making their craft products. The hand tools are made by themselves with their own technology know-how backup. Most of these crafts units are home-based, sometimes it is cooperative-society based and hence there is no fixed work duration, and industrial laws and regulations are not followed. Artisans choose their own work duration and rest suitable for their own requirement. There are no appropriate guidelines for safe work practices with lack of or no ergonomics considerations.

Research investigations from ergonomics perspective are very limited in Indian crafts and cottage sectors, and particularly in North-east, no study has been conducted so far from ergonomics point of view in cane, bamboo, wood, and brass metal sectors of Assam. Thus artisans of these sectors are far away from ergonomics benefits.

The present study has tried to highlight some prevailed occupational health and safety issues in cane, bamboo and brass metal production units of Assam with appropriate design solutions.

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Abhijit Das

Summary of the research

Individual's performance, productivity, occupational health and safety is greatly influenced by the way task is being performed, hand tools used, and posture is adopted. While performing a particular or set of tasks, individual adopts a particular posture or set of postures for varied duration which is either task defined or seating device dependant (e.g. work place seating-standing posture using chair and other related supportive devices). This is observed in most of the occupational settings, especially in offices and industrial workplaces. In most of the cases, these postures make individual to remain confined in a particular place. Individuals are also seen to adopt various leg-extended and cross-legged postures on floor with or without seating devices as seen in many traditional ways of working in small scaled, crafts, and cottage sectors in India. In these work settings, persons can change postures at their own will and hence these postures are freely adopted.

A large number of total work populations in Assam, North-east India, earn their livelihood from crafts and cottage sectors. No much ergonomic studies have been conducted specifically addressing the occupational health and safety issues in Assam crafts and cottage production units. The plentiful natural resources in Assam, makes it enable to set cane and bamboo production units. The strength, beauty, form and utility of brass and bell metal products along with fine artistic sense of craft artisans also have made brass metal products famous for their décor and design. The artisans, in both cane and metal crafts production units, produce different crafts items by performing their tasks in traditional way, using traditional hand tools, and adopting various leg-extended, knelling, cross-legged, and squatting postures on floor with or without proper seating devices. They are far away from safety guidelines and technological know-how input. Their prolonged work duration, low work standards, improper workplace design, ill-structured jobs, mismatch between body physical and physiological abilities and job demands impose ill-effect on performance and productivity which requires

ergonomics interventions with specific design solution to ease out the working conditions.

Muscles' electrical activity always provides researchers very good information for determination of posture and work load stress. During performance of different activities including adoption of a particular posture individual's voluntary muscles contract to exert force. For greater exertion of force, muscle has to contract strongly. If this force generation takes place in lesser time, muscles are driven into stress which can lead to muscular fatigue. Any activity or any posture which require greater utilisation of muscle energy or force can act as potential hazards for muscular fatigue that have been noticed in many work settings specifically in unorganised, crafts and cottage sectors where people are not aware of.

An ergonomic intervention in designing work equipment and workstation can improve work posture and reduce muscle stress by offering freeness in postural changes at workers' own pace and will, which would benefit the production scenario. In office work environment, success has been noticed while implementing this concept with new office furniture design idea that allows users to change posture freely. Corporate sectors also have benefited and some studies are being done in industrial sectors, involving large scale production units with application of varied workstations where workers do get opportunity to change posture freely.

In unorganised sectors, e.g., cane and metal work area, a similar approach would be beneficial by proper design and development of hand tools and work stations which in turn need to be evaluated to show its benefits in occupational stress reduction as well as improving production. Even small development considering huge number of likely beneficiaries, there will be a greater impact in performance and productivity. With this hypothesis, the study aims at to see effects of easy to use designing of work tools and workstations on the work posture adopted by the artisans for carrying out different work activities in order to reduce workload expressing through muscle stress, and improve performance and productivity.

The objectives of this study are:

- To find out prevalence of occupational stressors in cane crafts and brass-metal cottage sectors;
- Assessment of postural load on body muscles, applying EMG technique;
- To apply Ergonomics participatory approach for design development;
- To see role of free postural adoption on human performance and productivity.

Study locations and subjects

Cluster of cane crafts and brass metal cottage sectors in Assam were selected for this study. Total 100 craft artisans who are engaged in cane and metal crafts production units were visited and interacted in person. Of them, 30 artisans, 15 each from cane and brass metal crafts were involved for relevant laboratory experimentation.

Work methods and adopted postures analysis

Detailed observation of individual task performed by the cane crafts and brass metal artisans were done at their production premises and their adopted postures were recorded using Sony DVD movie camera. It is observed that for making cane crafts item, artisans perform following activities sequentially: a) Cane sharpening b) Cane straightening c) Cane cutting d) Cane strips and fiber making e) Cane bending f) Knitting and binding g) Polishing. Out of which the artisans opined fiber making is the most painful task which requires to work with a traditional knife and while working with it they have to fix themselves in a typical posture for total work duration. This activity was specifically chosen for a tool development to ease the task and postural improvement to workload.

For making different brass metal item, brass-metal artisans perform following activities: a) Sheet cutting b) Shape making c) Brazing d) Polishing. The polishing activity appears to be more time consuming and stressful where people opined for modification of existing system. A design attempt was taken where the work surface is elevated to a certain height so that squatting on the ground level may be avoided.

Artisans of both cane and metal crafts production units adopt various floor-seated crossed leg, squatting, and leg extended postures. To understand the occupational stress in existing work method, hazardousness of their adopted postures were analysed using ErgoMaster Software based on OWAS, RULA, and REBA methods. The same have also been used to evaluate the design developments attempted in this study.

Using ErgoMaster Software, relevant OWAS, REBA and RULA scores reveals, most adopted postures for different cane crafts making activities are low hazardous except for cane bending and straightening, which are medium hazardous. Adopted postures for different brass metal activities are medium hazardous except for brazing activity which is low hazardous.

Measurement of joint angles and range of joint motion

Joint angles measurement of selected postures of all cane crafts and brass metal activities they normally follow with traditional equipment and methods were carried out in Ergonomics Laboratory of IIT Guwahati to get various flexion, extension, and deviation values of different joints using Electro-Goniometer and Goniometric methods. Biopac System software was used for analysing the collected data and to get different joint angles and range of joint motion values.

From joint angle analysis, it is observed, for performing various cane crafts making activities, joint motions and range of joint movements are within comfortable limits. Where as, for brass metal artisans, abnormal range of joint movement for shape making and polishing activity is seen.

Determination of Muscle Activity

In order to observe the major muscular activity/load to maintain a posture and to perform a task or a set of tasks, electrical activity of selected muscles while performing different cane and metal crafts making task in commonly adopted posture was determined using surface electromyography method. For cane craft artisans, EMG signal was recorded while performing different tasks, e.g., cane sharpening, cane straightening, fiber making and cane bending activities where as for brass-metal artisans EMG signal was recorded while performing sheet cutting and polishing activities. Raw EMG signal was processed to get root mean square (RMS) EMG and mean power frequency frequency (MPF) values.

Both cane and metal craft artisans adopt various cross legged and leg extended postures on floor which allow them to change their postures freely as per their will. Only fiber making activity for cane craft artisans does not allow them to change posture because its operation requires operator's leg support to hold a typical knife while making cane fibers.

Surface EMG study shows, percentage of MVC utilisation is highest for cane bending activity followed by cane straightening, cane sharpening, and cane fiber making activity. High RMS value is found for trapezius muscle, followed by pectoralis major and erector spinae for all cane making activities. Remained in static position for prolonged duration leads static postural load in fiber making activity which transparent the needs of design intervention.

For metal craft artisans, high RMS values of all three muscles have been observed in both sheet cutting and polishing activities. This is due to, the way, by which, these two tasks are performed make extreme joint movements and subsequently, produce stress to neighbouring muscles. In order to reduce muscle stress, this also transparent a need for ergonomics design interventions.

Selective design development

From EMG study, it is observed, fiber making activity for cane craft artisans and polishing for brass metal artisans are stressful, because it utilizes greater muscle force. To reduce muscle stress and postural loading, design development of a new polish machine was carried out for brass metal artisans with elevated platform along with applied force is shifted from upper body to lower leg muscles because new polish machine is foot paddle driven. For cane artisans, to minimise static postural loading on muscle, traditional fiber making tool was modified in such a way that facilitates to adopt combination of postures rather than remained in static posture for entire fiber making duration. In whole design development process participatory approach was adopted.

Usability evaluation of newly developed polish machine and fiber making tool

Subjective performance level evaluation of both these developed products was carried out in field and its productivity is noted.

Laboratory evaluation of users' comfort, safety and work load was determined by using subjective and objective performance level study, and their usefulness to reduce specific muscle stress was measured using EMG technique. The recorded data was then analysed for its comparison. The productivity increment has also been observed.

Usability evaluation of newly developed tool and work station indicates, new polish machine is more productive and its operation is less stressful for muscles as evidenced by low RMS and %MVC utilisation of three selected muscles. Modified fiber making tool for cane artisans also have proved to provide comfort, safety and better productivity as this allow free change of posture.

Discussion

Crafts making is one of the leading profession in entire North-east India, especially in Assam. Craft artisans use traditional hand tools and perform their tasks in traditional way. As their work equipment and workplace are far away to get benefits from industrial safety norms, occupational hazards and safety is greatest concern in their occupational settings.

For making crafts items, crafts persons use traditional hand tools, which are made by their traditional technological know-how. They are not very much reluctant to change their hand tools even though it provokes physical stress to them. Most of them feel pain and discomfort while at work or during rest in all parts of body, especially in region of neck, back, wrist and knees. This is more in case of brass metal artisans due to their job types and used tools which make extreme joint deviations and exert greater load on task and posture maintaining muscles; and thus produces varied levels of muscle stress. Crafts artisans carry on their work as their body allow them to do so; there is no retirement age. There is no fixed time limit for their work; they work for 12 hours and sometimes for 4 to 5 hours when they are engaged in some other activities and usually they work for 7 days per week

In this study it has been investigated prevalence of occupational hazards and stressors, how does traditional work methods along with hand tools influence posture and muscle load of the crafts artisans. The EMG has been used as an analytical tool to evaluate muscle stress. All developed criteria, methods and design solution have been implemented using participatory approach, so that the development process go along with the intended users' capabilities and acceptability to use within their resource limitations. Both lab-based and field trial and testing methods have been used to see the efficacy of newly developed methods and design. All lab experimentations were done in Ergonomics Laboratory of IIT Guwahati. Experimental set up was developed in such a way that it should provide them feeling of their real work environment.

It is noted, the high electrical activity of upper Trapezius, Pectoralis Major, and Erector Spinae muscles for shape making and sheet cutting brass metal activities are due to repetitive motion and extreme range of joint movement that produce greater muscle load in existing set up. Prolonged static posture also can act as potential muscle stressor as seen in existing fiber making cane crafts activity which is expressed with high RMS values.

Newly developed polish machine for brass artisans and modified fiber making tool for cane crafts person provides better facility to adopt/change posture freely, reduce prolonged static postural burden, and decrease extreme range of joint deviation along with shifting of load from larger to smaller muscle groups reduces muscle stress and chances of muscles to become fatigue. This is evidenced by relevant EMG studies. The design features and specifications are made in such simple form that common artisans or entrepreneurs can make these without much technological complexity and cost; which are easy to repair and maintain.

Conclusion:

This study concludes prevailed physical stressors in unorganised cane and brass metal crafts occupational settings can be reduced, even be avoided with proper Ergonomics interventions. This can be achieved by developing work tool and workstation which in turn improve the task and work process with facility to change posture freely as per users' own will and pace with involvement of larger muscles group for force production and fine muscles for skilled movement. For users' friendly design solution, if participatory approach is taken into consideration for design development or task modification where direct beneficiaries are involved in whole developmental process, the results become more fruitful and sustainable.

The volunteered crafts person involved in this study are highly motivated to have these designs in their workplaces, specially polishing workstation they are very much willing to install.

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Chapter - I

Introduction

Occupational Ergonomics: Need justification to study North-East India crafts and cottage industries through design development and EMG based postural evaluation

1.0. Introduction:

Ergonomics, the science, technology, and art of man at work aims at improving the working conditions and working life of the workers by optimizing human-machine-environment interactions. In design of work and everyday life situations, the focus of ergonomics is man. Unsafe, unhealthy, uncomfortable or inefficient situations at work or in everyday life are avoided by taking account of the physical and psychological capabilities and limitations of humans. A large number of factors play a role in ergonomics; these include body posture and movement (sitting, standing, lifting, pulling and pushing), environmental factors (noise, vibration, illumination, climate, chemical substances), information and operation, as well as work organization. These factors determine to a large extent safety, health, comfort and efficient performance of man at work and in everyday life (J. Dul and B. Weerdmeester, 2001). In developed as well as in developing countries diseases of the musculoskeletal system and psychological illnesses in occupational work settings are due to poor design of equipment, technical systems, and tasks and there is inadequate relationship between operators and their task. This can be reduced by taking better account of human capabilities and limitations when designing work and everyday-life environments (F. Tayyari and J.L. Smith 1997).

1.1. Occupational Ergonomics and Indian context

Occupational ergonomics is a solution-oriented branch of ergonomics rather than just an evaluation of work-related problems. Its goal is to optimize worker well-being and productivity by treatment of the work stressors. Ergonomics interventions are preventive, before injuries occurred, thereby avoiding future medical treatments (Iikka Kuorinka , 1995). It is the domain of ergonomics that provides ability to apply information regarding occupational stressors, human capabilities and limitations while working in designing system that people use, work process they follow, and the workplace in which they operate safely, comfortably and efficiently.

Indian Context

India is the second most populous country of the world with about 102 million people, and its unemployment rate is huge even at the present time. Although, there is very limited numbers of large industrial/organised sectors, its major work populations are earnings their livelihood from small scaled industries, unorganised sectors, crafts and cottage industries and home-based production units.

Large organised industrial sectors, corporate offices follow ergonomics safety norms, and implement ergonomics criteria and guidelines in order to fulfil government regulation and to get various global certifications. Ergonomics considerations are lacking in production premises of small scale industries, crafts and cottage sectors and home-based production units. Prevailed occupational stressors in their workplace lead them to develop injuries and other health related disorders which ultimately reflect in productivity. Thus application of occupational ergonomics has become more and more necessary in the progress and development of the country as a whole, not only in large industrial sectors but also in all spheres of production premises.

1.1.1 Occupational Ergonomics in small-scaled industry, crafts and cottage sectors of India:

Small scale industry in India is heterogeneous, ranging from crafts, home based production units to high technology initiatives. The small-scale industries do not practice many common and basics principles of ergonomics and quite often experiences injuries and high accidents rates. There is lack of specialised function to take care of ergonomics safety and health. Industrial norms, laws and regulations are not practiced here. Large, medium and organised industrial sectors follow certain guidelines to get ISO certification, which does not seem in small scale industrial sectors as they do not go for the same. The struggle for productivity is a continuous concern in small scaled industrial sectors. All in together, make their work environment hazardous and create bad impact on workers health which in turn affects performance and productivity and to lead a dignified life.

Various levels of training programmes are organised by various groups, (governmental as well as NGOs), with different objectives which is mostly focused on sales, getting market and production process; but quite often it is noticed that while developing new products or giving it to a new market oriented shape, design ergonomics criteria does not get its proper utility acceptance by the users, sometimes these become low quality or remain within a sympathetic craft item image.

If work tools are developed and work conditions and methods of production are to be in tune to ergonomics principles, the scenario would obviously become different. The question arises, how this can be implemented and towards achieving this, what steps can be taken (Kroemer K and Grandjean E, 1997). Considering vastness of population and varied degrees of production process to cater local as well as larger market- context specific approach would be appropriate.

Lack of necessary resources for specific improvements in working conditions of small scale industrial, crafts and cottage sectors of India even in cases where workers' safety and health are in danger together need context specific ergonomics research interventions. Thus ergonomics is having very fertile soil in Indian small scale industries and can offer a mean to improve workers' health and safety ensuring better performance and productivity.

1.1.2 Centre and agencies practices different ergonomics issues in India: a brief account

In India, several research and educational institutes are practicing ergonomics, (Fig. 1). National institute of occupational health (NIOH) is looking after occupational health and safety concerns in social and organizational context. Defence Institute of Physiology and Allied Sciences (DIPAS) deals with health and safety issues for defence personnel. Central Labour Institute (CLI) is looking after ergonomics issues in industries. Organized industrial sectors are having occupational health and safety management cells looking after health and safety of industrial workers,

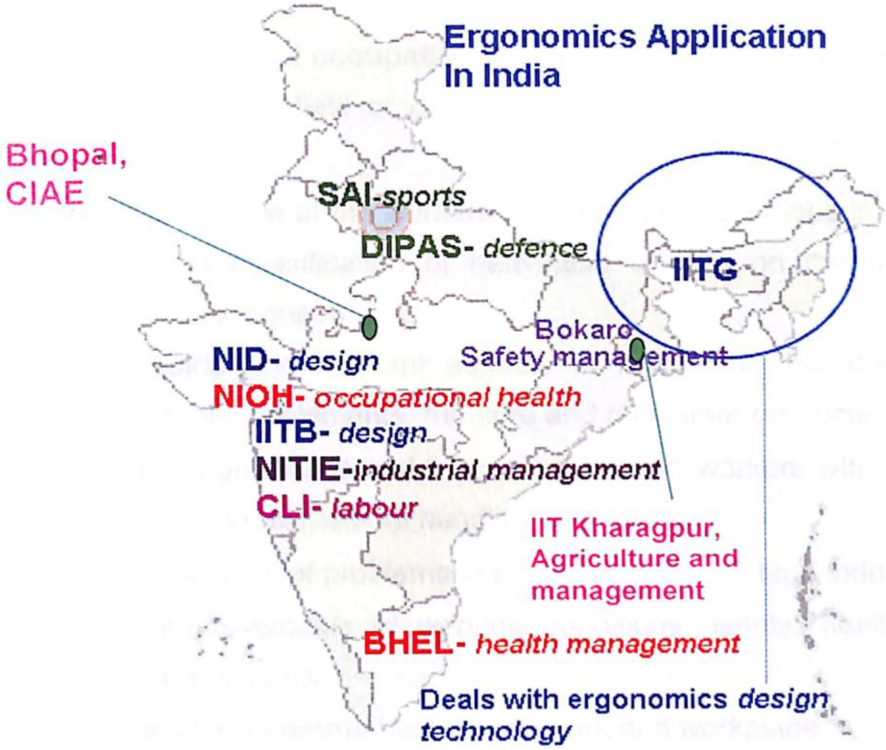


Fig. 1 Ergonomics Research centres in India, looking after different activities.

e.g., Bharat Heavy Electrical limited (BHEL) and Bokaro Steel Plant, etc. CIAE, Central Institutes for Agricultural Engineering, all India coordinated program on ergonomics and safety in agriculture is going on and one of the objectives are to relieve drudgery in agricultural practise. Several educational institutes are engaged in Ergonomics education and research, e.g., Indian Institute of Technology (IITs), National Institute of Design (NID), NITTE, Calcutta University, and Vidyasagar University. Bureau of Indian Standard (BIS) is making Indian contextual recommendations which mainly consider tasks, work process, and products to be more reliable to function, safe in operation and friendly to use. Scattered and scanty studies on relevant information generation and context specific applications with beneficial effects have been reported from time to time by various agencies and academician – towards a consolidated approach, BIS is now working through its subcommittee PG32 with members taken from experts of relevant ergonomics expertise in India.

1.1.3. Different aspects of occupational ergonomics researches in India

In India research work in field of occupational ergonomics is done in the following areas:

- Energy expenditure of the workers in different types of jobs in various factories, and classification of heaviness of jobs on the basis of physiological responses.
- Anthropometric and relevant aspects in relation to the design of machines, tools, implements, furniture and consumer products.
- Problems of agricultural and other unorganized workers with special reference to manual material handling and safety.
- Ergonomic solution of problems in small-scale and cottage industries.
- Low-cost improvements of working conditions, safety, health, and welfare of the workers.
- Postural analysis towards humanising work and workplace.
- Training programmes for workers, supervisors, trade union officers, managers, government executives, NGOs, etc., to bring awareness of ergonomics to people at all levels including the general populous.

In the unorganised sectors, such as in agriculture and among manual labourers in various occupation – e.g., masons, carpenter, blacksmith, construction workers, household workers, and service workers such as laundry workers, barbers, handloom workers, cobblers and about 8 million handicrafts workers in India – the use and application of ergonomics are much less common than in the organised sectors. This is due mainly to a lack of awareness of the basic principles, poor economic conditions, and reluctance to change existing and traditional work methods and tools. A little ergonomic improvement at the individual level would yield in total a very significant quantitative effect as Indian is having huge population to reflect upon the benefit. Specific production sectors may need specific attention than to make a thumb rule type generation; because need, local condition, know-how expertise, skills, raw material availability and market are different. North-east part of India enjoys a totally different socio-geographical nature than other part of the country. The products and production scenario is also unique. After studying the need, development specific to this region may be tried out/implemented. The same is to be carried out to other locations with some modifications relevant to that context.

1.1.4. Crafts and cottage in North-East India

North-East part of India falls under tropical rain forest zone and is very rich in flora and fauna. These plentiful natural resources have got translated into the décor and design in almost all the artifacts and work of artisans in handloom and handicraft products. This has not only raw material but fine artistic sense of people have made this region rich in handicrafts and handloom.

Artefacts using natural materials

Assam and its neighboring states are very rich in cane and bamboo tress. Assam has probably the maximum resources for the cane and bamboo products in India, comparable with Canada and the Scandinavian countries like Sweden, Norway and Finland (http:// www.ignca.nic.in/craft). In bamboo, Assam has the most concentrated forests as a whole in India. As many as 51 species of bamboo grow in Assam and they are being used for diverse purposes (www.webindia123.com/craft/state/assam). Cane and Bamboo has played an important part in the lives of the people of Assam. It has been an integral part of the cultural, social and economic traditions of the state, and is an important component of the wealth of Assam. Cane and bamboo grow in natural forests. Bamboo is also cultivated in homesteads, groves and on private plantations. People possess traditional skills of working with the material, and knowledge of the cultivation and management of bamboo.

Wood is in abundance in Assam which had enriched with wood craft in the State. Assam's woodwork is famous for its special styles and objects.

Metal crafts

Assam has its own tradition of jewellery. The most exclusive among its jewellery are bangles which are a composition of clay and lacquer work. The decoration is made of pure lac and laid in narrow strips of red, yellow or blue. Jewelry, particularly of gold is a tradition in Assam. Terracotta art is quiet proficient in West Assam. Assam has its own special shapes and patterns in metal ware.

Brass and Bell metal products are famous for their beauty, strength and utility. In Hajo of Kamrup district and Sathebari of same district of Assam, brass and bell metal is an important cottage industry.

Availability of raw material and traditional skill

Availability of raw material and traditional skill has promoted this region to set crafts and cottage industries on small-scale basis with small machineries. The manufacturing of this crafts and cottage items are mostly carried out in dwelling houses, sometimes it is done in outdoor shades near by the houses of craft artisans forming society or cooperative bodies. This is mostly found in rural areas. In the urban areas, however, it is found that cane products are manufactured in workshops and the majority of the establishments are housed in factory premises and in rented buildings.

1.1.5. Health and safety issues in their occupational premises

The artisans in crafts and cottage sectors produce different crafts items by performing their tasks in traditional way, using traditional hand tools, and adopting various work postures in combination of standing and sitting along with different leg-extended and cross-legged postures on floor with or without proper seating devices. Hands tools are made by themselves with their own technology and local manufacturing facilities back-up. They are totally unaware about safe work practices, ergonomics principles. Accident and unsafe acts are considered as inevitable without any better option. Application of relevant ergonomics guidelines can prevent potential work injuries and accident and can increase their performance and productivity. To identify the potential problem areas a holistic approach to understand the work process in specific trade is necessary and then development to respective problem may be attempted. The beneficial effect may e audited to implement in mass.

1.1.6. Specific needs to study postures and muscle stress of people engaged in cane and metal crafts profession

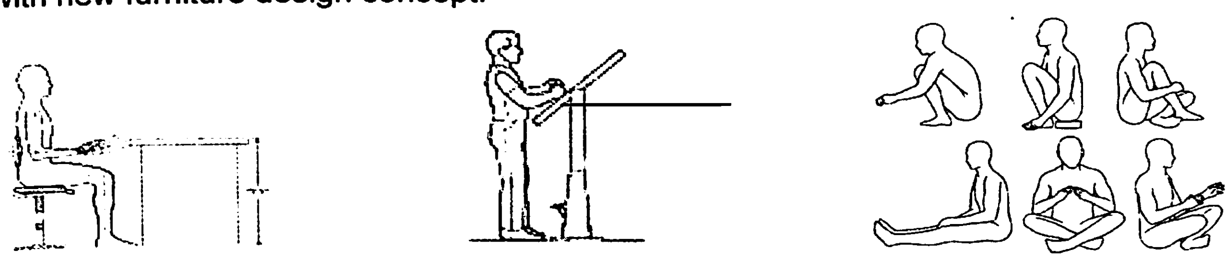
Individual's performances, productivity, comfort and safety is greatly influenced by the working posture which he is adopting to do that very task with specific tools/machines. Posture is termed as geometric relation between two or more body segments (e.g. head, trunk, and limbs). If orientation of different body parts is improper and joint angles, range of joint motions are not within physiological limits, the posture can be awkward. Awkward posture is one of the most common occupational hazards reckoning substantial costs, and imposes adverse impact on production and quality of life as a whole.

While performing a particular task, individual adopts a particular posture or set of postures, (Fig. 2), for varied duration which is either task defined or seating device dependant (e.g. work place seating-standing posture using chair and other related supportive devices).

Fig. 2 Common postures adopted in different work situations in India.

This is observed in most of the occupational settings, especially in offices and industrial workplaces. In most of the cases, these postures make individual to remain confined or restricted in a particular place and hence these are called confined or restricted postures. Mostly if office areas seat-desk posture, and during work standing, seat-desk and sitting on floor are seem to be specific to a certain task requirement. Individuals are also seen to adopt various leg-extended and cross-legged postures on floor with or without using seating devices as seen in many traditional ways of working including cane and metal crafts production premises of North-east India. Varied degrees of combination of these postures, (Fig. 3), are common where individual worker performs many tasks and do not remain confined to a certain task for long duration as job requirement. In these work settings, persons can change these work postures at their own will and these postures are termed as freely adopted postures.

In organised industrial workplace it is observed, industrial practices restrict individual in a specific work position with a particular posture to do a particular task for long duration. At office work environment, generally people remain confined in a particular posture, but there is liberty to adopt various postures with new furniture design concept.



Confined chair-desk posture

Standing posture

Socio-culturally influenced various ground-sitting posture as observed to be practiced by crafts artisans

Fig. 3 Common postures are seen to be used in North-east small scale and home based production units.

At unorganised crafts and cottage work settings, combination of many floor-sitting postures have been observed where people can change their postures as per their will and choice.

Investigations related to posture and musculoskeletal stress has always been of great Ergonomics research interest with development of appropriate guidelines and solutions to address specific target area. In most cases, emphases have been given on chair-desk, seating device, and work tool/machine dependent postures. Impact of various freely-adopted postures, normally practiced by traditional craft artisans in India specifically in its North-east Assam and neighboring states on performance and productivity have not been addressed from ergonomics perspective. Therefore, it has not become possible to provide appropriate guidelines for work equipment design, workstation development, task/work process modification in order to ensure occupational health, safety and productivity in their particular occupational settings. Hence, it requires systematic research investigations and proper evaluation of postures relevant to various kinds of work settings rather to find out a single solution to cater the whole unorganised sectors using common postures. Similar work settings may be grouped together and studies can be conducted accordingly.

1.2. Motivation to choose North-east cane and metal crafts sectors for the present research study

No study has been conducted in areas of cane and metal crafts of Assam, North-east India, from ergonomics perspective to determine potential occupational hazards in their work place, effect of various ground-sitting postures on performance and productivity, effect of the use of traditional hand tools and work methods for crafts making activities on body muscular system. This motivates to conduct this research study in areas of cane crafts and brass metal cottage sectors of North-east, Assam, focusing ergonomics and occupational health and safety issues of people who are engaged in crafts profession. The reason for selection of cane and metal crafts sectors is that, majority of crafts populations are in these two sectors and their nature of work, used hand tools, adopted postures, work duration, all seems ideal for systematic ergonomics research interventions. Specific design solution may also be attempted to improve productivity and safe and comfortable work. The effects of these design initiations are to be evaluated to see its beneficial effect. To see postural benefit EMG studies can be used as one of the many evaluation tools.

1.3. Purpose to use of surface EMG as an analytical tool for evaluation of posture and muscle stress

During performance of different activities including adoption of a particular posture individual's voluntary muscles contract to exert force. For greater exertion of force, muscle has to contract strongly. If this force generation takes place in lesser time, muscles are driven into stress which can lead to muscular fatigue. Any activity or any posture which require greater utilization of muscle energy or force can act as potential hazards for muscular fatigue that always been noticed in many work settings specifically in unorganized sectors where people are not aware of this.

Surface electromyography (SEMG) provides ergonomics researchers a very good information about muscle stress and fatigue in particular occupational setting (Hagg G, and Luttmann A., 2000). An increase in EMG amplitude or shifts in the spectral distribution towards lower frequencies are fatigue-induced changes in muscles. Root Mean Square (RMS) and Electrical Activity (EA) which is low-pass filtered EMG provide most information in this regard. From a practical perspective both approaches yield the same information. In both cases, a time averaging window has to be specified. At RMS estimation, it is usually defined as a software time averaging window. When applying the EA technique, it can be implemented in hardware with a full-wave rectifier and a low pass filter, with the averaging time defined by the time constant of the low-pass filter.

The EA can also be calculated on software basis with a time window (Merletti R and Parker P 2004). In all cases the averaging time has to be adapted to in the dynamic properties of the studied work. The magnitude of the time window in Ergonomic applications is usually in the range of 100–400 ms (R.H. Westgaard, 1984). Spectral parameters are derived from a power spectrum calculated over some epoch, usually 1–5 sec long. The most commonly used spectral parameters are the median frequency (MDF), and the mean power frequency (MPF). Thus using SEMG technique someone can get information relevant to muscle load. If there is increase in RMS and EA activity in time domain along with increase in MPF in frequency domain, muscle is exerting greater force and are in stress in particular situation (Kumar Shrawan and Mittal Anil, 1996).

1.3.1. Application of EMG information and relevance

An ergonomic intervention in designing work equipment and workstation can improve work posture and reduce muscle stress by offering freeness in postural changes at workers' own pace and will, which would benefit the production scenario. In office work environment, success has been noticed while implementing this with new office furniture design concept that allows users to adjusts furniture dimensions according to postural. Corporate sectors also have benefited and some studies are being done in industrial sectors, involving large scale production units.

In unorganised sector, e.g., cane and metal work area, a similar approach would be beneficial by proper design and development of hand tools and work stations which in turn need to be evaluated to show its benefits in occupational stress reduction as well as improving production. Even small development considering a great number of likely beneficiaries, there will be a big impact in performance and productivity. All these are motivating to conduct this present research work in area of work postures in small scale crafts sectors through design of tools and work station development using EMG as analytical tool this present work in area of work postures in small scale crafts sectors through design of tools and workstations development using EMG as analytical tool to see the feasibility in mass implementation. Work has been carried out with EMG relevant to postural evaluation may be reviewed as below:

1.3.2. Literature review of postural evaluation including EMG relevance

Literatures relevant to EMG and work postures in Indian context are very limited. To see the effect of ground sitting postures on muscles, a study was conducted by Dr. PK Nag (1986) on middle-aged Indian women. Seven ground sitting work postures were selected for this study and compared with reference to relaxed standing position. The muscles, the author included in that investigation were pectoralis major, levator scapulae, deltoideus, latissimus dorsi, upper fibers of the trapezius, erector spinae, vastus medialis and lateralis, rectus femoris and gastrocnemius muscles. The commoner sitting postures were sitting on floor with crossed leg, sitting on floor with right leg bent at the knee without any back support, sitting on a plank of 10 cm height with both legs bent at the knee, sitting on the floor with legs extended, and sitting upright on a stool of 40 cm height. It was observed that the relative load on the muscles was highest in the case of sitting on the floor with the right leg bent at the knee.

Alwin Luttmann Matthias Jäger and Wolfgang Laurig (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 spectral distribution towards lower frequencies can be the fatigue induced change

Study was conducted by Elisabeth A. C.(1992) to investigate how changed work organisation and different work tasks influence shoulder muscular load and to quantify the magnitude of the same which confers posture and shoulder muscle load is related.

A study was conducted by Kamal Kothiyal and Berman Kayis (2001) to determine the effect of varying magnitude of load and work rate on muscular strain in seated manual handling tasks performed with one hand. They also investigated the effect of direction of movement on muscular strain. Electromyography (EMG) activity was recorded from 5 muscles of the dominant arm-shoulder region. Root-mean-squared (RMS) values of EMG signals were computed to compare the influence of experimental conditions on muscle strain. It is observed that muscular strain in general sensitive to variations in magnitude of load and work rate.

Marco J.M. Hoozemans and Jaap H. van Dieën (2002) applied surface EMG techniques for evaluation of hand tools based on the EMG of 6 forearm muscles. Based on RMS value they evaluate different hand tools.

To see effects of automobile seating posture on trunk muscle activity, a study was conducted by Milton Maada-Gormoh Saidu (2001). He found increased backrest height and inclined seat angle decreases muscle activity in the latissimus dorsi muscle.

Stephen Bao and Barbara Silverstein and Martin Cohen (2002) conducted muscle load study of poultry processing operators performing three different jobs, basket packing, cutting/packing and trimming. Surface electromyography (EMG) was recorded from bilateral upper trapezius, right forearm flexor and extensor muscles during the job performance. Results showed high muscle loads of the forearm flexor and extensor muscles for the operators conducting all three jobs. The static loading for both trapezius muscles was low (<1% MVC). However, the peak load could be up to 24% MVC on the upper trapezius muscles in some individuals. The job of cutter/packer had significantly higher trapezius loads, while trimmer operators had significantly higher peak forearm flexor and median extensor loads than the other jobs.

Min K. Chung, Inseok Lee and Dohyung Kee(1998) performed a study to see how different stool height affects individual's muscle activity in squatting posture. They observed that adoption of squatting postures in four different situations, i.e., squatting without using any stool and varied height of stool at 10, 15, and 20 cm. The results showed that the squatting posture with a 10-cm height stool (close to crotch height, Debkumar Chakraborti, 1997) was more comfortable than the other stool heights studied, while the posture with a 20-cm height stool was most uncomfortable. They also observed discomfort levels increased almost linearly with the posture holding time. Based on the findings of this study, it is recommended that a stool with the proper height be provided for reducing the postural load when adopting.

Study was conducted by E. Chabran, B. Maton and A. Fourment (2002) to examine whether fatigue of postural muscles influence the coordination between segmental posture and movement. Surface EMG from muscles Deltoïdeus anterior, Biceps brachii, Triceps brachii, Flexor carpi ulnaris, and

Extensor carpi radialis were recorded simultaneously with wrist, elbow and shoulder accelerations and wrist and elbow displacements. Fatigue was evidenced by a shift of the elbow and shoulder muscles EMG spectra towards low frequencies.

OWAS (Ovako's work posture analysing system): As used for evaluation of work posture which is chart-based posture evaluation system and one of the earliest whole posture coding systems for industrial use was developed in Finland, to investigate the working postures in a steelworks. The company Ovako Oy, in conjunction with the Finnish Institute of Occupational Health (1992) developed the OWAS method (Corlett 1986). The OWAS code for a posture comprises a record of the posture itself in the first three figures, the load or 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. 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.

RULA (Rapid upper limb assessment): A procedure analogous to OWAS was developed by McAtamney and Corlett (1993) to assess the exposure of people to postures, force and muscle activities known to contribute to upper limb disorder. This RULA technique uses observations of postures adopted by the upper limbs, the neck, back and legs, recording the values drawn from charts. After recording the values representing the observed posture in score sheet. In RULA, as in OWAS, the higher the code number, at any stage of the analysis, the further does the part concerned depart from a desirable posture. So changes concentrate on reducing the magnitudes of the individual numbers, which in turn reduce the total score. Thus the analyst has some guidance regarding where to introduce changes.

REBA (Rapid entire body assessment): It is basically advanced form of RULA, where rather than remaining confined to upper limb, whole body is assessed observing the particular posture and getting respective score values from REBA chart (Hignett and McAtamney S, 2000).

1.4. Background for thesis hypothesis justification

From above literature review it appears,

- Most of the ergonomics studies on work postures have addressed the issue on some confined, task-dependent conventional postures; i.e., seating-standing aspects in various workstations;
- In most cases, postural analysis have been carried out using Ovako Work Posture Analysing System (OWAS), Rapid Upper Limb Assessment (RULA), and Rapid Upper Limb Assessment (REBA) method which is based on range of joint angle values;
- Not much study data is available on traditional, socio-culturally influenced, ground sitting postures which are very common in Indian crafts and cottage sectors to find out its impact on human musculoskeletal system, specific to NE crafts and cottage units;
- Relation between freely adopted posture with muscle load have not been quantitatively established;
- Surface Electromyography (sEMG) has not been used as an analytical tool for evaluation of postural load on muscles in crafts and cottage sectors;
- If the need for any design development has been identified, appropriate methodology has not been followed (participatory approach) for its development and better acceptance to direct beneficiaries.

The lacunae of previous and existing researches in field of work postures in crafts and cottage sectors promotes to set the hypothesis for the present study which is as follows:

1.5. Hypothesis

- It is assumed that if different floor-sitting postures that are commonly adopted by craftsmen reduce muscle stress in cane crafts and brass metal occupational settings, then informal work tool development or task/work process modification can be done in such a way where combination of many postures can liberally be adopted to do that particular task.
- While performing different cane and brass metal activities in traditional way, if work load can be measured using EMG technique, then a usable workstation can be designed in such a way which require larger and stronger muscles for its operation where force production is necessary and smaller muscles for skillful movements
- If ergonomics participatory approach have found successful in criteria, guidelines, and design development, then it can be evaluated scientifically involving direct beneficiaries to achieve greater success from practical perspective

1.6. Aim and Objectives

This study aims at investigating the effects of easy to use designed work tool and workstation on the work posture adopted by artisans for carrying out different cane and brassware making activities in order to reduce postural muscle stress and to improve performance and productivity

The objectives of this study are set:

- To find out prevalence of occupational stressors in cane crafts and brass-metal cottage evaluating postural load on body muscles by applying EMG technique

- To see the effect of free postural adoption on human assertive and design development through ergonomics participatory approach in selective tasks.

1.7. Work flow

The whole research study was carried out in following steps:

Step I : Identification of study locations;

Step: II Detail questionnaire survey, meeting and discussion to know the state-of-the-art;

Step III: Ergonomics evaluation of work methods, performed tasks and used tools;

Step IV: Evaluation of work posture including range of joint motion;

Step V: Muscle load evaluation while performing different crafts making activities through EMG method;

Step VI: Design of work equipment and tools applying participatory approach; and

Step VII: Trial and testing of developed items to know its efficacy.

Chapter – II

Products, production process and occupational status of cane, bamboo and brass metal crafts in Assam

- Products and production methods and postures adopted by cane-bamboo and brass metal artisans of Assam
- Evaluation of hand tools, posture, postural load on muscles

2.0. Introduction

Clusters of cane and bamboo crafts and brass metal production sectors selected to observe products and production scenario. Details about commonly manufactured products and their production processes were carried out. Though North-east is known for its cane and bamboo products, but the cane items are considered as valued products add specific traditional skill is necessary to produce it. Moreover, artisans are motivated to make cane items rather than bamboo products due to existing market demands. This study concentrates on cane sector if some positive development is achieved. Brass metal artisans make various brass metal products to satisfy ritualistic and household demands in traditional way.

Occupational status details of selected crafts person from both cane-bamboo and metal crafts sectors were collected. Performance level evaluation of hand tools, performed tasks, adopted postures were carried out.

2.1. Objectives are set to:

1. Study cane and metal crafts product details that are mostly prevailed;
2. Evaluation of different tasks performed by craft artisans to make their products;
3. Evaluation of hand tools and adopted postures; and
4. Determination of postural load on muscles

2.2. Materials and Method

Study locations and organisation of study

Cluster of cane crafts and brass metal cottage production sectors in Assam were selected for this study, (Fig. 4); local cane craft units at Ambari, Kalapahar and Bijaynagar in Guwahati and brass metal production centres at Hajo and Sathebari were interacted. Detailed discussion and purpose of this study were explained to them. All relevant experimental studies were conducted at Ergonomics Laboratory of IIT Guwahati.

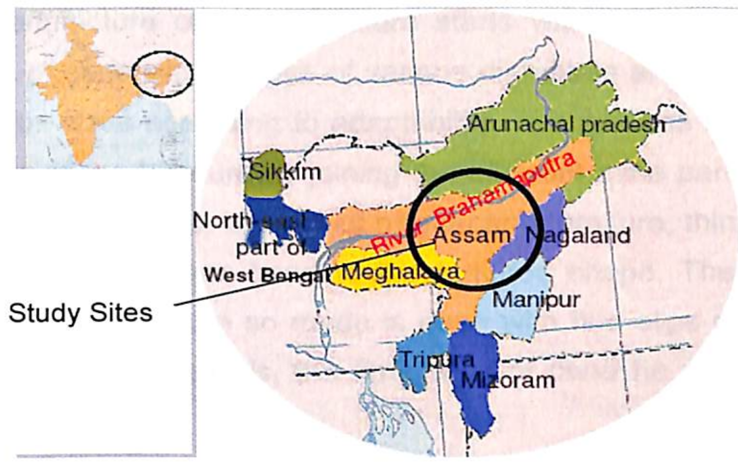


Fig. 4 Study locations: Ambari, Kalapahar, Bijoynagar, Hajo, Sathebari in Assam.

Informed consent from the volunteered subjects was obtained prior to the study. They were asked to bring raw cane and brass metal sheet along with their traditional hand tools and other accessories that are required to make cane and brass metal products necessary for laboratory experimentation and were asked to do their normal tasks as they used to do in their original workplace. A total of 100 crafts artisans (N = 100, 50 each from cane and brass metal production units) were interviewed and of them 30 (N = 30, 15 each from both cane and brass metal units) were selected for laboratory experimentation. All of them were healthy males, having no previous history of neck or back injury.

2.3. Brief account of cane-bamboo and brass metal products prevailed in Assam

Cane products

The manufacture of cane furniture, however, calls for a high degree of skill on the part of the workers. Such skill is found to be traditional. In the manufacture of cane furniture, Cachar district of Assam enjoys a special advantage over the other districts of the state as far as skilled artisans are concerned. The craft has commercial production in almost all the important urban areas of the State.

The manufacture of cane furniture starts with the preparation of requisite amount of cane slips. Canes of various diameters are also reduced into slips of various sizes according to adaptability. The artisans then prepare a rough structure of the furniture by joining the different cane parts (previously sized) with the help of nails. In case of round-cane furniture, thin iron rods are used to get the round cane bend to the required shape. The actual weaving or coiling of the structure so made is done with fine slips of flexible cane. The more skilful an artisan is, the finer slips of cane he can use in coiling and plaiting.

To meet the growing needs of the consumers, urban establishments are found to be engaged in the manufacture of various types of cane furniture and other sundry articles, like boxes, low height stools (murrahs), cradles, office trays, bottle carriers, baskets, waste paper baskets, etc. The cost of such products is higher than other common bamboo products.

Assam has a great tradition of durable and elegant cane furniture. Sofa sets in the latest contemporary styles, beds, occasional tables, racks, garden furniture, sitting stools, etc are the many of the cane furniture items being crafted.

A variety of other cane and bamboo products like bamboo mats, sital pati, baskets of various sizes and shapes, winnowing trays, sieves, japi or chatta, various types of fishing implements, etc., are manufactured in large numbers in the plains districts of the state. The cane and bamboo products used for domestic purposes are prepared in every nook and corner of the state out of split bamboo and fine flexible cane strips. It is observed that there is no particular caste or community in the Assam Valley who are exclusively connected with this traditional craft (U, Barua, 2007). It is generally carried on by all, particularly the peasants irrespective of caste, community or creed.

Examples of some cane and bamboo products can be sited as below predominantly found in Assam, (Fig. 5).

Sitalpati (mat): Sitalpatis are usually made from green cane slips, the beautiful (literal translation - cool spread) sitalpati mats are crafted out of reed. After washing in soda the reed is dried, split and boiled in rice water. For the natural colours used in the mats, dyes are extracted from hibiscus, tamarind seeds etc. The usual motifs are trees, creepers, animals, birds human forms etc.

Chalani (sieve): It is woven with fine bamboo slips in a criss-cross way, keeping some open spaces between the different slips as required for different purposes. The 'chalani' is a round-shaped disc-like object and its diameter varies from (45 x 105) cm. It is used sieving rice, paddy, tea-leaves, etc. and also for washing fish.

Kula (winnowing fan): It is prepared out of flat bamboo slips for winnowing purposes in different sizes and shapes. Twilled design is used for a '*kula*'. The edge of the '*kula*' is made strong by fixing of two sets of one-inch wide bamboo pieces wrapped up in flexible cane strips.

Khorahi (small basket): Khorahi is made of fine bamboo splits for washing rice, vegetables, fish, etc. It is a small basket-like thing with provision to allow water and dirt to pass out. The Khorahi is woven in plain and square form but is gradually bent in a round form at the time of final stitching by flexible cane slips.

Dukula / Tukuri (Big basket): The shape of a *dukula* is exactly the same as that of the *Khorahi*, but the size and process of preparation is a bit different. The required shape of a '*tukuri*' is made by bending the bamboo splits forming the warp gradually when the process of weaving with the weft is in operation. Fixing two or four flat bamboo strips strengthens the edge. The last stage is to stitch the edge along with those flat bamboo strips with some flexible cane slips. The size of a '*dukula*' or a '*tukuri*' is much bigger than that of the *Khorahi* and is used for carrying as well as keeping paddy, rice, etc.

Dala (tray): *Dala* is prepared out of flexible cane slips in twilled design. The shape of a *dala* is exactly like a disc with various sizes for different purposes. The edge around the *dala* is stitched in the same way as that of the edge of a *tukuri* or *dukula*, but the bamboo rims used in the edge of the *dala* is about 45 cm. The *dala* is used specially for rearing silk worms and for winnowing in addition to other domestic purposes.

Duli (Assamese) / Tali (Bengali) - Big Basket: The '*duli*' or '*tali*' are used for preserving paddy. The process of weaving is almost the same as that of a *tukuri* but the size of bamboo slips used is more flat and flexible. The dulis are much bigger than the *tukuri* and the shape is a bit different too.

Japi or Chhata' (Bamboo / leaf head-gear): Bamboo and leaf headgear is the most indispensable item of the open air workers. Such ordinary headgears are produced throughout the State. 'Chhatas' on commercial basis are largely produced in some villages (e. g. Rangpur, Chinipatan, etc.) of Cachar district and supplied mainly to neighbouring tea-gardens and some parts of Nowgong district. The products are generally carried on shoulder loads to the nearby 'hats' and sold to consumers in retail or to middlemen in bulk.

Many varieties of '*Japis*' such as '*halua japi*', '*pitha japi*', '*sorudoiya japi*', '*bordoiya japi*', '*cap japi*', etc. are produced in the districts of Kamrup, Nowgong, Darrang, Sibsagar and Lakhimpur. Nalbari and its neighbouring villages (such as Kamarkuchi, Mughkuchi, etc.) of Kamrup district deserve special mention in respect of manufacturing of '*fulam japis*' (decorated bamboo umbrellas). In olden days, this particular type of '*japis*' served as headgears for the females of noble and rich families, but now it has become outdated. Productions of '*fulam japis*' are now only intended to serve as items of drawing-room decorations.

A *japi* is more advantageous to the cultivators and other open air workers than the conventional umbrella, because the cultivator after putting it on can tie the strings around his chin leaving his hands free to work in any position-standing, squatting or stooping. 'Japi' can also be called a poor man's umbrella, because of its cheap price.

Morah (Stool): It is made up with jathi cane, a particular variety of cane which is more flexible in comparison to other cane variety. Strips are used for knitting and binding.

Basketry: Assam's crafts artisans weave a large variety of functional baskets out of cane and bamboo, each with a special form and design to suit a particular function. A large number of cane and bamboo measures in conical shapes, fishing contraptions, winnows and sieves, headgear for farmers as well as a large variety of baskets are handcrafted in a fascinating range of designs and weaves.

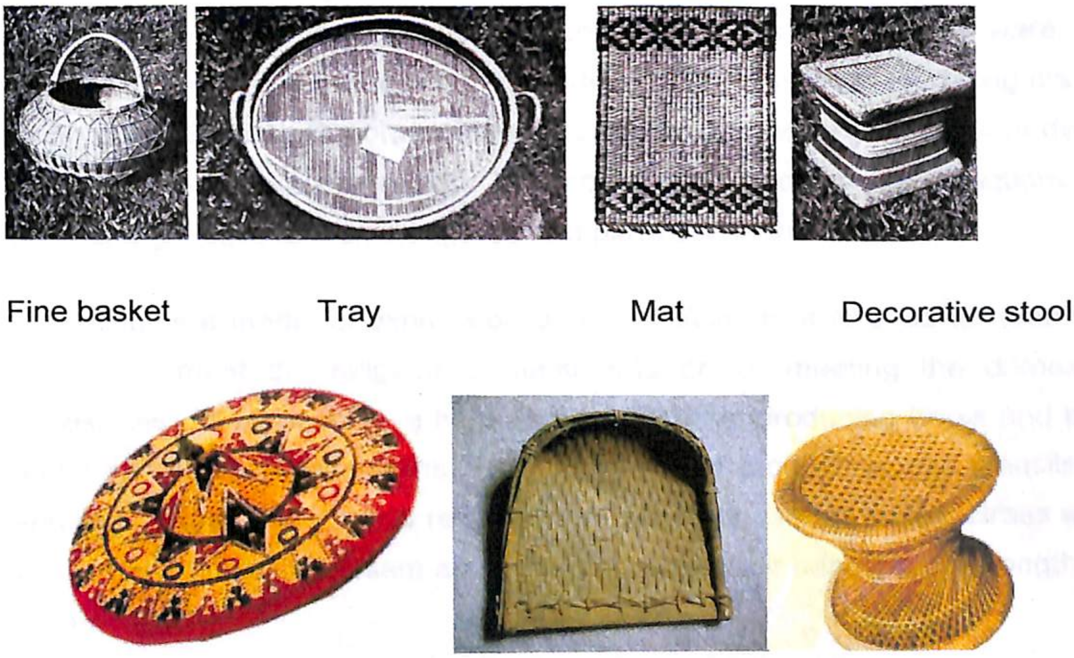


Fig. 5 Illustration of some cane and bamboo products available in Assam (from top left to bottom left clockwise – fine basket, tray, mat, decorative stool; round shaped stool, winnowing fan and japi).

Brass metal and Brassware products

Bell metal casting is an age-old industrial art. Bell metal is made from a combination of copper, zinc, tin, iron and mercury. The metals are mixed together and worked into ingots. These ingots are heated in order to make them malleable. Then these bell metals are heated and continuously beaten until the required shape is achieved.

For long bell metal ware was dominantly cooking ware but now it is supplemented with some decorative items. The bell metal alloy has several medicinal properties which the food or water kept in them acquires. This is the reason for traditionally making cooking ware and kitchen ware from the bell metal alloy. The ability of bell metal to relieve joint inflammation and pain is well known in natural medical science.

As apparent, the primary product made by bell metal is cooking ware. In addition to the traditional cooking ware, decorative items are also being made using the bell metal. Decorated plates, long-spouted water jars, idols of deity and wall hangings are common. The popular designs include depictions of gods and goddesses, human figures and birds and animals.

Bell metal is a media of expression by the craftsman. It is used for creating objects to meet the religious commitments or for meeting the domestic necessities. Artisans achieve high degree of skill in producing brass and bell metal articles of different sorts. Their main line of production was utensils in endless designs and shapes required for every day use for house. Brass and bell metal products of Assam are also famous for their beauty and strength of form and utility.

A shallow bowl on a stand with a dome-like cover (Fig. 6) is a typical item in both brass and bell metal called *sorai* is made that is used during rituals. It has delicate motifs on the sides and sometimes on the cover. Something similar but embellished by dangling pendants is called *donari* and is an essential item during an Assamese wedding. There are also pitchers of special designs called *koloh* (Fig. 7), which sometimes have attractive motifs engraved on them. Assam also has beautifully shaped and finely decorated pan boxes.

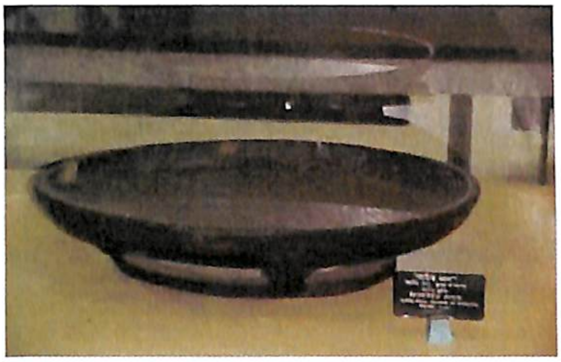
Fig. 6 Sorai   Different sized sorai

Fig. 7 *Brass koloh*   Artisan making koloh

Fig. 8 Different sized *bati* *and* Soria

Ban bati

Bata



Tau

Fig. 9 Illustration of some brassware products available in Assam (ban bati, bata, and tau)

In Hajo, Kamrup district of Assam, at the Muslimpatti cluster, nearly 350 artisan families belonging to the muslim community with another 10-12 families of Hindu artisan living close by comprise the brassware artisan community at Hajo. All of these are family run units engaged in making utilitarian articles of everyday use. Each artisan is working in his residence, and often takes help from other family members. The products, they make are of final demand of traders. They transform raw material into finished products. Brass in sheet form is predominantly used for making different brass metal products. It is sourced in form of rectangle and round pre-cut discs. Rectangle brass sheets size range (cm) 54 x 122, 56 x 122, pre-cut round brass disc is having different diameter, ranges from 15 to 26 cm and above 26 cm by order as and whenever necessary (R. Punekar 2006).

The basic requirements of the brass metal artisans are a solid hollowed out wooden work surface on which to beat a vessel into shape. To produce the lower section of the pot, large wooden mallets are used to alternately beat a circular precut sheet of copper/brass to develop the bottom form on the stone anvil. Later a worker using a smaller mallet shapes this. The upper section is similarly beaten out, the central disc cut from it to accommodate the neck. The undulated fringe is taken out with an iron hammer against an iron anvil. The neck itself is fashioned from a strip of copper/brass, which is bent, then brazed into a tube, its rim being a flange hammered out from it.

The different parts are brazed using a mixture of four parts of brass to one of zinc. The sides of the pot are beaten with an iron hammer against a specially shaped iron anvil. This is a bar bent at right angle at one end, so that it can be inserted into a vessel and applied to its inner wall, counter posing the hammer blows. This produces a characteristic dimpled hammer tone pattern.

Once the shape has been given, articles are then decorated. Pots and bowls are filled with a molten mixture of lacquer or resin, brick dust and oil, then put into cold water so that it sets. This supports the thin metal sheet while the pattern is beaten into it. The design is completed the vessels are inserted on a flame and heated with a blow lamp so that the mixture melts and flows out ready to be used again and again.

The market demand and supply is typically affected by the season of the year. April to July, which is monsoon period, is 'off season'. October to March is considered 'season'. On occasion of marriage, the bride offers *Paan-Tambul* using brass container called *Sarai or Bata*. *Thali*, glass, *lota*, *bati* (Fig. 8), etc. made of brass is given away to the bride during marriage. '*Gamosha*' and '*Sarai*' are typically offered to elders as mark of respect. Forms and shapes of brassware articles are distinct expressing not only identity of the region, but also community of the craftsman making them. For example 'Sarai', 'Koloh' are typically made by Hindu craftsman of the region while utility articles like *'Karahi' 'Charia', 'Tau'*(Fig. 9) are made by Muslim artisans at Hajo. The brass articles usually find a predominantly local market. The aesthetic sensitivity and richness of shapes and forms of articles are unique and offer possibility of developing a distinct brand identity for the craft. (R. M. Punekar, 2006).

2.4. Production method

Cane items

Detailed study of individual task performed by the cane craft artisans and brass metal workers were done and their adopted postures were recorded using Sony DVD movie camera. It is observed that for making various cane crafts item, artisans perform following activities:

1. Cane sharpening (Fig. 10): Craft artisans bring raw cane from local vendors. The branches and nodes of raw canes are sharpened with varied sized sickles.

Fig. 10 Cane sharpening activity.

2. Cane straightening (Fig. 11): The canes were then heated with blow lamps and straightened by applying pressure at appropriate points with wooden block.

Fig. 11 Cane straightening activity.

3. Cane cutting (Fig. 12): The canes are cut into pieces of different sizes depending upon the types of crafts items to be made.

. Fig. 12 Cane cutting activity.

4. Cane strips and fiber making (Fig. 13): With a typical device where stick mounted knife is fixed with the artisans' legs and seat front edge, craft artisans make cane strips and fine fibers which to be used for knitting and binding of crafts items.

Fig. 13 Cane strips and fiber making.

5. Cane bending (Fig. 14): Cane pieces are then bended using blow lamp to soften the cane strip and using pressure with both hands depending upon the types of crafts items are to be made.

Fig. 14 Cane bending activity.

6. Binding (Fig. 15) and Knitting (Fig. 16): Different pieces are joined and knitted with prepared cane fiber and cane strips.

Fig. 15 Binding Fig. 16 Knitting

7. Polishing: After knitting and binding prepared different cane products are polished with varnish.

Brassware item

For making different brass metal item, brass-metal workers perform following activities:

1. Sheet cutting (Fig. 17): Brass metal in sheet form is purchased from market. The shape of the sheet is rectangular or round. Rectangular sheet is 61x122 cm in size and round sheet is having 38-72 cm in diameter. Based on the type of products to be made, sheet is cut according to the shape of the mould.

Fig. 17 Sheet cutting activity.

2. Shape making (Fig. 18): Through hammering cut sheets are shaped. Different sizes of hammer, solid hollowed out wooden block, different iron anvils are used for making shapes.

Fig. 18 Shape making through hammering.

3. Brazing (Fig. 19): Different parts of shaped cut sheet is interlocked by cutting edge and brazed using copper, zinc (copper and zinc in ratio of 3:2), and borax. The brazing mixture is poured onto the interlocked parts and it was inserted on flame heated with a blow lamp so the mixture is melt and spread over interlocked portion. To make the container waterproof, black lac (laha) is used from outside.

Fig. 19 Brazing activity

4. Polishing (Fig. 20): To increase shinning and brightness of brass metal products, the surface is polished using wooden shaft and sharp edged cutting tool. The job is carried out by two persons' jobs, one presses cutting tool for surface peeling of brass metal products and the other pulls string to rotate the object. The brass metal items are inserted or attached with shaft which is rotated using jute rope. Sharp edged cutting tool is pressed on product to peel upper layer against rotation. In this way products show brightness and shining and turn into a finished product.

Fig. 20 Polishing through rope operated wooden shaft rotation.

2.5. Occupational status: Subjective response and objective evaluation of volunteer crafts persons

A total number of 30 craft artisans (15 from each cane and brass metal sectors), Table. 1, mean age of cane crafts artisan is (years) 39±10; height (cm) 167 ± 3.2; weight (Kg) 61 ± 3.2; work duration (hours/week) 7± 3; number of days (per week) 6.86 ±1.23; professional experience (years) 21±10. For brass metal artisans mean age (years) 29±9.1; height (cm) 168 ±7.28; weight 62 ±10.71; work duration (hours/week) 7±0.87; number of days (per week), 6 days, professional experience (years) 15± 7.81, were selected for the detailed observation in their work environment and for specific experimentations. Most of the crafts artisans have informed about shoulders, wrist, back, and knee pain with medium to high intensity.

Table – 1 Occupational status details of cane and brass metal artisans

Subjects	Age: Mean (SD) Years	Height: Mean (SD) cm	Weight Mean (SD) Kg	Daily working hours Mean (SD)	Working days per week Mean (SD)	Years in this profession Mean (SD)
Cane crafts artisans	39±10	167 ± 3.2	61 ± 3.2	7± 3	6.86 ±1.23	21±10
Brass metal artisans	29±9.1	168 ±7.28	62 ±10.71	7±0.87	6	15± 7.81

2.5.2. Discomforts ratings

Cane artisans:

Evaluation of pain and discomfort felt by craft artisans in different body parts while at work and after work was based on a 5-point rating scale, where 0= no pain at all, 1= mild pain, 2= moderate pain 3 = medium pain, 4= severe pain, 5 = very severe pain. The subjects were asked to rate their pain level in different parts of body picture shown to them and their ratings values were recorded. Pain and discomfort ratings value indicates, majority of cane craft artisans feel pain and discomfort in shoulder, neck and lower back region with medium to high intensity. There is also pain and discomfort in wrists and knees for some artisans with mild to moderate intensity. Few artisans complained about headaches and eye strain. Occurrence of frequent finger cut take place for carrying out different cane performing tasks. Discomfort rating value for cane crafts artisans is presented in table – 2.

Table – 2 Discomfort rating values for cane craft artisans (in 5-point scale)

Name of the subjects	Discomfort in shoulder	Discomfort in low back	Discomfort in upper back	Discomfort in wrist	Discomfort in knees	*Discomfort in other body parts
GOPAL DAS	0	5	4	0	0	0
NILKAMAL DAS	4	4	0	0	0	0
MANTU DAS	4	4				Chest (3)
RAGHU DAS	4	5	0	0	0	0
HIREN DAS	2	5	2	0	0	Hip (4)
NIRMAL DAS	2	5	4	0	0	0
SANTOSH DAS	4	5	4	0	4	0
TAPAN MALLICK	4	5	0	0	0	0
SOHIDUL HOQUE	0	3	0	3	0	0
CHANDRA	3	4	2	0	0	0

OJA						
DILIP DAS	0	5	4	0	0	0
BIMAL BISWAS	0	3	0	0	0	Eyes(3)
MAHESH PATHAK	3	5	4	0	0	0
SONARUDDIN SHEIKH	3	0	5	3	5	Thighs (4) Eyes (3)
TAPAN MALLICK	4	5	0	0	0	0

[*Some craft persons seldom feel discomfort in chest, hip, eyes, and thighs with medium to moderate intensity].

Brassware artisans

Most of the brass metal artisans feel severe pain in shoulder and neck while at work or resting after the job is over. Prevailing of pain has also been reported at wrists, knees, and chest for some artisans, especially in those who perform hammering and polishing jobs. While interviewing they reported there is no incidence of major accidents except for mild hand finger cut and coal burning. Discomfort rating values for brass metal artisans is presented in Table - 3

Table – 3 Discomfort rating values for brass metal artisans (in 5-point scale)

Name of the subjects	Discomfort in shoulder	Discomfort in low back	Discomfort in upper back	Discomfort in wrist	Discomfort in knees	Discomfort in other body parts
RAHAMAN	3	3	0	0	0	0
KISIM ALI	4	3	0	2	0	0
ROSAN ALI	3	5	4	4	2	Eyes (2)
AKBAR ALI	0	4	4	2	0	0
ABU BAKKAR	2	4	2	4	2	0

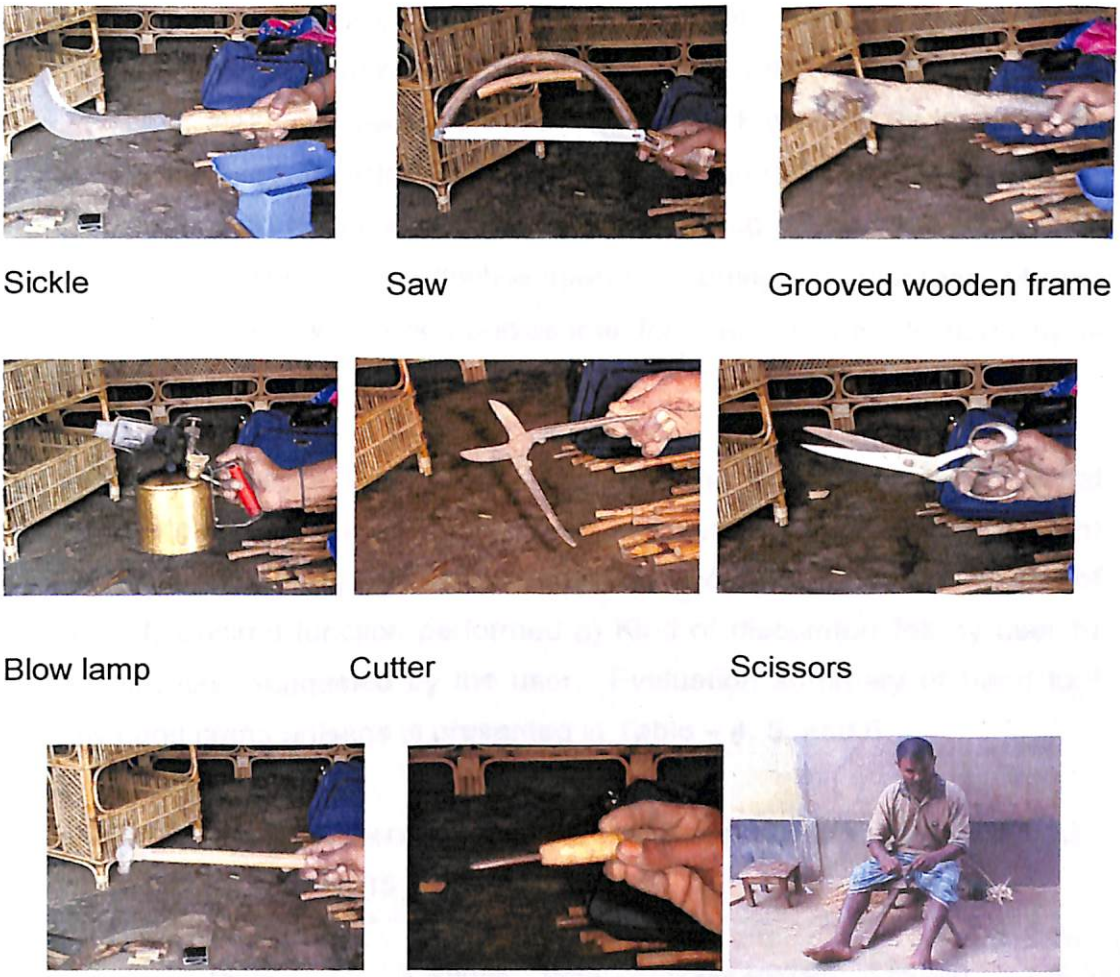
ALI						
MUKSOOD ALI	4	5	2	5	0	0
AIJOR RAHAMAN	0	4	0	0	3	0
SHER ALAM	3	4	2	0	3	0
NIZAM ALI	4	5	0	0	4	0
AMJAD KHAN	3	4	0	3	0	0
AZIZ ALI	3	4	0	0	2	0
RAHAMAN ALI *	3	5	0	0	3	0
AYUB KHAN	4	4	0	3	0	0
DILDAR ALI	0	4	0	4	3	0
AKIMUDDIN ALI	4	4	0	3	0	0

[*One artisan informed about felling of discomfort in eyes].

2.6. Hand tools and usability evaluation

2.6.1. Cane artisans:

It is noticed that for cane works simple and inexpensive tools are used throughout the state. The essential tools required (Fig. 21) for cane craft consists of different sized 'dao' (bill-hooked sickles), grooved wooden block, blue lamp, scissors, cutter, hammer, saws, pliers, pincers, knife, a 'jak' ('v' shaped wooden frame), sharp and pointed carving blade.



Sickle Saw Grooved wooden frame

Blow lamp Cutter Scissors

Hammer Pinchers Fiber making tool

Fig. 21 Essential hand tools for performing different cane activities are sickle, saw, grooved wooden frame, blow lamp, cutter, scissors, hammer, pinchers, and fiber making tool.

Evaluation of hand tools used by cane craft artisans indicate tool weight is within recommended ergonomics limit (2-3 kg for power griping and less than 0.4kg for precision griping). Weight of hand tool used by them is less or equal to 1 kg. Tool grip diameter is also within recommended values (recommended value for grip diameter 3-5 cm for power griping and 0.8 to 1 cm for precision griping). While operating the tools, in most of the cases, wrist is deviated and forearm is flexed. Many of the commonly used hand tools are used for this activity is fabricated by the artisans. The hand tools are made by themselves using their own know-how and they appeared to be quite satisfied as per their desired function is concerned. While interviewing, they informed feeling of discomfort in arms and neck which they least bother about. They opined, if certain modification or design development can serve them to perform in better ways. Especially they suggested modification for fiber making tool would be worthwhile apart from design development of their ranges of products., which is troublesome for them as per its usability is concerned.

Usability evaluation of hand tools used by cane crafts and brass metal artisans were carried out based on basis of criteria, like: a) Tool weight b) Tool grip diameter c) Tool grip surface d) Tool grip length e) Mode of operation f) Desired function performed g) Kind of discomfort felt by user h) Any modification suggested by the user. Evaluation summary of hand tool used by cane crafts artisans is presented in Table – 4, 5, and 6.

Table –4 Physical characteristics of Hand Tools used by cane crafts artisans (Average data taken from 15 subjects)

Name of the tools	Tool weight (gm)	Tool grip diameter (cm)	Tool grip cross section type	Tool grip length (cm)	Tool grip surface texture
 SICKLE (BIG ONE)	600	5 (Power gripping)	Circular	22	Smooth
 SICKLE (SMALL ONE)	250	2.4	Circular	15	Smooth
 HAMMER	250	2	Rectangular	29	Smooth

 SAW	200	4.1	Circular	9.5	Smooth
 GROOVED WOODEN BLOCK	350	4.4 (power griping)	Circular	34	Unevenly textured
 BLOW LAMP	1000 and 100 gm with and without oil	2..2 (power griping)	Circular	9	Smooth
 CUTTER	200	1 (each handle diameter) and 16 (contracted both handle diameter)	Circular	11	Smooth
 SCISSOR	250	5	Circular	6	Smooth
 PINCH HOLE MAKER	25	1.8	Circular cross section for handle	5.5	Smooth
 FIBER MAKING TOOL	3500 gm	NA	NA	NA	NA

[NA = Not applicable]

Table – 5 Mode of operation and modification suggested for hand tools used by cane crafts artisans (data based on responses from 15 subjects)

Name of the tools	Hand/wrist position while operation	Desired function of the tool	Modification suggested by the user
 SICKLE (BIG ONE)	Forearm and wrist is straight	Cane sharpening	Nothing
 SICKLE (SMALL ONE)	Forearm and wrist is kept straight	Cane sharpening and burnt dark spot sharpening	Nothing
 HAMMER	Forearm horizontal and keeping wrist straight	Nailing	Nail plucking option at one end of hammer is required Variable contact heads with diff. diameter is preferred
 HEXO	Forearms horizontal and keeping wrist straight preferable	Cane cutting	Good handle griping is required
 GROOVED WOODEN BLOCK	Forearm extended below elbow height with wrist straight	Cane straightening and bending	Appropriate design solution is required
 CUTTER	Forearm horizontal with wrist straight	Cutting of small cane	Good finger griping with fingered texture surface is required
 SCISSOR	Wrist slightly deviated	Cutting of cane fiber and strips	Good finger griping is required

 PINCH HOLE MAKER	Wrist deviated	Making hole into cane	Nothing
 FIBER MAKING TOOL	Knee extended and holding of the tool with thighs required	Cane strips and fiber making	Proper design development is necessary

Table – 6 Usability evaluation of hand tools based on individual (15 subjects average response) ratings value (in 1-5 point scale)

Name of the tools	Functional purpose served by this hand tool (0= not at all, 1= minimum, 2= moderate, 3= medium, 4= good, 5= excellent	Discomfort feeling 0= no pain at all, 1= mild pain, 2= moderate pain 3 = medium pain, 4= severe pain, 5 = very severe pain
 SICKLE (BIG ONE)	4	0
 SICKLE (SMALL ONE)	4	0
 HAMMER	4	0
 HEXO	3	2 (wrists)

 GROOVED WOODEN BLOCK	2	4 (in shoulder, arm and wrist
 BLOW LAMP	4	1 (headaches and eye strain)
 CUTTER	4	0
 SCISSOR	3	2 (wrists)
 PINCH HOLE MAKER	4	0
 FIBER MAKING TOOL	3	4 (back, neck, thighs and elbow)

2.6.2. Brassware artisans

Brassware artisans use scissors and cutters for cutting of brass metal sheets. Different anvils and hammers are used for making shape, tongs and brazing pots are used for joining of brass metal cut pieces (Fig. 22). Angled metal-pointed tips along with roped wooden block is used for polishing of different brass metal products.

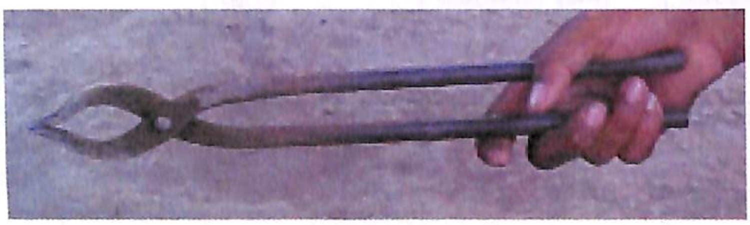

Pointed cutting tools

Hammers

Brazing pot

Brass sheet cutter

Single-headed hammer



Tongs

Anvils

Anvil

Anvil

Fig. 22 Different hand tools used by brass metal artisans; pointed cutting tools, hammers, brazing pots, brass sheet cutter, single headed hammer, tongs, and different anvils.

Hand tools used by brass metal artisans, also have been made by conventional technology without proper consideration of comfort and safety issues. Tool grip diameter was found not appropriate and grip surface was also noticed unevenly textured. Some types of hammers are unnecessarily heavy and there are perceived discomfort in body regions while operating them for prolonged duration as opined by artisans. Extreme forearm, elbow, and wrist joints deviation have been noticed especially during the shape making (through hammering) and polishing activities. The artisans also opined modification of some tools (hammers and anvils) and work machines (polish machine) for better performance and productivity. Physical characteristics of these tools (average data of 15 subjects) are presented in table – 7, mode of usage in table – 8, and their usability evaluation through rating scale is presented in table – 9.

Table – 7 Physical characteristics of hand tool (average data of 15 subjects)

Name of the tools	Tool weight (gm)	Tool grip diameter (cm)	Tool grip cross section type	Tool grip length (cm)	Tool grip surface texture
 POINTED CUTTING TOOL	400	2.5	Rectangular	19	Smooth
 POINTED POLISHING TOOL	300	2.5 x 0.5	Rectangular	29	Highly textured
 HAMMER	600	2.5	Circular	21	Uneven textured
 BRAZING TOOL	25	0.3 (Precision griping)	Circular	35	Finely textured
 SHEET CUTTER	950	2 (at holding end)	Circular	15	Smooth

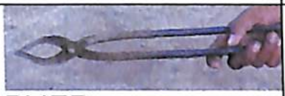
 ONE-HEAD HAMMER	800	2.6 (Power griping)	Circular cross section	27	Unevenly textured
 PLIER	600	1.3 each handle (Power griping)	Circular cross section	25	Smooth
 ROUND-HEAD ANVIL	55	65	Circular	NA	NA
 POINTED ANVIL	39	31	Circular and pointed	NA	NA

Table – 8 Mode of operation and modification suggested for hand tools used by metal crafts artisans (response of 15 subjects)

Name of the tools	Hand/wrist position while operation	Desired function of the tool	Modification suggested by the user
 POINTED CUTTING TOOL	Forearm horizontal and wrist straight	Shape making through hammering action	Good griping is required
 POINTED POLISHING TOOL	Forearm below elbow height and wrist deviated (radial deviation)	Polishing through scrubbing product surface	Circular griping is required
 HAMMER	Wrist shows ulnar deviation	Shape making through hammering	Larger contact surface area (presently it is 3x3 cm) with good griping is required

 BRAZING TOOL	Forearm horizontal and wrist straight	Filling and pouring of chemical (masala) for brazing	Brazing material pouring head with larger groove is required
 SHEET CUTTER	Forearm flexed and wrist is deviated (ulnar deviation)	Cutting sheet metal	Short tool handle length is required Less weight is preferred Good griping is required
 ONE-HEAD HAMMER	Wrist straight with forearm flexed	Shape making through hammering	Larger contact surface is required (preferably more than 5 cm)
 PLIER	Wrist shows ulnar deviation	For pinching of utensils during brazing	Larger pinching surface along with less weight preferable
 ROUND-HEAD ANVIL	NA	Act as stable base surface for sheet shape making through hammering	More contact surface diameter is required
 POINTED ANVIL	NA	Act as stable base surface for sheet shape making through hammering	More height from ground is preferable

[NA = Not applicable]

Table – 9 Usability evaluation of hand tools based on individual (15 subjects average) ratings value for brass metal artisans (in 1-5 point scale)

Name of the tools	Functional purpose served by this hand tool (0= not at all, 1= minimum, 2= moderate, 3= medium, 4= good, 5= excellent	Discomfort feeling 0= no pain at all, 1= mild pain, 2= moderate pain 3 = medium pain, 4= severe pain, 5 = very severe pain
 POINTED CUTTING TOOL	3	2 (while operating for a long duration)
 POINTED POLISHING TOOL	3	3 (getting pain in palm after 30 minutes of operation
 HAMMER	4	2 (pain in wrist)
 BRAZING TOOL	3	0
 SHEET CUTTER	3	3 (shoulder, wrist, and hand)
 ONE-HEAD HAMMER	4	2 (wrist and hand)
 PLIER	3	1 (shoulder and elbow)
 ROUND-HEAD ANVIL	4	0
 POINTED ANVIL	4	0

2.7. Adopted postures

For making different cane craft and brass metal items, crafts persons adopt various crossed leg and leg extended postures. Sometimes they sit on floor without any sitting devices, sometimes they use low-height stool. Below are the postures that crafts persons commonly adopt for making different crafts products (Table 10 and 11).

2.7.1. Cane crafts artisans

Out of eight different postures listed herein, while making fiber, sitting on a low height stool with both legs typically extended to support the tool for keeping it in a fixed position, cane crafts persons opined strenuous as it creates static load with restriction of movement.

Table – 10 Adopted postures for cane crafts persons

Adopted posture	About posture
 Cane sharpening activity	Seated on a low height stool with fully extended legs.
 Cane Straightening activity	Seated on a low height stool with one crossed leg and other bent at knees.
	Seated on a low height stool with both legs extended.

Fiber making activity	
 Cane bending activity	Seated on a low height stool with bent legs at knees.
 Sharpening activity	Seated on a low height stool with one leg partially extended and other bent at knee.
 Cane cutting activity	Seated on a low height stool with bent knees.
 Knitting activity	Seated on a stool with bent knees
 Knitting activity	Seated on floor with bent knees

2.7.2. Brassware artisans

Out of four brass making activities, polishing requires two persons to work together in squatting posture, which artisans opined for an immediate attention to study with; whereas other activities are done by single person and work rest can be decided by their single mind will.

Table – 11 Adopted postures for brassware artisans

Adopted posture	About posture
 Sheet cutting activity	Squatting posture on a low-height stool (Pirah)
 Sheet cutting activity	Seated on floor with crossed legs bent at knees
 Shape making activity	Seated on a low ht stool with partially extended legs
 Shape making activity	Sitting on a low ht stool with partially extended legs, bent at knees

 Shape making activity	Seated on floor with crossed legs bent at knees
 Shape making activity	Seated on floor with crossed legs bent at knees
 Shape making activity	Seated on a wooden plank with one leg crossed and other partially extended at knees
 Brazing activity	Seated on low height stool (pirah), leg crossed, bend at knees.
 Brazing activity	Squatting posture
 Brazing activity	Knee bending Posture on floor

 Polishing activity	Squatting posture
 Polishing activity	Seated on a low height stool with one leg fully bent at knees and other partially bent

2.8. Body movements and Joint angles

Subjects were undergone laboratory experimentation while doing their normal work in a simulated working environment similar to as they do in their real workplace.

Flexion, extension and range of joint motion: Flexion and extension movement occur in the sagittal plane about an axis that lies in the coronal plane. Abduction, adduction, and lateral flexion occur in the coronal plane about an axis that lies in the sagittal plane. Medial and lateral rotation and horizontal abduction and adduction occur in the transverse plane about a longitudinal axis. For the head, neck, trunk, upper extremity, and hip flexion is movement in the anterior direction. However, flexion of the knee, ankle, foot, and toes refers to movement in the posterior direction. Extension is movement in a direction opposite flexion.

In order to determine joint angle position and range of joint motions for different crafts making activities in most commonly adopted postures, goniometric techniques and electro-goniometer is used. The goniometers are unobtrusive and lightweight, and can be attached to the body surface using double-sided surgical tape and was further secured with single sided tape. The goniometers have a telescopic end block that compensates for changes in distance between the two mounting points as the limb moves (Fig. 23). The gauge mechanism allows for accurate measurement of polycentric joints. All sensors connect directly to the MP150/100 unit as part of an MP System. Activity data can be displayed and recorded, leaving the subject to move freely in the normal environment. By calibrating acquired data, output comes in degrees.

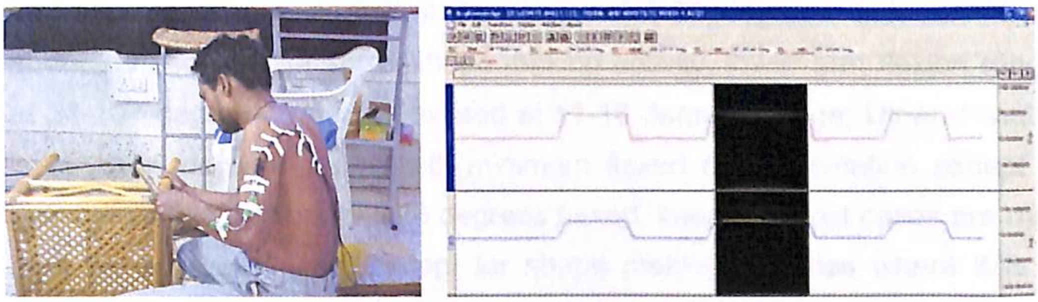


Fig. 23 Attachment of goniometer and goniometric recordings.

This experiment was carried out in Ergonomics Laboratory to get flexion, extension and deviation values of different joints. Two end blocks of goniometer was attached on both sides of joints. Biopac System software was used for analysing the collected data and to get different joint angles values.

2.8.1. Cane crafts artisans

joint angles and range of joint motion for performing various cane crafts making activities, neck flexion ranges at 11-24 degrees, trunk flexion at 11-17 degrees, upper arm flexed at the range of 3-16 degrees with minimum abduction, lower arm flexion ranges at 44-97 degrees; wrist deviation is at 4-13 degrees, knees in most cases are more than 90 degrees flexed; except for fiber making activities where it is 12 degrees flexed. Thus ranges of all joint angles are within normal physiological ranges as referred in ErgoMaster

Software. The joint angle and range of joint motion values are presented in table – 12.

2.8.2. Brassware artisans

Subjects were undergone laboratory experimentation while doing their normal work in a simulated working environment similar to as they do in their real workplace.

In similar way, for performing various brass metal activities range of neck flexion varies from 9-23 degrees range, trunk flexion at range of 11-15 degrees, upper arm flexion at the range of 3-35 degrees with raised and abducted shoulder for some shape making activity, lower arm flexion ranges at 34-107 degrees, wrist is deviated at 11-18 degrees range; Ulnar deviation is at 9-25 degrees range with minimum flexed radial deviation except for polishing activity where it is 26 degrees flexed, knees in most cases are more than 90 degrees flexed; except for shape making activities where it is 54 degrees flexed. Thus there is abnormal range of joint movement for shape making and polishing activity.

Table – 12 Joint angles and range of joint motion values of cane and brass metal artisans

Subjects	Neck flexion ranges (in degrees)	Trunk flexion ranges (in degrees)	Upper arm flexion range (in degrees)	Lower arm flexion range (in degrees)	Wrist deviation range (in degrees)	Knee flexion range (in degrees)
Cane crafts artisans	11-24	11-17	3-16	44-97	4-13	>90
Brass metal artisans	9-23	11-15	3-35	34-107	11-18	>90

2.9. Postural load analysis

Subjects were undergone laboratory experimentation while doing their normal work in a simulated working environment similar to as they do in their real workplace.

2.9.1. Using OWAS, REBA, RULA technique

It is observed both cane crafts and brass metal artisans adopt various crossed leg, leg extended, kneeling, and squatting postures. Sometimes, they work on floor, sometimes, they use low-height stool for their postures.

Adopted postures were analysed using ErgoMaster Software based on REBA (rapid entire body assessment) and RULA (rapid upper limb assessment) principles. Posture Analyst Module of ErgoMaster Software (Fig. 24) determines hazardousness of different postures once the image of that particular posture is being imported to this module.

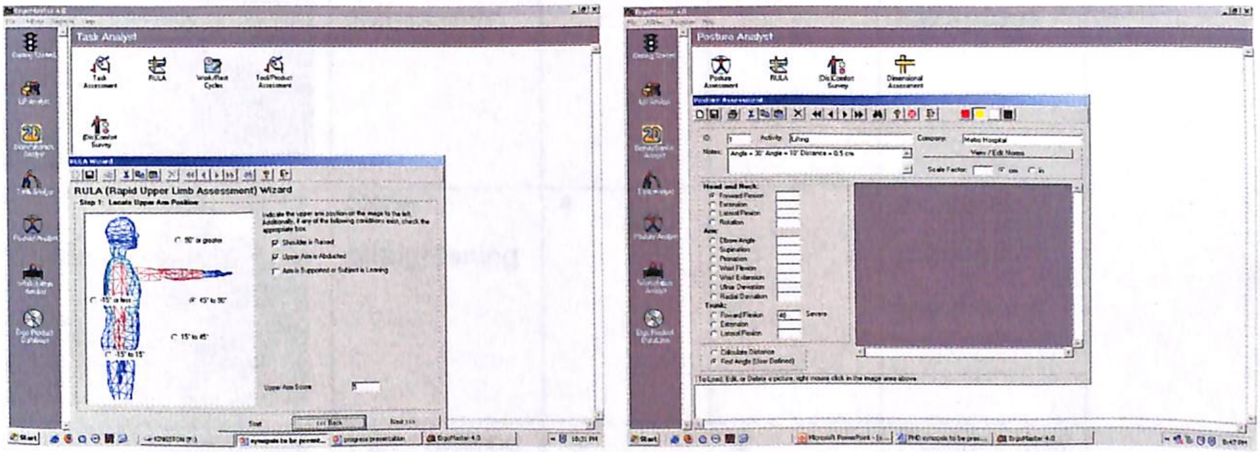


Fig. 24 Posture analyst module of ErgoMaster Software.

It is observed from respective RULA and REBA score values that most of the adopted postures for cane crafts making activities are low hazardous except cane bending and straightening which are medium hazardous. In similar way, most of the adopted postures for brass metal activities are medium hazardous except for brazing activity which is low hazardous.

Postural hazardousness analysis reveals cane crafts artisans adopt various ground-sitting postures on some low height stools and sometimes on floor. These cross-legged and leg-extended postures allow them to change their postures freely as per their will. Only fiber making activity does not allow them to change posture because its operation requires operator's leg support to hold it while making cane fibers. In similar way, brass metal artisans also adopt various ground sitting postures on low to medium height stool for performing different brass metal activities. Summary of the scores are presented in table – 13 and table – 14.

Table – 13 Postural hazardousness analysis for cane crafts making task (average response from 15 subjects) using ErgoMaster Software based on REBA and RULA Score

Adopted posture	Activity	RULA SCORE	REBA SCORE	Conclusion
	Cane sharpening	3	3	Posture low hazardous
	Cane straightening	4	4	Posture medium hazardous
	Fiber making	3	2	Posture low hazardous

	Cane bending	4	4	Posture medium hazardous
	Cane sharpening after bending	3	3	Posture low hazardous
	Cane cutting	4	4	Posture medium hazardous
	Knitting	3	3	Posture low hazardous
	Knitting	2	2	Posture low hazardous

Table – 14 Postural hazardousness analysis for brass metal activities (average response from 15 subjects) using ErgoMaster Software based on REBA and RULA Score)

Adopted posture	Activity	RULA Score	REBA Score	Conclusion
	Sheet cutting	4	4	Medium hazardous
	Sheet cutting	4	6	Posture medium hazardous
	Shape making	3	4	Posture medium hazardous
	Shape making	4	5	Posture medium hazardous
	Shape making through hammering	4	4	Medium hazardous
	Brazing	4	3	Posture low hazardous

	Polishing	4	4	Posture medium hazardous
	Polishing	4	4	Posture medium hazardous

2.9.2. Determining of individual task oriented postural adoption

While performing different cane and brass metal activities in different postures, subject volunteers are instructed to hold a specific posture which commonly they adopt for doing that particularly activity in their real work situation as long as they can without feeling any discomfort in any body parts. Adoption time for individual posture is recorded.

Mean postural adoption time is found for cane sharpening activity to be 40 (SD± 8) minutes; mean postural adoption time for cane straightening is 35 (SD ± 7.81) minutes; for cane bending activity it is 32 (SD ±6.46) minutes; in fiber making, it is 45 (SD± 9.77) minutes and for knitting activity the mean postural adoption time is 36 minutes (SD± 0.36) minutes. Though subjective opinions mentions fiber making posture is less tiring at a time but due to long time work in a single posture leg movement is highly restricted.

In case of brass metal artisans, mean postural adoption time without any discomfort/pain feeling for sheet cutting activity is 11 (SD± 3.2) minutes, for shape making it is 15 (SD± 4.7) minutes, for brazing it is 15 ((SD± 4.4) minutes and for polishing it is 9 (SD± 2.9) minutes. The low postural adoption time for polishing activity reflexes the polishing task is tiresome and artisans need frequent micro-breaks which is also opined by volunteered subjects. For carrying out all brass metal activities, metal crafts artisans are in frequent postural changes. Mean postural adoption time for carrying out different cane crafts and brass metal activity is presented in table – 15.

Table – 15 Mean postural adoption time (average responses from 15 subjects) for different cane and brass metal activities

Postural adoption time Mean (SD) minutes	Cane crafts artisans	Postural adoption time Mean (SD) minutes)	Brass metal artisans
Cane sharpening activity	40 (SD± 8) Range (26-46)	Sheet cutting	11 (SD± 3.2) (9-15)
Cane straightening activity	35 (SD ± 7.81) Range (19-47)	Shape making	15 (SD± 4.7) (7-22)
Cane bending	32 (SD ±6.46) (21-38)	Brazing	15 ((SD± 4.4) (13-17)
Cane fiber making activity	45 (SD± 9.77) (24-55)	Polishing activity	9 (SD± 2.9) (7-14)

2.9.3 Muscle electrical activity determination towards evaluating different tasks-specific (cane and metal crafts) postural load on muscles

Using EMG of selected muscle activity

Activity of different muscles for performing different cane crafts and sheet cutting and polishing brass metal activity in most commonly adopted postures as mentioned above were measured using surface electromyography (EMG) method. All four cane performing activities but only sheet cutting and polishing activities were included for EMG study. This is due to space and time constraints. A total 20 craft artisans were involved for EMG study (10 each from cane crafts and brass metal production units). All subjects were healthy with no previous history of back and neck pain. Informed consent was obtained from all of them. Permission from registered medical person was obtained before conducting this study. The EMG study was conducted in following steps (Kumar Shrawan and Mittal Anil, 1996):

a) **Selection of muscles**

Erector spinae (at L4-L5), upper trapezius, and pectoralis major muscles were investigated for this study. The reason for selection of these muscles are located on surface, origins of their fibers are such that muscle belly can easily be traced out and while interacting with artisans they informed feeling of discomfort and pain in those particular regions where these muscles are located (Fig. 25).

Pectoralis major muscle: Origin of the upper fibers; anterior surface of sternal one-half of clavicle.

Origin of lower fibers: (Sternocostal portion) anterior surface of sternum, cartilages of first six or seven ribs, and aponeurosis of the external oblique.

Insertion of upper and lower fibers: Crest of greater tubercle of humerus. Upper fibers are more anterior and caudal on the crest than the lower fibers which twist on themselves and are more posterior and cranial.

Action of muscle as a whole: With the origin fixed, it abducts and medially rotates the humerus. With the insertion fixed, the Pectoralis major may assist in elevating the thorax as in forced inspiration. In crutch-walking or in parallel-bar work, it will assist in supporting the weight of the body.

Action of upper fibers: Flex and medially rotate shoulder joint, and horizontally abduct the humerus towards the opposite shoulder.

Action of lower fibers: Depress the shoulder girdle by virtue of attachment on the humerus, and obliquely abduct the humerus toward the opposite iliac crest (P. Kendall, .

Trapezius:

Origin of upper fibers: External occipital protuberance, medial one-third of superior nuchal line, ligamentum nuchae, and spinous process of seven cervical vertebra.

Origin of middle fibers: Spinous processes of first through fifth thoracic vertebrae.

Origin of lower fibers: Spinous processes of sixth through twelfth thoracic vertebrae.

Insert of upper fibers: Lateral one-third of clavicle acromian process of scapula.

Insert of middle fibers: Medial margin of acromian and superior lip of spine of scapula.

Insert of lower fibers: Tubercle at apex of spine of scapula.

Action: With the origin fixed, adduction of the scapula, performed chiefly by the middle fibers with stabilization by the upper and lower fibers. Rotation of the scapula shows the glenoid cavity faces cranially, performed chiefly by the upper and lower fibers with stabilization by the middle fibers. In addition, the upper fibers elevate and the lower fibers depress the scapula. With the insertion fixed, and acting unilaterally, the upper fibers extend, laterally flex, and rotate the head and joints of the cervical vertebra so that the face turns toward the opposite; and acting bilaterally, the upper trapezius extends the neck (F.P. Kendall, 1983).

Erector spinae:

Origin: Common origin from anterior surface of broad tendon attached to medial crest of sacrum, spinous processes of lumbar and 11th and 12th thoracic vertebrae, posterior part of medial lip of iliac crest, supraspinous ligament, and lateral crests of sacrum.

Insertion: by tendon into inferior borders of angles of lower 6 or 7 ribs.

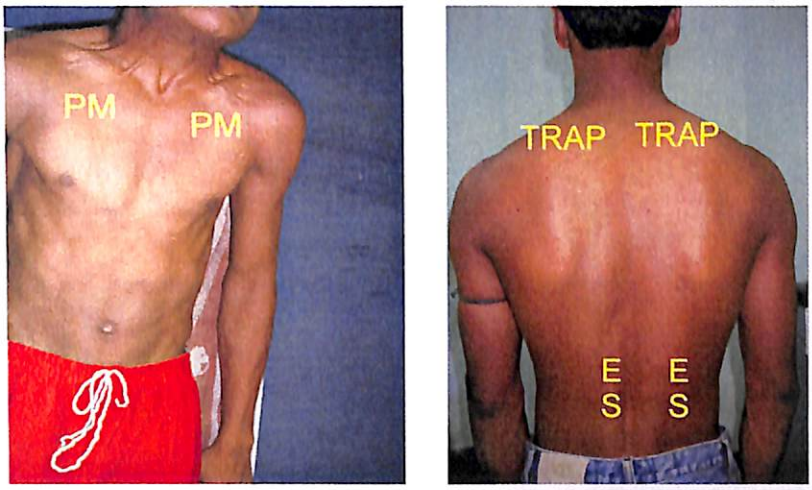


Fig. 25 Location of pectoralis major (PM), upper trapezius (TRAP), and erector spinae (ES) muscles

b) **Placement of electrodes**

Bipolar Ag-AgCl (Silver-silver chloride) surface electrodes were placed on skin surface over three muscles after shaving the skin, at muscle belly, with an inter-electrode distance of 10 mm (P. Zip, 1982, Fig. 26). After gently rubbed with cotton rinsed with alcohol, markings of electrode placement sites were done by applying tiny drop of silver nitrate solution on skin under direct sunlight. Ground electrode was placed over inactive site preferably over forehead. Electrodes were secured on the skin with medical adhesive tape. The lead wires were connected with EMG amplifier (Make: Biopac, USA) where the recorded signals were amplified 5 times with gain setting of 500 at sampling rate of 1000 samples per second. A/D converter was used to convert analog signal into digital one. The signals were band pass filtered at 20-400 Hz and finally stored in computer.

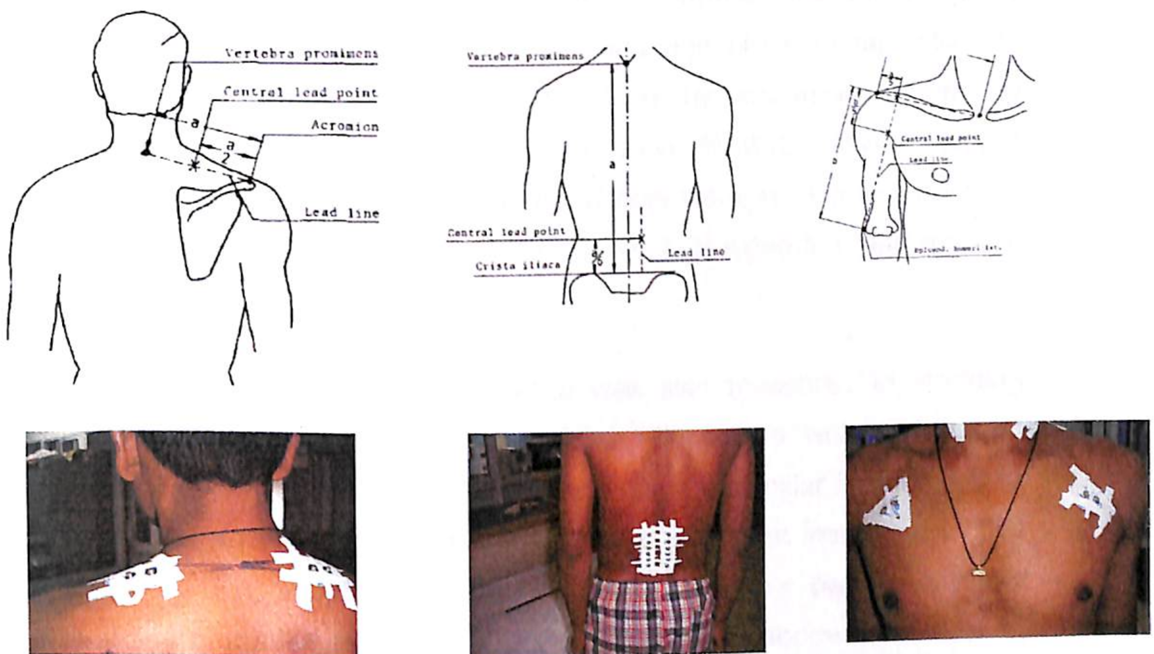


Fig. 26 Placement of electrodes at different muscles location (P. Zip, 1982).

c) **Recording of EMG signal**

After all electrodes, lead wires were secured with adhesive tape, subjects were instructed to do different cane and metal crafts performing task adopting specific posture that they normally adopt in their real workplace. Before starting the activity, the subjects remained relax and baseline resting EMG signals were recorded for 60 seconds. A series of maximal voluntary contractions were performed in order to obtain EMG signals representing each muscle's maximal voluntary contractions. These recorded EMG signals during maximal voluntary contractions were to be used to normalize the EMG signals recorded during performance of different cane activities. Normalization of EMG recordings were done by expressing them as percentages of the maximal voluntary contraction (% MVC).

d) **Determination of MVC**

MVC of upper Trapezius, Pectoralis major, and Erector Spinae muscles were determined (R. Maity, GG Ray, 2004, and Florence P. Kendall, 1997). *Determination of MVC*: MVC of upper trapezius, Pectoralis major, and Erector spinae muscles were determined in order to normalize the EMG signals recorded during performance of different cane and brass metal activities. Normalization of EMG recordings was done by expressing them as percentages of the maximal voluntary contraction (% MVC). MVC of upper trapezius muscle was determined when subjects were in standing posture, with upper arm abducted at 90 degrees, elbows fully extended, and forearm fully pronated (Fig. 27).

The MVC for erector spinae (at L4-L5) was also measured in standing position. The subject chest was strapped with Velcro which was then connected with spring balance. The hip was fixed with pillar in such a way that lumbar joint remains hyper-flexed. The subjects were instructed to pull the straps up Fig. 28). Measurement of MVC for upper pectoralis major muscle was conducted in supine position, elbow was extended, shoulder in 90 degrees flexed and slight medially rotated and humerus is horizontally abducted toward the sternal end of the clavicle (Fig. 29). Pressure was applied firmly against forearm in the direction of horizontal abduction.

Fig. 27

Fig. 28

Fig. 29

Fig. 27 MVC of Trapezius, Fig. 28 MVC of Erector Spinae Fig. 29 MVC of Pectoralis Major

e) **Recording of EMG signal during performance of different cane and brass metal activities**

The EMG signals were recorded by MP100, BIOPAC SYSTEM during performance of different cane and brass metal activities. Signals from respective muscles were picked up by the electrodes and transmitted to the EMG amplifier (Fig. 30). The amplified signal was then captured by MP100 data capturing unit where A/D converter converted the analog signal to digital one which was then connected to the computer for data storage. The recorded EMG signal was then converted to the text files and imported to MATLAB signal processing and analysing program for signal processing.

Fig. 30 Set up for recordings of EMG during performance of different cane crafts and brass metal activity

f) **Normalization of EMG signals**

After subtracting the resting EMG values, the work EMG signals were normalized by the signals obtained during the maximal voluntary contractions which are expressed in terms of % maximal voluntary contractions. The normalized signals were then processed get root mean square (RMS) EMG and MPF (mean power frequency) value.

g) **Processing of EMG signals**

The recorded EMG signals were processed using MATLAB signals processing software. The required code for analysing EMG signal was developed.

h) **Root mean square (RMS), mean power frequency (MPF), and percentage of MVC utilization (%MVC) value of three muscles (RMS) for different cane crafts making activities and sheet cutting and polishing brass metal activities**

Raw EMG signal is processed using MATLAB software to get RMS values of different muscles for different cane performing and sheet cutting and polishing brass metal activities. High RMS value is found during cane bending activity for all three muscles, followed by cane straightening and cane sharpening. Cane fiber making activity shows low RMS value. RMS values of Erector Spinae muscle indicates all cane performing activities require almost same level of muscle force except cane straightening activity which require the most. RMS values of pectoralis major muscle is highest for cane bending activity followed by cane straightening and sharpening. Fiber making activity shows lowest RMS value for all crafts artisans.

Highest RMS value of trapezius muscle is found for cane bending activity followed by straightening and sharpening. Fiber making activity shows lowest RMS value for trapezius muscle.

Percentage of MVC (Maximum voluntary contraction) utilization by Erector spinae muscle for performing different cane activities remains below 45% except cane straightening activity for some crafts artisans who utilizes 65%-70% of MVC. Percentage of MVC utilization by Pectoralis major muscle is highest for cane bending activity and it lies in a range of 45-50%, followed by cane straightening and cane sharpening. Cane straightening activity utilizes 30%-45% of MVC and cane sharpening 25%-35%. Percentage utilization of MVC is lowest in case of fiber making activity which is 15%-25% of MVC.

Percentage of MVC utilization by trapezius muscle is highest for cane bending activity which lies in a range of 55-65%, followed by cane straightening and cane sharpening. Cane straightening activity utilizes 45%-60% of MVC and cane sharpening 30%-50%. Percentage utilization of MVC is lowest in case of fiber making activity which is 20%-45% of MVC.

Mean power frequency (MPF) values of erector spinae muscle for performing different cane activities lies within a range of 80-160 Hz. MPF value of pectoralis major muscle lies in a range of 90 to 155 Hz for different cane activities. MPF value for trapezius muscle for performing different cane activities are within a range of 107-179 Hz. RMS values of trapezius and pectoralis major muscle in brass metal artisans indicate polishing activity utilizes greater muscle force in comparison to sheet cutting activity. Where as erector spinae muscle utilizes same muscle force level for both sheet cutting and brass metal polishing activity. Percentage of MVC utilization and RMS value of three muscles during performance of different cane and brass metal activities is presented in table – 16.

Table – 16 Percentage of MVC utilization and RMS values of trapezius, pectoralis major, and erector spinae muscles for carrying out different cane and brass metal activities

Activities	MVC% for trapezius muscle	MVC% for pectoralis major muscle	MVC% for erector spinae muscle	RMS value of trapezius muscle (High, medium, low)	RMS value of pectoralis major muscle (High, medium, low)	RMS value of erector spinae muscle (High, medium, low
Cane sharpening	30-50%	25%-35%.	<25%	Medium	Medium	Low
Cane straightening	45-60%	30%-45%	<25%	High	Medium	Low
Cane bending	55-65%,	45-50%,	<25%	High	High	Medium
Cane fiber making	20-45%	15-25%	38-42%	Low	Low	Medium
Sheet cutting	64-67%	35-52%	<25%	Medium	High	Low
Polishing	70-72%	48-58%	35-45%	High	High	Medium

2.10. Finding that transparent the need to develop/modify of work tools and work methods

High root mean square (RMS) value is observed of all three muscles (upper Trapezius, Pectoralis Major, and Erector Spine muscles) for cane bending activity, followed by cane straightening and cane sharpening activity in specified posture. RMS value is lowest for cane fiber making activity of all three muscles. Similarly percentage of MVC utilization is higher for cane bending activity which is 65% for Trapezius 60% for Pectoralis Major, and 52% for Erector Spinae muscles respectively. Where as percentage of MVC utilization for cane straightening activity is 50%, 44%, and 38% respectively for Trapezius, Pectoralis Major, and Erector Spinae muscles. Cane sharpening activity requires 44%, 38%, and 32% of MVC for all three muscles. Percentage utilization of all three muscles is below 40% of MVC for cane fiber making activity. Thus greater electrical activity of upper Trapezius muscle for all four cane performing activities, followed by Pectoralis Major and Erector Spinae muscle are observed. Cane bending activity requires greater utilization of muscle force, followed by cane straightening and cane sharpening activity. Relatively high RMS value of erector spinae muscle has been noticed during cane fiber making activity, which is due to static load to this muscle for their performance of work in particular posture for prolonged duration produces exerts greater muscle stress to this muscle which can be minimized by introducing short work-rest pause along with appropriate design application.

Mean power frequency value (MPF) of Trapezius, Pectoralis Major, and Erector Spinae muscle lies in the range of 80-160 Hz for performing different cane activities. In case of metal craft artisans, high RMS values of all the above three muscles have been observed in both sheet cutting and polishing activities. Comparatively, polishing activity requires greater muscle force than sheet cutting. This is due the way, by which, these two tasks are performed make extreme joint movements and subsequently, produce stress to neighbouring muscles. In order to reduce muscle stress, this also needs ergonomics design interventions.

Earlier subjective opinion from brass metal artisans, it appeared that polishing task is the most tiring job in comparison to other brass metal performing task. Though shape making and brazing brass metal activity has not been included in EMG study, still it do get support from relevant EMG data that comparatively polishing activity utilises greater muscle force. In similar way, fiber making cane craft activity requires leg support to cutting tool and restrict artisan to a single posture without change which was also stressful as opined by cane artisan in subjective evaluation. EMG study is also indicative relatively high erector spinae muscle activity is due to prolonged static load to erector spinae muscle as individual do not get chance to change posture freely.

2.11. Need for task-specific postural adjustment in order to reduce muscle load

As all cane and brass metal performing tasks are being performed in different floor-sitting postures, if some tasks may be tried out to be performed with elevated work surface with change of applied force by lower leg muscles instead of upper back muscles. Methods may also be modified if single person can do all type of tasks or workstation should be such that any member of family can do that job. Even if it is performed on floor, adopting floor-sitting posture, it should not restrict movement.

From above study, it is assumed that cane fiber making task can be improved, if fiber making tool is being modified in such a way where knife fixing with legs can be avoided. In traditional method, Polish machine requires two persons for its operation on squatting posture, if the work surface can be elevated and shaft rotation task are performed through paddling instead of hand roping and/or installation of electrical power for shaft rotation can minimise tasks-specific postural loading to muscles. Here rather than engaging two persons for single job, one person can serve the same.

With this thought, design development of new polish workstation and modification of fiber making tool for brass metal and cane craft artisans are undertaken.

Chapter – III

Design development and evaluation

- Fiber making hand tool – a design development for cane craft artisans
- Polish machine – an elevated workstation development for brass metal artisans
- Evaluation of newly developed items

3.0. Introduction

Design of a product or system is a continuous problem solving process with conversion of ideas into reality, keeping in mind the user's characteristics and limitations, art and aesthetics, material and process, and new technology. A good design is combination of many factors; like aesthetic, functionality, human factors, technology, material & method, and cost effectiveness (Fig. 31). Aesthetic and functionality of a product follow a balance with human factors or Ergonomics. The designed products satisfy users need and provide comfort and safety to the user. Application of best scientific principles and appropriate technologies may generate a design best to deliver its intended function, still its user ultimately has to feel comfort while using it to qualify the same to be a good design.

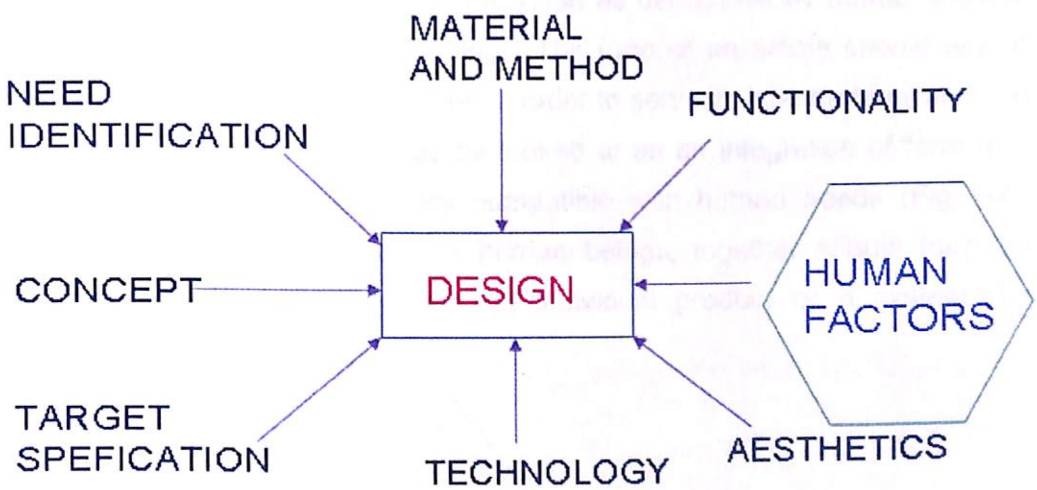


Fig. 31 A good design is combinations of many factors.

The final outcome of man-made article for human use with a definite form, shape and size required to perform a particular task termed as a product. The range of such products extend from a small individual pin in a household, to a group of articles assembled together like machine tools, toys, a complex electronics article or a vehicle. Product design is defined as the process whereby, with the help of arts, science and technology together a product of aesthetic acceptance and functional value is developed. Any innovative products we use, incorporating all the best scientific principles in them for functioning, it has to provide comfort and safety to its users, if not, they will serve no purpose, because man ultimately has to use the product.

The product of the first generation in any innovation is restricted by the "form follows function" type of design process. In the beginning one develops the components and their links for getting a proper functional output. The second generation will improve upon it, that is after getting confirmation about the details of the functional elements, design development is based on "function follows form", i.e., all the functional elements are housed in a desired aesthetic form and then the shape and size of the elements and their functional links are modified accordingly. If an article of good functional value does not match the human aesthetic perception or have a good aesthetic look, it does not serve its intended function as demanded by human beings. Hence it will not be worth accepting. The form of an article should reveal aesthetics, as well as its utility value in order to serve its intended function. At present the design process may be looked at as an integration of form and function which should be ideally compatible with human needs (Fig. 32). Form, function and the needs of human beings, together should form an integral concept when designing an individual product or a system (D. Chakrabarti, 1997).

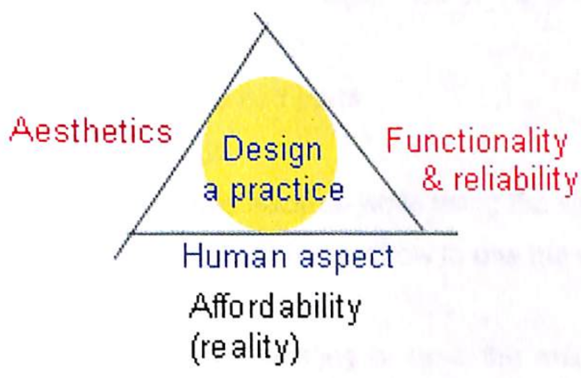


Fig. 32 A good designed product must follow a balance between human factor, aesthetic and function.

3.1. Ergonomics principles for product design

Identification of need and finding of appropriate solution comes early in design development process, thus reflecting the solution-focused nature of design thinking. This initial solution conjecture is then subjected to analysis, evaluation, refinement and development of final product. The end-point of the process is the communication of a design, ready for manufacture. Prior to this, the design is subject to evaluation against the goals, constraints and criteria of the design brief. Thus design development process begins with an initial statement of a need, and the first design activity is analysis of the problem. The analysis of the problem is a small but important part of the over-all process. Ergonomics principles for good design comprises following (D. Chakrabarti, 1997):

- 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
- Proper semantic applications; and
- Product 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 about probable hazards while using the same and
- Training by specific instructions on how to use the system efficiency

Basically, in any system, either existing or new, the man who performs the work would be the prime consideration. Accessories, machines and other work equipment are aids. The work space should make it easy to use all theses facilities.

The following questions must be answered while designing any product/system.

- Who: the individual or organization designing the work place and their special corporate aim
- Whom: the intended users with their basic limitations, and the facilities available
- Why: the need of that product/system
- What: the considerations to be taken into account
- When: the context in which the same is to be used
- Where: the spaces and the relationship with the other articles to be used when performing the intended task, and
- How: means to interlink the above six Ws to arrive at a design solution of human compatibility

Hence design should be based on:

- The users' information i.e., the psycho-physiological and physical body dimensions of the human operator/use
- The type of work to be done – the work context
- The dimensions and designs of the accessories, e.g., seats, work tables, machines, consoles, etc, and

Technology advancement makes

- efficient and quality life
- easy and comfortable,
- accessible to easily available ready-mades
- more and more dependent on machines; so the design should consider the elimination of ergonomics risk factors of posture, applied force and frequency (Fig. 33).

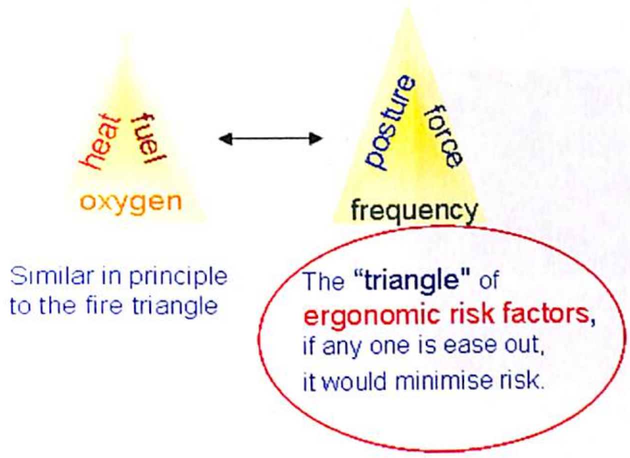


Fig. 33 . Design requires elimination of ergonomics risks factors similar to fire triangle to improve users' comfort and safety.

After considering all the above ergonomics criteria for product design, development of two specific items; fiber making tool and polish were carried out.

3.2. Design modification of existing fiber making tool

The traditional fiber making tool used by cane crafts artisans restrict them to remain in static posture because to make it functionally operative, crafts artisans have to hold it with their legs. If applied pressure becomes unstable due to change of posture and leg position, fiber making tool does not work. Thus artisans have to remain in same posture for entire work duration which produces stress to back and neck muscles, especially to erector spinae muscle and its surrounding musculoskeletal system as also evidenced from EMG data. In order to reduce muscle stress, design idea to modify traditional cane fiber making tool was conceived in such a way where it facilitates free change of posture adopting several ground sitting postures.

3.3.1. Dimensions and functional characteristics of modified tool

Dimension details and different functional parts of modified fiber making tool is shown in following figure (Fig. 34):

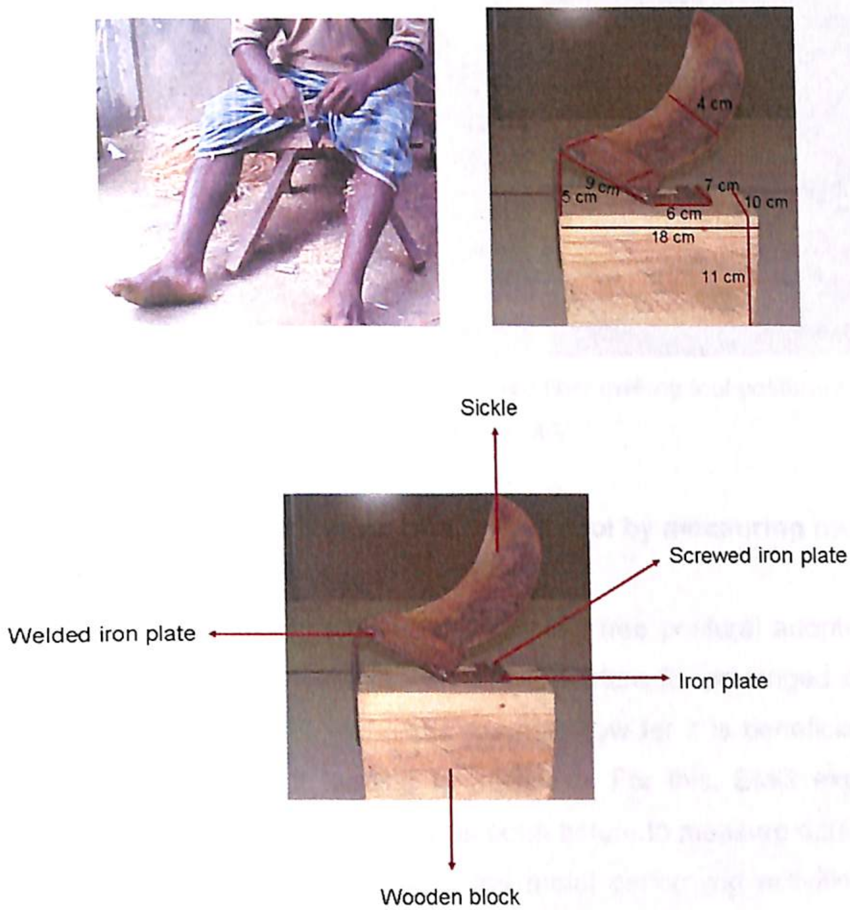


Fig. 34 Top left: working with existing tool, Top right and bottom : modified fiber making tool

The modified fiber making tool is portable, can be attached to any wooden plank and the artisans do not have to hold it with their legs during operation. Thus in single sitting, crafts persons can adopt several postures (Fig. 35). In whole design developmental process participatory approach was adopted, starting from initiation of design theme to each and every concept generation steps, volunteer subjects were taken into confidence that each design component would help them better functioning and they can make and maintain easily within their capabilities.

Fig. 35 While working with modified fiber making tool postural benefits are being evaluated with EMG

3.3.2. Usability evaluation of modified tool by measuring muscle electrical activity

Modified fiber making tool which facilitates free postural adoption and does not restrict artisans to remain in single posture for prolonged duration, was evaluated using EMG technique to know how far it is beneficial in reducing task-specific postural loading to muscles. For this, EMG experiment was carried out in similar way as it was done before to measure different muscles' activity for different cane and brass metal performing activities. A total 10 (N=10) cane crafts artisans were involved for this study.

a) **Selection of muscles:** Same muscles which were investigated earlier while making cane strip and fiber with traditional fiber making tool; Erector spinae (at L4-L5), upper trapezius, and pectoralis major muscles were investigated for this study.

b) **Placement of electrodes**: Bipolar Ag-AgCl surface electrodes were placed on skin surface over muscle belly of these three muscles after shaving the skin with an inter-electrode distance of 10 mm (P. Zip,1982).

c) **Recording of EMG signal during performance of cane fiber making activity with modified fiber making tool:** The EMG signals were recorded by MP100, BIOPAC SYSTEM during performance of cane fiber making activity with modified fiber making tool. Signals from upper trapezius, pectoralis major, and erector spinae muscles (at L4-L5) were picked up by the electrodes and transmitted to the EMG amplifier. The amplified signal was then captured by MP100 data capturing unit where A/D converter converted the analog signal to digital one which was then connected to the computer for data storage. The recorded EMG signal was then converted to the text files and imported to MATLAB signal processing and analysing program for signal processing in order to determine Root mean square value

d) **Normalization of EMG signals:** After subtracting the resting EMG values, the work EMG signals were normalized by the signals obtained during the maximal voluntary contractions which were expressed in terms of % maximal voluntary contractions. The normalized signals were then processed to get root mean square (RMS) EMG value. The collected RMS value of upper trapezius, pectoralis major, and erector spinae muscle during cane fiber making activity with modified fiber making system is presented graphically in following figure (Fig. 36):

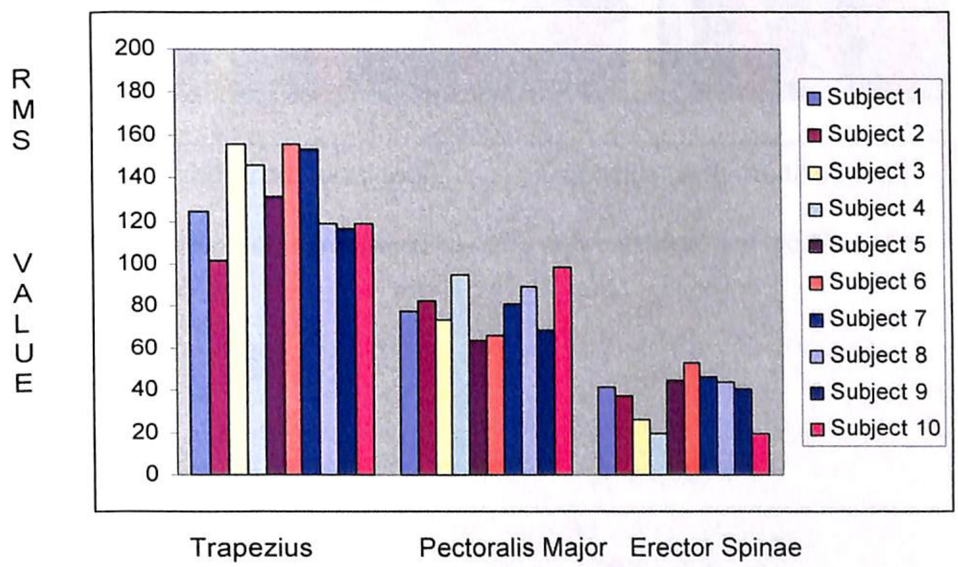


Fig. 36 RMS value for trapezius, pectoralis major and erector spinae while making cane fiber with modified system

From RMS value figure, it is seen, high RMS value for upper trapezius, followed by pectoralis major and erector spinae muscles in cane fiber making activity with modified system.

3.3.3. Comparison of muscles' electrical activity with traditional and modified fiber making tool

The recorded RMS value is compared with RMS data collected from three muscles with traditional system and is presented in following figures (Fig. 37-39).

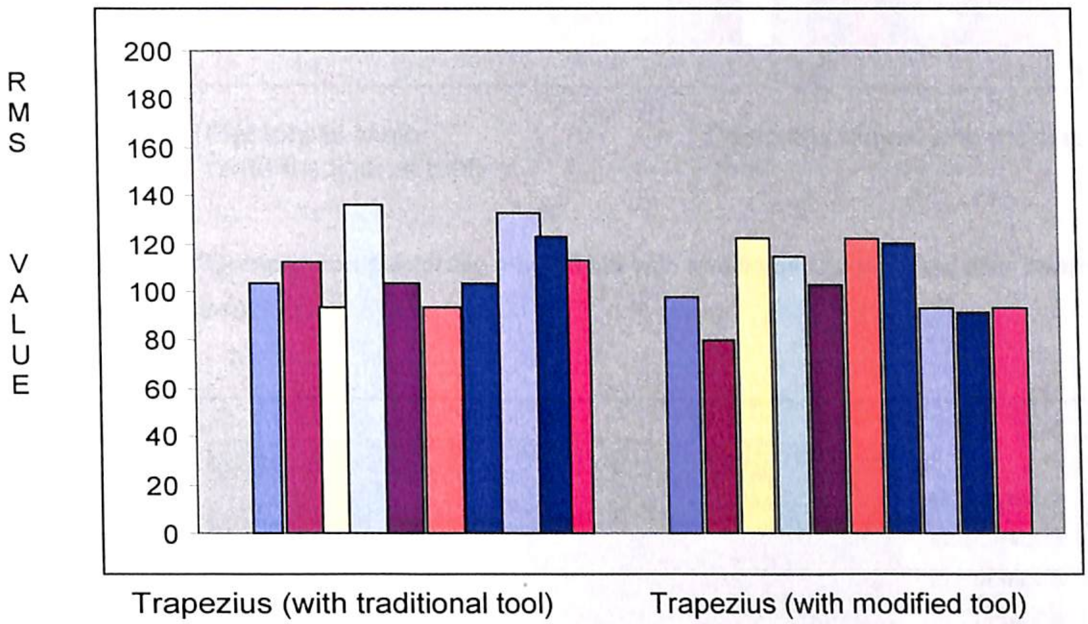


Fig. 37 Comparison of upper trapezius RMS with traditional and modified fiber making tool system

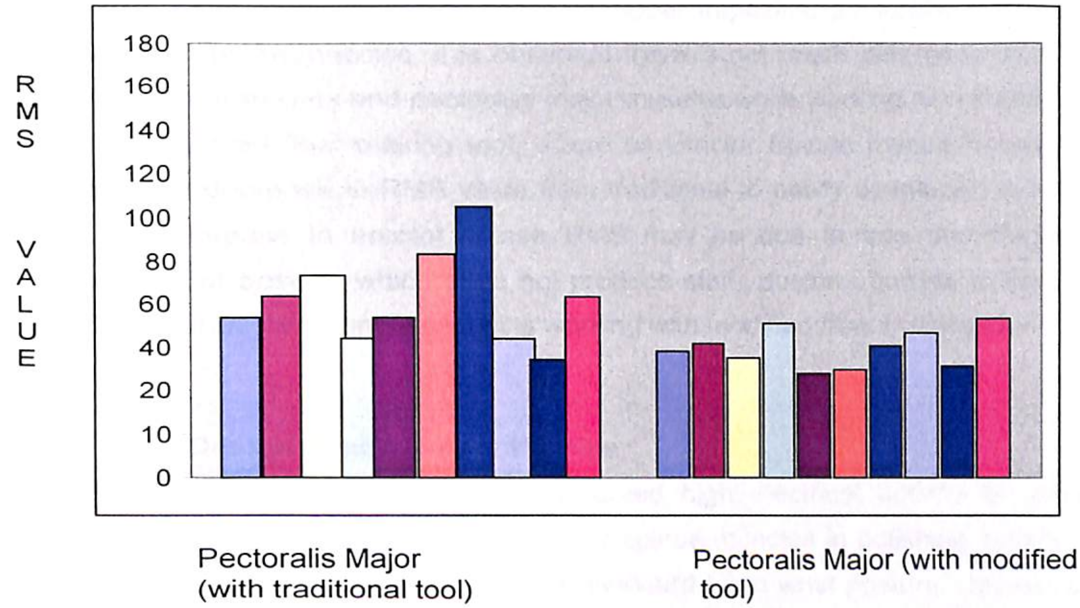


Fig. 38 Comparison pectoralis major RMS with traditional and modified fiber making tool system

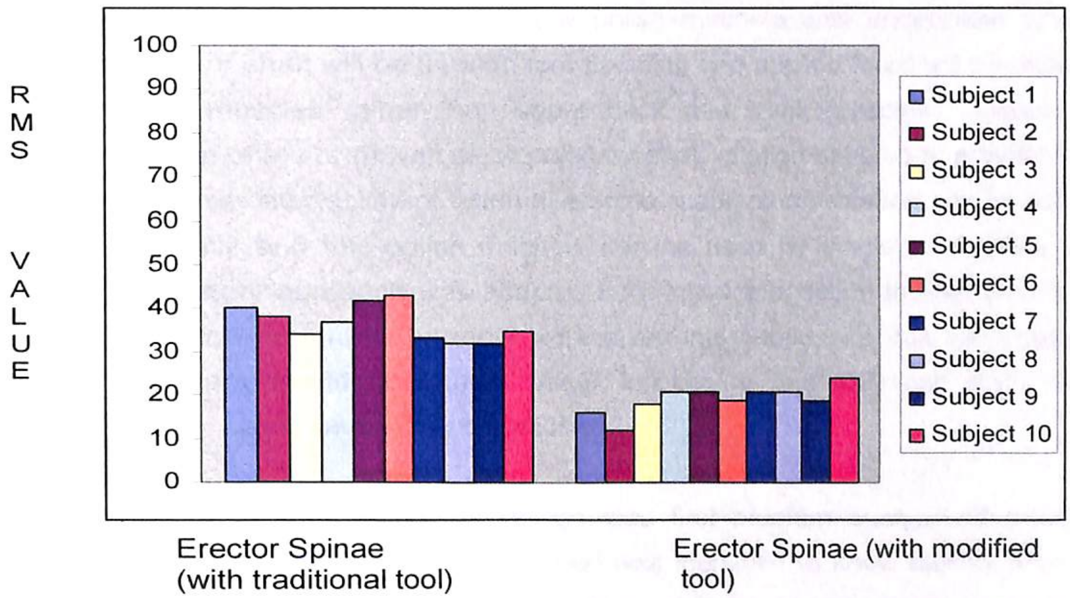


Fig. 39 Comparison of Erector Spinae (at L4-L5) RMS in traditional and modified fiber making tool system

From EMG study and RMS values of upper trapezius, pectoralis major and erector spinae muscles, it is observed there is not much difference in RMS value for trapezius and pectoralis major muscles while working with traditional and modified fiber making tool, where as Erector Spinae muscle shows an obvious decrease in RMS value from traditional to newly developed system. This decrease in erector spinae RMS may be due to free and frequent change of posture which does not produce static postural burden to Erector Spinae muscle when individual is working with modified fiber making tool.

3.4. Design of new polish machine

For brass metal artisans, it is observed high electrical activity of upper trapezius, pectoralis major and erector spinae muscles in polishing activity is due to operation of polishing tool in awkward hand wrist posture. Moreover, roping with hands for rotation of its shaft requires greater amount of force and it utilizes high muscle force of hand and upper back muscles and there is a greater chance of trunk and upper back muscles to become fatigue in lesser time. In order to reduce high force utilization of trunk and upper back muscles, design concept to develop a new polish machine was undertaken where rotation of shaft will be through foot paddling and applied force will be utilised by leg muscles rather than upper back and trunk muscles. Moreover, provision of motor (driven electrically) for shaft rotation have been provided so that as per availability of external electric supply shaft rotation can be made electrically and this polish machine can be used by single user. Here too participatory approach was adopted from initial conception to final prototype generation. Volunteer subjects were taken into confidence that each design component would help them better functioning and they can make and maintain easily within their capabilities.

Before conceptualisation of design idea first problem analysis of existing products was carried out. The need was identified to know exactly what is wanted and to set up the objectives of the product development and determine what is required to be incorporated into the product. A methodology was set up on what could be done to fulfill the objectives, including incorporation of users' information. Initial sketches, conceptualization of product design and prototype making was carried out along with verification of its feasibility through feedback from probable users and experts (Ergonomics and Design faculty of IIT Guwahati). Refinement of the design, final product design and prototype was developed at workshop of Department of Design. 3-D model of this developed polish machine is presented below (Fig. 40):

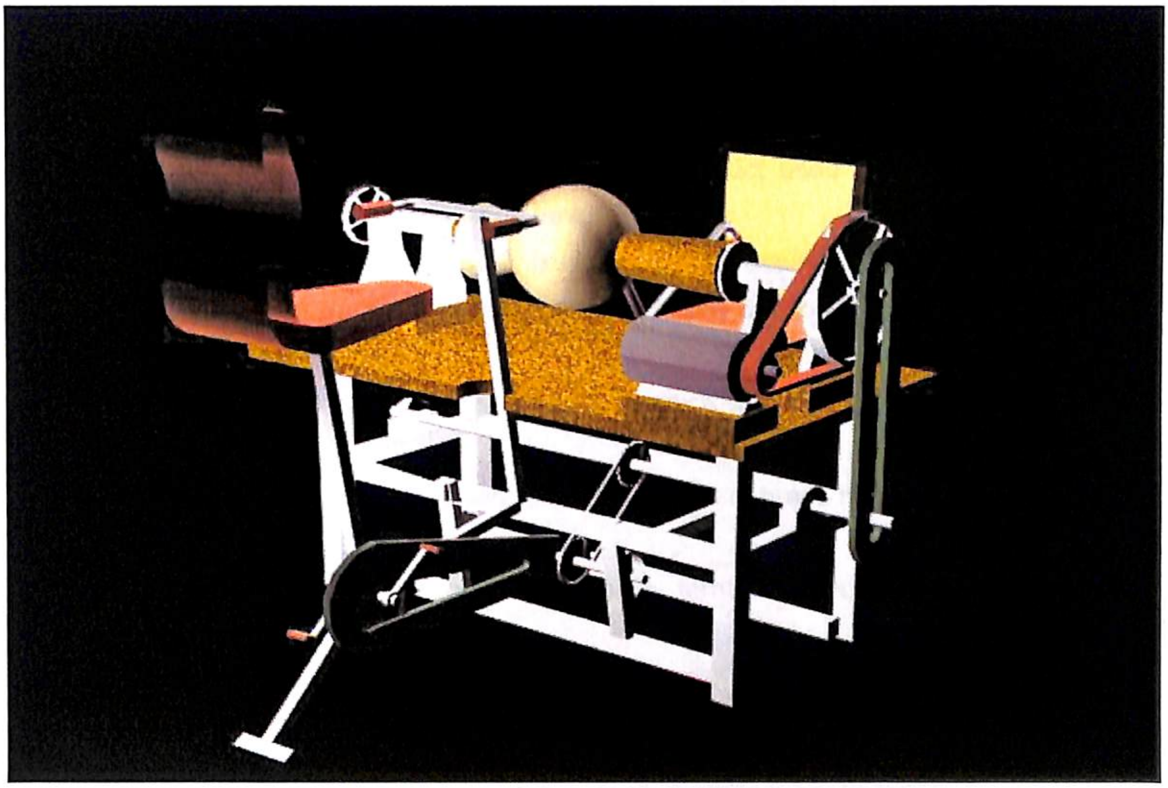


Fig. 40 3-D model prototype of polish machine for brass metal artisans to polish a number of brass metal products.

3.5 Functional characteristics of new polish machine

The polish machine satisfies the below ergonomics product design criteria as:

- The shape of this machine is aesthetically appealing. The geometry of different parts of this machine and the user's anthropometry fit each other for ensuring safety as well as better function. The shape, size, and overall form of this product is according to the various confirmed and anticipated behavioral patterns of a normal user when using a similar article
- The size of the product is handy to operate and easy to handle
- The direction of applied force synchronizes with the human natural body axis movement so that maximum mechanical advantage could be achieved
- It is having preference of emergency features (instant on/off switch)
- Groupings of similar body parts of this product used for the same purpose or for similar activities have been done
- It ensures safety through optimization of safety features
- It is very easy to operate, does not require any previous training for its operation.
- Overall appearance of this machine is such that it is convenient to use.
- Products is durable, and can polish a number of brass metal products at single pace
- Obviously, it is very cost-effective in terms of productivity and economy

3.6. Technological know-how and other characteristics including anthropometric body dimensional features incorporated

To make an article of the correct size, to create a system of multiple units and a work space, or to design an article for a single individual's need, the individual's own dimensional requirements may be of direct importance. But for mass production and use, proper percentile selections of the anthropometric data should be made and adequate allowances should be considered. Support of anthropometric data (collected from the specific population groups) to design specific articles, e.g., product, equipment, furniture, machine tools, etc., should be looked into. Dimensions of equipment or work accessories and work spaces should be considered while designing, in order to achieve effective accommodation layout and for enabling easy handling of equipment by moving within and around the space provided. For design purposes, to fit an intended user from amongst the known population group, different percentile values of different human body dimensions should be considered for different design dimensions. Designing an article or a system with a single percentile value for all the relevant human dimensions would fail to satisfy all the other dimensional features of the design. As a general rule, to avoid reach higher percentiles and to get easy reach lower percentile values would be of relevance in design.

Selection of the average or mean value of a dimension depends on its contextual use and whether it demands critically to be fitted into the whole range of the users' population. The terms mean or average, and median or the 50th percentile value may not be identical. But, if there is no dearth of sample sizes on which data were collected, the median (50th percentile) value normally is close to the mean value. Hence, in practice, the average is used as a synonym for the 50th percentile (D. Chakrabarti 1997).

For developing this polish machine following anthropometric body dimensions were considered and anthropometric data was taken from Indian Anthropometric Dimensions Book. 50th percentile value of following dimensions are considered. These are:

Stature (Top of the head, standing in erect stretched posture)
Waist height (Upper margin of the lateral iliac crests)
Crotch height (Lower most point of the trunk between the legs)
Normal sitting height (Top of the head, sitting in normal relaxed posture)
Erect sitting height (Top of the head, sitting in erect stretched posture)
Upper lumbar height (Uppermost point of the first lumbar vertebra)
Knee height (Upper most point of the knee)
Popliteal height (Popliteal angle point at the underside of the thigh immediately behind the knee, where the tendon of biceps femoris muscle inserts into the lower leg)

Thigh clearance height with raised knee (Highest point on the knee, at the lower thigh when the leg is raised upward to the maximum supported on the toes).

Buttock to knee length, normal sitting (Horizontal distance from the most posterior point on the uncompressed buttocks to the most anterior point on the knee)

Buttock to popliteal length, normal sitting (Horizontal distance from the most posterior point on the uncompressed buttocks to the back of the lower leg at knee. i.e., popliteal angle point)

Buttock to leg length normal sitting (Horizontal distance between the most posterior point on the uncompressed buttocks and the tip of the longest toe, when the legs are placed on the floor with the knee at an angle of 90 degrees)

Buttock to extended leg comfortable length (Horizontal distance between the most posterior point on the uncompressed buttocks and the tip of the longest toe, when the legs are extended horizontally and the knee is lifted to the maximum height keeping the toes on the floor)

Waist breadth (Maximum horizontal distance across the waist at the upper margin of the lateral iliac crests)

Hip breadth (Maximum horizontal distance across the hips)

Mid thigh-to thigh breadth, relaxed (Maximum horizontal distance across the mid thigh, most lateral surfaces, spreading external sideways, in relaxed position)

Hand grip length (Length of the hand grip, from the base of the palm to the centre of the grip, while holding a rod of 30 mm diameter)

All the above body dimensions are considered for appropriate work surface height, operator's seat height, proper positioning of back rest, good gripping of cutting tool, foot paddle height, handle length and comfortable arm reach, idle positioning of hand/wrist and range of joint motion while using cutting tool and to incorporate other design features to this polish machine

3.7. Product dimensions

Different product dimensions and parts are presented in following figures (Fig. 41-46)

Fig 41 Product model of new polish machine.

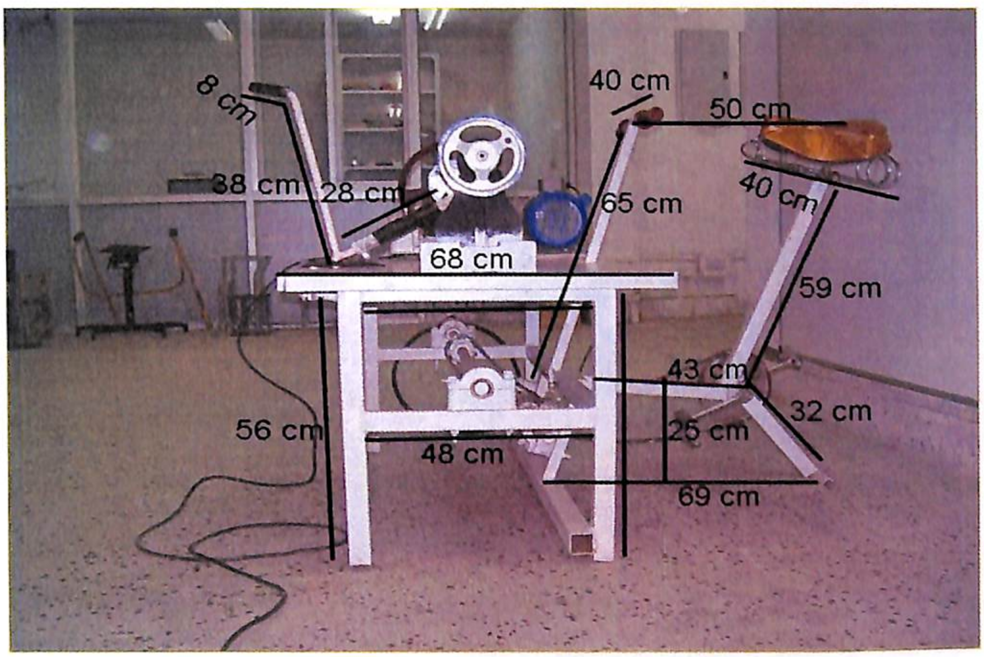


Fig. 42 Dimensions of the polish machine, side view.

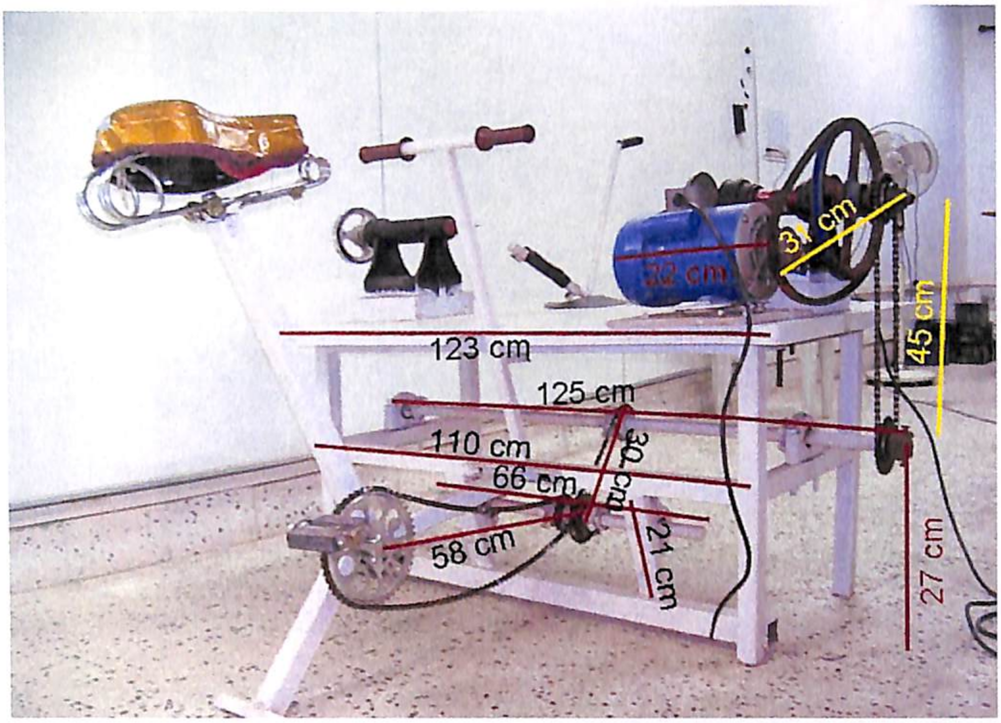


Fig. 43 Dimensions of the polish machine, front view.

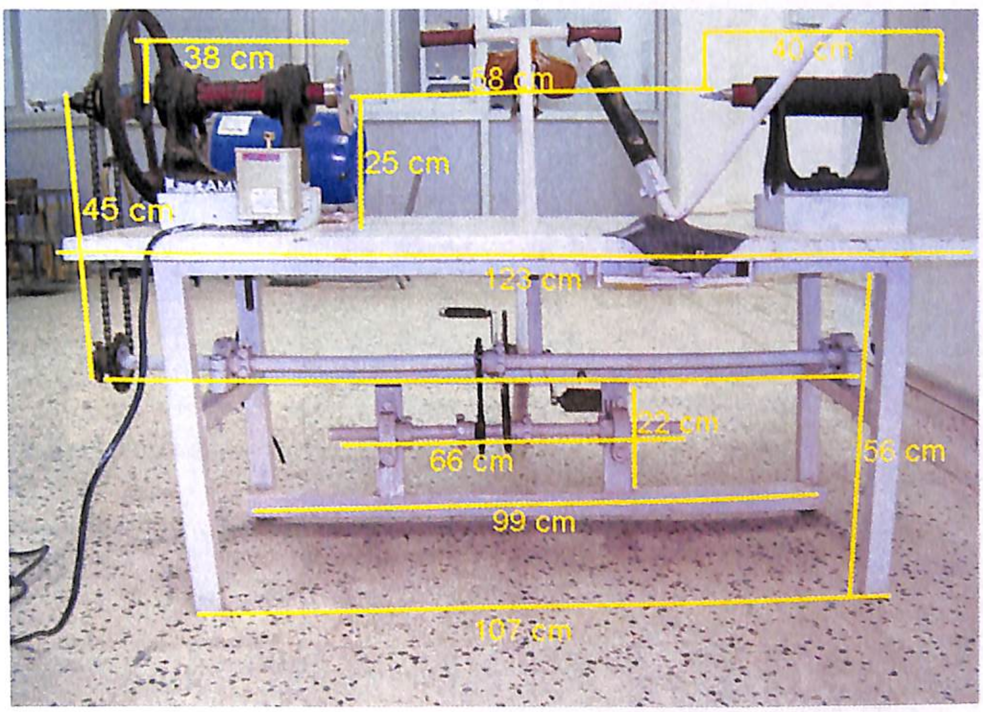


Fig. 44 Other dimensions of the polish machine, front view.

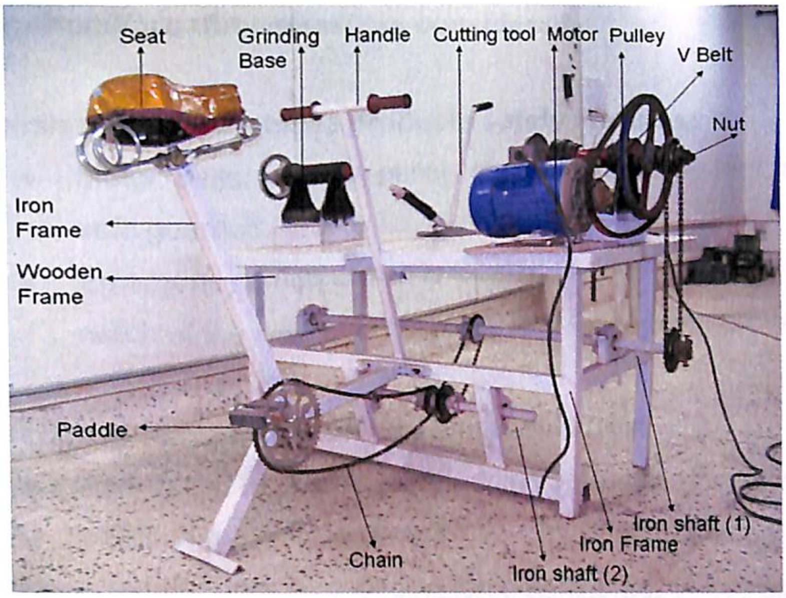


Fig. 45 Different parts of the newly developed polish machine prototype.

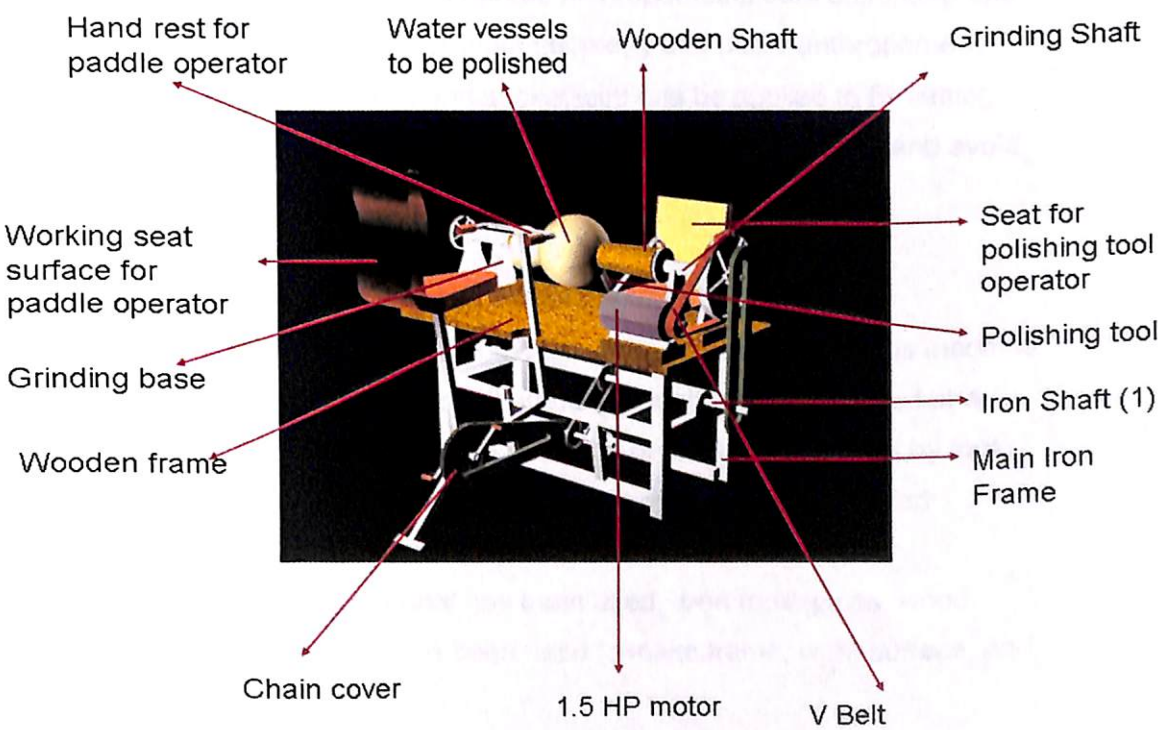


Fig. 46 Different parts of the newly developed polish machine, 3-D model.

3.8. Ergonomics safety measures considered

Polish machine satisfies products safety features:

- Motor, belts, bearing, pulley, chains and cutting tool; all are safe guarded.
- Emergency on/off switch is located at comfortable and visible reach of the users. Emergency brake has been provided

It satisfies human comfort and safety features:

- As rotation of shaft is foot-paddled operated, operator can produce more force because legs muscles are more strengtheners in producing force particularly in this context than upper back and trunk muscles
- Seat height, work surface height, cutting tools height is adjustable hence can be used by multiple users
- Application of appropriate anthropometric data ensures proper match between product geometry and users anthropometry
- Principle of ball and socket joint has be applied to fix cutting tool so that it ensures good gripping to the operator and avoid wrist joint deviation

3.9. Manufacturing process and material used

- Technological know-how which has been incorporated in this machine is very simple. Various brass metal products can be polished at a time by rotating central shaft. Rotation of shaft is carried out by foot paddle, bearing, pulleys and chains. Shaft also can be rotated electrically through a motor, pulley and belt.
- Locally available material has been used. Iron rods, pipes, wood, leather, and foams have been used to make frame, work surface, and seat surface.
- Cast iron made grinding hand lathe has been used to hold central shaft. Shaft is made up with wood which has been tapered for polishing of water pot with varied diameter (Fig. 47).

- Fixation has been done with clamps, jigs, screw and metal arc welding wherever required
- For free rotation of cutting tool, ball and socket from old vehicle's gear box has been fixed
- 1.5 HP motor with RPM of 1428 has been used along with toggled on/off switch
- Several units having connection with each other to serve desired function have been linked using simple nuts and bolts so that whole system can be detached into several parts and also can easily be assembled
- Its operation is very simple, does not require any training. When the machine is motor driven, single person just for placing of cutting tool is needed. When there is short of power supply, machine is foot-paddled operated then two person is required, one for rotation of shaft and another for cutting tool operation. Thus there is provision for both facilities as and when necessary.

Fig. 47 polishing operation through shaft rotation and cutting tool, one is paddling and other one is engaged in polishing.

3.10. Utility measures undertaken through participatory approach

Participatory ergonomics as a concept has been defined in several differing but complementary ways. As Wilson (1995) proposed participatory ergonomics is the process where involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals. Participatory ergonomics is the principal and most often used methodology in the optimization design.

Here in whole design development process, ergonomics participatory approach (Fig. 48) has been adopted through involvement of direct beneficiaries (brass metal artisans) in idea generation, product planning and development, prototype making, evaluation and final product development, so that they can be aware of its technological know-how, manufacturing processes, material used, functionality checks, and necessary repairing if situation demanded.

Fig. 48 Participatory approach for development as well as usability evaluation of polish machine.

3.11. Analysis of productivity, usability and cost effectiveness

Subjective and performance level evaluation of newly developed polish machine (Fig. 49) indicates, two crafts artisans can polish 46-51 "*koloh*" (water pot) per day in 10 hours shift. The productivity of this machine is 20-22% higher as compared to conventional one. When external power is used to drive this machine, single crafts artisan can make 68-72 water pot per 10 hours shift. Considering electricity charge, productivity is still 31% than conventional type.

Moreover, while carrying out polishing activity with traditional polish machine, the crafts artisans have to take micro-breaks in every 35-45 minutes due to physical stress and strain on upper back, chest and knees. The crafts artisan opined, working with newly developed polish machine does not make them to feel exhausted, and it is less strenuous, easy to operate, and very effective to polish other brass metal items too.

Fig. 49 Subjective and performance level evaluation while working with newly developed polish machine and traditional one.

Comparison of water vessels polished per day by brass metal artisan in 10 hour shift using traditional polish tool, newly developed polish machine operated through foot paddle, and newly developed polish machine operated through electric motor (Fig. 50).

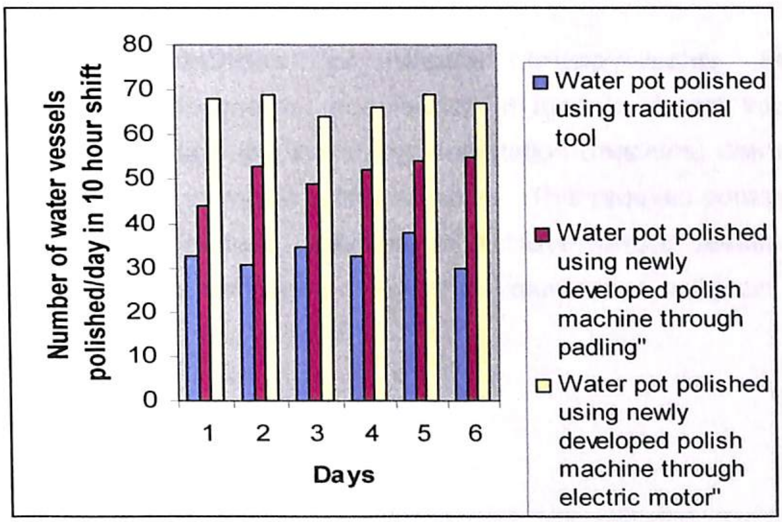


Fig. 50 Comparative statement of productivity by traditional polishing system and newly developed polish machine operated through foot paddle and electric motor.

3.12. Beneficial effect of modified work equipment: productivity and work posture

Any developed products which provides better facility to adopt/change posture freely, reduce prolonged static postural burden, and decrease extreme range of joint deviation along with shifting of load from smaller to larger muscle groups reduces muscle stress and chances of muscles to become fatigue.

Newly developed polish machine provides craft artisans elevated work surface and facility to adopt comfort posture. Force applied in traditional system with hands are more stressful in comparison to the newly developed system which is foot paddle operated. The leg muscles are comparatively stronger than muscles in hands and upper back and can exert greater force reducing chance of the muscle to become fatigue. Moreover, operation of cutting tool does not deviate hand/wrist extremely away from neutral position. Because ball-socket fixate of hand tool require minimal pressure and not much deviation of hand/wrists for peeling out of brass metal products surface. Thus productivity, performance, and safety are ensured in newly designed system. User satisfaction level and productivity is very high.

3.13. Possibilities of similar improvements for other tasks

Similar developmental possibilities in tune to design improvement of fiber making tool and the polishing workstation (machine) can also be studied for other cane and metal crafts activities. This requires context and task-specific study of individual activities to achieve similar results. This has also commonly been opined by the volunteered subjects in both sectors.

Chapter – IV

Discussion and conclusion

4.0. Discussion

The North eastern states of India fall under the tropical rain forest zone and thus the richness in flora and fauna. These have got translated into the décor and design in almost all the artefacts and work of artisans in handicraft products. This region has not only the raw material but the fine artistic sense of the craft artisans of making handicrafts products which are highly appreciated all over and are in great demand for their functional and aesthetic values. To maintain this, relevant studies has become essential towards having a comfortable work environment and dignified life of the crafts persons.

In any occupational settings, individual's performance and productivity is greatly influenced by the way task is performed, type of hand tools are used, joint movement and range of joint motion, adoption of particular or set of postures in carrying out that particular tasks, work duration and rest pauses, designing of various workstations, machines, tools, seating devices, relations between work demands and individual's ability, and certain environmental factors, like heat, humidity, noise, vibrations etc. If any of these factors are not proper, this can lead to production loss, occupational health hazards that may range from musculoskeletal disorders to health injuries and loss of motivation.

Ergonomics/ human factors application has been found successful in reducing occupational hazards, injuries, and workplace accident. It aims at optimizing human-machine-environment interactions to get the maximum efficiency, productivity, and improvement of the working conditions and working life of the workers. The principle, guidelines, and criteria of ergonomics is fitting the task to the man (Grandjean, 1977, Sanders and McCormick, 1987, and Chakrabarti, 1997).

Indian economy is predominantly depends upon agriculture, small scale industries, crafts and cottage production units, and unorganized industrial sectors. It is having very limited number of large organized industries. Bareau of Indian Standards expresses excellence of industries and quality of their products. It has formulated certain specification to be practiced in industrial workplace and standards to be maintained for industrial products. Following certain guidelines, industries do get ISO certifications that transparence the level of excellence of that particular industry performance and quality of product. Organised large scaled industries in India go for ISO certifications and they maintain industrial laws and regulation formulated by BIS and other government agencies like central labour institutes (CLI), National Institute of Occupational Health and Safety (NIOH). They practice safety issues and ergonomics safe work practice guidelines in their production premises and well bothered about occupational health and safety concerns of their workers.

Most of the semi and medium scaled industries, small scale production units, crafts and cottage sectors, and home based production units in reality are least concern about occupational health and safety of the workers. For them productivity only means machines out put as expressed by the number of products or items are made in unit time. Industrial laws and regulations are not strictly followed here. Lack of proper guidelines, safety measures, and ergonomics safe work practice guidelines make their work environment unhealthy. Poorly-designed hand tools, bad work postures, improper seating devices, extreme range of joint movement and joint motion while operating hand tool or machine, mismatch between job demands and operator's ability, heat, humidity, vibration and other environmental stressors altogether lead them to develop musculoskeletal and other related health disorders, injuries, and accident. In order to make their work environment healthy and more user-friendly, ergonomics research interventions with appropriate design solution is highly required which has not been carried out to that extend.

For any ergonomics research investigations in occupational setup, work posture has always been given great importance. If adoption of particular or set of postures are improper, i.e., orientation of different body joints are not within physiological limits, it restricts individual's body movement and hamper performance and overall productivity. Ergonomics has found successful in developing guidelines for good postures practiced commonly in organized industrial workplace which are mainly device dependant seating and standing postures.

In crafts, cottage, small scaled industries, and home-based production sectors in India, people adopt certain postures that are quite different from conventional type of posture as observed in organized workplace. Most of these are squatting, kneeling, cross legged, and various leg extended posture adopt by artisans on floor. Sometimes using some support, e.g., walls, etc to rest the back. Sometimes, they use seating device and sometimes without any devices. These postures are also been practiced in India traditionally in houses for doing different house-hold chores.

Not much ergonomics research has been conducted on these floor-sitting postures to see its effects on body muscular system. Though some researchers opined sitting on the floor cross-legged, is a traditional and common practice in India. These facilitate changing of body positions with some vital physiological benefits, e.g., reduction of localised muscular static fatigue and good flow of venous blood. It also eases the task of doing certain operations, with the facility of shifting the body load from one muscle group to another muscle group, as there are no supportive structural (furniture, etc.) restrictions on free body movement (Sen, 1984). But in depth studies have not been visibly reported.

Muscle electrical activity always provides researchers very good information about generation of force or load level of muscle for any activity including adoption of posture. High electrical activity resembles greater exertion of force or load level to the muscle. This is derived from the time domain parameters of EMG, expressed as Root Mean Square EMG or Integrated EMG value. During sustained or repetitive muscle contractions as observed in any dynamic work activity, typical changes in surface electromyograms (EMG), such as an increase in the amplitude or a shift in the frequency spectrum towards higher or lower frequencies, can be observed. In occupational electromyography such EMG changes are commonly interpreted as signs of higher force production if both amplitude and frequency spectrum shifts towards higher side, and if there is increase in amplitude and shift of frequency spectrum in lower frequency used to establish the occurrence of fatigue. Thus there is linear relationship between force production, EMG amplitude and frequency spectrum.

An increase in muscular force is accompanied by an increase in EA, and if this is expressed in terms of RMS or IEMG value there is subsequent increase of these two parameters. This mainly results from an increase in muscular activation, namely, of the number of action potentials per unit of time. An increase in muscular force is not only accompanied by an increase in the EMG amplitude but also by an increase in Median or mean power frequency level (MPF) which reflects a spectral shift to higher frequencies and is caused mainly by an increase in the number of action potentials per unit of time.

The design of different work and habitat built environments depend on the postural adaptations required to perform varieties of tasks, sequentially. To create a user compatible optimum work space, the layout of various articles within it must provide adequate postural comfort, while standing, sitting, semi-standing (i.e., with hip rest), lying in actual work conditions, and resting. While working, the body and limb weight should be properly distributed; natural body and limb positions are an upright head must be maintained. It requires proper structural supports, if the work demands that an unusual posture be adopted. This is to avoid quick fatigue, which can adversely affect safety, induce musculoskeletal problems, etc., pose occupation related hazards, and sometimes result in accidents. General work postures are seen as sitting, standing, supine, kneeling, and crawling. Moreover, in the oriental cultural context a few more work postures are also seen in use, sitting cross-legged on the floor with various leg extended positions and squatting postures. While designing the functional volumes of any work station and work space, these adopted postures must be analysed according to the demand of the work context so that most of the postures required to perform the intended task may be accommodated (D. Chakrabarti, 1997).

A body position adopted without much discomfort and used in a work demanding position satisfactorily without causing muscular fatigue, can be said to be good posture. In such a posture, a man would be able to give his best efforts towards his task. His working condition should be such that if it demands a sitting position, his vertebral column should be comfortably straight, the body load should be balanced on both sides and in a standing position, the body weight should be equally distributed on both the legs, and the head should be in a comfortable position in line with the vertebral column. Postures must be adopted which would allow as many muscles as possible to come into play. Thus the muscles would be more efficient and skilful and would perform the task well. If adopted postures does not satisfy above conditions and produce discomfort, musculoskeletal stress, then posture to be turned out as awkward.

Crafts making is one of the leading profession in entire North-east India, especially in Assam. Craft artisans use traditional hand tools and perform their tasks in traditional way. As their work equipment and workplace are far away to get benefits from industrial safety norms, occupational hazards and safety is greatest concern in their occupational settings.

The purpose of this study was to investigate prevalence of occupational hazards and stressors, how does traditional work methods along with hand tools influence posture and muscle load of the crafts artisans. The EMG has been used as an analytical tool to evaluate muscle stress. All developed criteria, methods and design solution have been implemented using participatory approach. Both lab-based and field trial and testing methods have been used to see the efficacy of newly developed methods or design. All lab experimentations were done in Ergonomics Laboratory of IIT Guwahati. Experimental set up was developed in such a way that it should provide them feeling of their original work environment.

4.1. Findings of the present study

The below are summarised as the salient findings of this research work:

- In the occupational settings of cane and metal craft sectors, artisans produce different crafts items in traditional way, using traditional methodology and hand tools. They perform their work adopting various cross-legged, leg extended, kneeling and squatting posture on floor. Sometimes, they use low-height stool (pirah), sometimes they sit on floor without using any seating device using wall as back support. Some of these floor-sitting postures allow them to change their postures freely as per their will whenever they feel to do so.

- It has been observed, some crafts artisans carry on their work till their physical fitness allows them to work. There is no retirement age. There is no fixed time limit for their work, sometimes they work for 12 hours and sometimes for 4 to 5 hours and so, whenever it is required. They usually work for 7 days per week. While using different hand tool, artisans feel pain and discomfort while at work or during rest in all parts of body, especially in region of neck, back, wrist and knees. This is more in case of brass metal artisans due to their job types and used tools which make extreme joint deviation, exerts greater load on muscles, and thus produces muscle stress., which they feel needs to be studied to develop specific design and work methods. This development, they feel should go along with their capabilities and resources.

- It is noticed, all activities are performed traditionally on floor which allows free postural movement at their own will; only fiber making job confined their leg movement as the tool needs continuous legs support till the job is over. To overcome this problem, a self-standing device has been developed and tested satisfactory.

- For brass metal activities, the polishing job requires to perform on floor with two persons adopting squatting posture. Traditionally brass metal artisans polish different brass metal products (mainly bowl and water vessels) on floor using wooden shaft that is rotated with rope. In whole process, two artisans are required one has to press the cutting tool for peeling out of brass metal surface to make shining and glossiness of the products. Another person applied force through rope for half cycle rotation of the shaft. For both the persons, their perform job is stressful from ergonomics perspective, because for roping activity, it utilizes hand and upper back muscles which has lesser efficiency to generate force as compared to lower back and leg muscles due to difference in their muscle fiber content and has greater chance to become fatigue. Moreover, for pressing of cutting tool, brass metal artisans have to deviate wrist in awkward posture which add substantial amount of pressure on neighbouring muscles and soft tissues as there is no arm support. The job is tiresome from occupational stress perspective. Moreover, as it is inter-dependable tasks, if one person take rest, other is compelled also to stop work or continue vice versa.

- A polish machine (workstation) has been developed with elevated work surface. In newly designed polish machine, for shaft movement force has to be applied with legs, because the machine is foot-paddled operated. Moreover, with raised work surface hand/wrist position does not become awkward and cutting tool has been designed in such a way that its ball-socket movement technology does not require that much force as required with traditional system for surface peeling of brass metal products.

- Postural load while performing different floor-sitting tasks in cane and brass activities has been assessed measuring muscle electrical activity using surface EMG technique. It is observed from EMG study, which has been carried out for this study, the high electrical activity (expressed in terms of RMS value) of upper Trapezius, Pectoralis Major, and Erector Spinae muscles for cane bending activity, followed by cane straightening and cane sharpening activity. Cane fiber making activity shows lowest RMS value for trapezius and pectoralis major muscles. Relatively high RMS value of erector spinae muscle in fiber making activity is due to prolonged static posture produces postural load to the erector spinae muscle.

- At the same time, high mean power frequency value (MPF) from frequency domain of EMG signal has been observed for all three muscles in cane bending activity, followed by cane straightening, sharpening and fiber making. According to JASA model (Joint analysis of EMG spectrum and amplitude), if there is increase of both amplitude and frequency spectrum, force production is higher. That means, muscle has to exert higher amount of force in that circumstances. Thus, exerted force of trapezius, pectoralis major, and erector spinae muscle is higher for cane bending activity, followed by straightening, sharpening and fiber making.

- For brass metal artisans, sheet cutting and polishing brass metal activities utilize high muscles' electrical activity as evidence by high value of RMS and MPF. This is due to repetitive motion and extreme range of joint deviation produces higher load to trapezius, pectoralis major, and erector spinae muscles in traditional work set up.

- Modified fiber making tool is appeared to be beneficial in reduction of muscle load as evidenced from EMG study which indicates the value of RMS amplitude is significantly lower for trapezius, pectoralis major and erector spine muscles in modified fiber making tool system as compared to the RMS extracted from the same muscles when individual is working with traditional fiber making system. The traditional fiber making tool makes individual to remain in particular posture for prolonged duration and hence it produces static postural load on muscles and surrounding soft tissues which is reduced significantly by free and frequent change of posture with modified fiber making tool system.

- Newly designed polish machine appeared to beneficial which can be operated by two persons (polisher and puller) as well as it can also be operated by one person (polisher), when shaft is rotated with external electric power.

  With elevated work surface, squatting posture is avoided. Application of force to rotate shaft is through cycling operation involving leg muscles rather puling strings by hands.

  Polishing person can operate using a seat, even hip rest and standing posture can also be adopted. Thus multi-postural adoption facility is provided through this system. Cutting tool is mounted on a specially designed device which is fixed on workstation platform which provides natural joint movements with proper arm rest facilities.

  Subjective and performance level evaluation indicates productivity increment of 31% with reduced postural load.

4.2. Conclusion:

Any developed products which provides better facility to adopt/change posture freely, reduce prolonged static postural burden, and decrease extreme range of joint deviation along with shifting of load from smaller to larger muscle groups reduces muscle stress and chances of muscles to become fatigue.

Newly developed polish machine provides craft artisans elevated work surface and facility to adopt comfort posture. Force applied in traditional system with hands are more stressful in comparison to the newly developed system which is foot paddle operated. The leg and lower back muscles are comparatively stronger than muscles in hands and upper back and can exert greater force reducing chance to become fatigue compared to hand and upper back muscles. Moreover, operation of cutting tool does not deviate hand/wrist extremely away from neutral position. Because ball-socket fixate of hand tool require minimal pressure and not much deviation of hand/wrists for peeling out of brass metal products surface. Thus productivity, performance, and safety is ensured in newly designed system. User satisfaction level and productivity is much more high.

This is evidenced by relevant EMG studies. Newly developed polish machine and fiber making tool satisfy all these requirements in order to ensure comfort, safety, and productivity.

This study concludes physical stressors in unorganised cane and brass metal crafts occupational settings can be reduced, even be avoided with proper Ergonomics interventions. This can be achieved by developing work tool and workstation which in turn modify the task and work process with facility to change posture freely as per users' own will and pace with involvement of larger muscles group for force production and fine muscles for skilled movement. For users' friendly design solution, if participatory approach is taken into consideration for design development or task modification where direct beneficiaries are involved in whole developmental process, the results become more fruitful.

Similar developmental possibilities can also be studied for other cane and metal crafts activities and also in other crafts and cottage production sectors. This requires context and task-specific study of individual activities.

4.3. Suggestions for further scope of studies including limitations

Apart from cane and metal crafts, North-east has plenty number of other crafts and cottage industries which also require to be studied. In order to ease out prevailed occupational stressors and to increase comfort, safety, and productivity, ergonomics research investigation through appropriate design solution can be carried out to these occupational settings and also other parts of country.

Occupational work load is assessed using many physiological parameters; in this study muscle's electrical activity was used to evaluate postural load, only three muscles have been observed. Few more muscles can also be investigated to have greater reliability of the result from both sides of the body.

As craft artisans have been working for years in similar job patterns, some age-old adapting mechanism is working there, thus, before making some conclusion based on EMG study, if more EMG data from more number of subjects to be analysed including other relevant parameters (e.g., Heart rate, blood pressure, oxygen consumption, blood lactate, body heat etc) would be good..

References

1. Bao Stephen, Silverstein Barbara, and Cohen Martin, 2001, An electromyography study in three high risk poultry processing jobs, International Journal of Industrial Ergonomics, 27, 375-385.
2. Barua Utpal, 2007, A study on Design Element in Craft Practices with Special reference to Textile and Basketry of Northeast India (PhD thesis), pp. 166
3. Corlett E.N., J. Wilson and I. Manenica, 1986, The Ergonomics of Working Postures; Models, Methods and Cases, Taylor & Francis, London
4. Chung Min K., Inseok Lee and Dohyung Kee, 2003, Effect of stool height and holding time on postural load of squatting postures, International Journal of Industrial Ergonomics, pp. 309-317
5. Chakrabarti, D., 1997, Indian Anthropometric Dimensions for Ergonomics Design Practice, National Institute of Design, Ahmedabad
6. Dul, J. and Weerdmeester B., 2001, Ergonomics for Beginners; A quick reference guide, 2nd ed., Taylor & Francis, London
7. Elisabeth A. C. Fernström and Carl M. Aborg, 1999, Alterations in shoulder activity due to changes in data entry organisation, International Journal of Industrial Ergonomics, 23, pp. 231–240
8. E. Chabran, B. Maton and A. Fourment, 2002, Effects of postural muscle fatigue on the relation between segmental posture and movement, Journal of Electromyography and Kinesiology, pp. 67-79
9. E. Grandjean and W. Hunting, 1977, Ergonomics of postures-review of various problems of standing and sitting postures, Applied Ergonomics, 8, pp. 135–140
10. Hagg G, and Luttmann A., 2000, Methodologies for evaluating electromyographic field data in ergonomics, Journal of Electromyography and Kinesiology, 10, pp. 301-312.
11. http://en.wikipedia.org/wiki/Participatory_Ergonomics- likka Kuorinka (1995)

12. http:// www.ignca.nic.in/craft202.htm
13. http:// www.webindia123.com/craft/state/assam/gal.html
14. Kothiyal Kamal and Berman Kayis, 2001, Workplace layout for seated manual handling tasks: an electromyography study, International Journal of Industrial Ergonomics, 27, pp. 19-32
15. Kendall Peterson F and Kendall Elizabeth (1997): Muscles Testing and Function; 3rd ed., pp. 120-135, McCreary, Williams & Wilkins.
16. Kroemer K and Grandjean E, 1997, Fitting the task to human, a textbook of Occupational Ergonomics, 5th ed., , Taylor & Francis, London pp. 225-235.
17. Kumar Shrawan and Mittal Anil, 1996, Electromyography in Ergonomics , Taylor and Francis, London, pp 140-172
18. Luttmann A, Jäger M and L. Wolfgang, 2000, Electromyographical indication of muscular fatigue in occupational field studies, International Journal of Industrial Ergonomics, 25, pp. 645-660
19. Maiti R and Ray GG, 2004, Study on the variation of peak isometric strength and EMG activity in static field simulated lifting postures, International Journal of Industrial Ergonomics 33, pp. 109-122.
20. Marco J.M. Hoozemans and Jaap H. van Dieën, 2002, Prediction of handgrip forces using surface EMG of forearm muscles, Journal of Electromyography and Kinesiology, 15 pp. 358-366
21. Marras William S and Karwowski Waldemar, 2006, Fundamentals and assessment tools for occupational Ergonomics, 2nd ed., CRC Press, Boca Raton, pp. 76-110
22. Merletti R and Parker P, 2004, Electromyography: Physiology, Engineering and non-invasive applications, 1st ed., John Willey and Sons, New Jersey, pp. 145-153
23. Nag P, Chintharia S, Saiyed S, and Nag A, 1986, EMG analysis of sitting postures in women, Applied Ergonomics, 17, pp. 195-197.
24. Ravi Mookashi Punekar, 2006, Study on Hajo cluster brass metal crafts artisans (IITG Project Report)
25. Sanders, M S. and McCormick E.J., 1987, Human factors in Engineering and Design, 6th ed., McGraw-Hill.

26. Tayyari F and Smith J.L, 1997, Occupational Ergonomics; Principles and applications, 1st ed. , Chapman and Hall, London, pp. 96-113

27. Zipp P (1982): Recommendation for the standardization of lead position in surface Electromyography, European Journal of Applied Physiology, 50, 41-54.

Bibliography

1. A.M. Genaidy, A.A. Al-shedi and W. Karwowski, 1994, Postural stress analysis in industry, Applied Ergonomics, 25, pp. 77–87
2. Basmajian, J.V. and De Luca, C., 1985, Muscles Alive - Their Functions Revealed by Electromyography, 5th ed; Williams and Wilkins, Baltimore
3. Bilodeau, M., Arsenault, A.B., Gravel, D. and Bourbonnais, D., 1990, The influence of an increase in the level of force on the EMG power spectrum of elbow extensors, European Journal of Applied Physiology 61, pp. 461–466
4. Bilodeau, M., Arsenault, A.B., Gravel, D. and Bourbonnais, D., 1991, EMG power spectrum of elbow extensors during ramp and step isometric contractions, European Journal of Applied Physiology 63, pp. 24–28
5. Broman, H., Bilotto, G. and de Luca, C.J., 1985, Myoelectric signal conduction velocity and spectral parameters, influence of force and time, Journal of Applied Physiology 58, pp. 1428–1437
6. Buchholz et al (1996). B. Buchholz, V. Paquet, L. Punnet, D. Lee and S. Moir, 1996, a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work, Applied Ergonomics, 27, pp. 177–187
7. Caffier, G., Heinecke, D. and Hinterthan, R., 1993, Surface EMG and load level during long-lasting static contractions of low intensity. International Journal of Industrial Ergonomics, 12, pp. 77–83

8. Cobb, S. and Forbes, A., 1923, Electromyographic studies of muscular fatigue in man, Americal Journal of Physiology 65, pp. 234–251

9. D.C. Montgomery, 1991, Design and Analysis of Experiments, 3rd ed; Wiley, NewYork.

10. Hagberg M., Hagberg, 1982, Local shoulder muscular strain-symptoms and disorders, Journal of Human Ecology, 11, pp. 99–108

11. Han et al; S.H. Han, M. Song and J. Kwahk, 1999, A systematic method for analyzing magnitude estimation data. International Journal of Industrial Ergonomics, 23, pp. 513–524

12. Hignett and McAtamney S. Hignett and L. McAtamney, 2000, Rapid entire body assessment (REBA), Applied Ergonomics, 31; pp. 201–205

13. Jung and Choe., E.S. Jung and J. Choe, 1996, Human reach posture prediction based on psychophysical discomfort, International Journal of Industrial Ergonomics, 18, pp. 173–179

14. Krogh-Lund, C., 1993, Myo-electric fatigue and force failure from submaximal static elbow flexion sustained to exhaustion. European Journal of Applied Physiology 67, pp. 389–401

15. Kumar, S., 1996, Electromyography in ergonomics. In: Kumar, S. and Mital, A., Editors, Electromyography in Ergonomics, Taylor and Francis, London, pp. 1–50.

16. Laurig, W., Luttmann, A. and Jäger, M., 1987, Evaluation of strain in shop-floor situations by means of electromyographic investigations. In: Asfour, S.S., Editor, Trends in Ergonomics/Human Factors IV, Elsevier Science Publishers, Amsterdam, pp. 685–692.

17. Luttmann, A. and Jäger, M., 1992, Reduction of muscular strain by work design: Electromyographical field studies in a weaving mill. In: Kumar, S., Editor, Advances in Industrial Ergonomics and Safety IV, Taylor & Francis, London, Washington, pp. 553–560

18. Luttmann, A. and Jäger, M.,1998, Discrimination between fatigue-induced and force-related EMG changes in occupational field studies. In: Kumar, S., Editor, Advances in Occupational Ergonomics and Safety 2, IOS Press, Amsterdam, pp. 218–221

19. Merletti, R., Knaflitz, M. and De Luca, C.J., 1992, Electrically evoked myoelectric signals CRC Critical Reviews in Biomedical Engineering 19, pp. 293–340
20. Moritani, T. and Muro, M., 1987, Motor unit activity and surface electromyogram power spectrum during increasing force of contraction, European Journal of Applied Physiology 56, pp. 260–265
21. Nagata, S., Arsenault, A.B., Gagnon, D., Smyth, G. and Mathieu, P.-A., 1990, EMG power spectrum as a measure of muscular fatigue at different levels of contraction. Medical & Biological Engineering & Computing 28, pp. 374–378.
22. P. van Wely, 1970, Design and disease, Applied Ergonomics, 1, pp. 262–269
23. R.H. Westgaard and A. Aarås 1984, Postural muscle strain as a causal factor in the development of musculoskeletal illnesses, Applied Ergonomics, 15, 3, pp. 162–174
24. Spaepen, A. and Hermans, V., 1996, EMG in occupational settings, Measurement of muscle load or muscle fatigue. In: Mital, A., Krueger, H., Kumar, S., Menozzi, M. and Fernandez, J.E., Editors, 1996. Advances in Occupational Ergonomics and Safety, International Society for Occupational Ergonomics and Safety, Cincinnati, pp. 557–560.
25. Strasser, H. and Müller, K.-W., 1999, Favourable movements of the hand-arm system in the horizontal plane assessed by electromyographic investigations and subjective rating, International Journal of Industrial Ergonomics, 23, pp. 339–347
26. T.J. Armstrong, E.N. Corlett, J. Wilson and I. Manenica, 1986, Editors: Upper-extremity postures: definition, measurement and control, The Ergonomics of Working Postures: Models, Methods and Cases, Taylor & Francis, London, pp. 59–73
27. T.J. Armstrong, P. Buckle, L.J. Fine, M. Harberg, B. Jonsson, A. Kilbom, I.A.A. Kuorinka, B.A. Silverstein, G. Sjogaard and E.R.A. Viikari-Juntura, 1993, A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scandinavian Journal of Work Environment and Health, 19 , pp. 73–74.

28. . Westgaard, R.H., Jansen, T. and Jensen, C., 1996, EMG of neck and shoulder muscles: the relationship between muscle activity and muscle pain in occupational settings; Kumar, S. and Mital, A., Editors, Electromyography in Ergonomics, Taylor and Francis, London, pp. 227–258
29. www.craftscouncilindia.org/crafts/crafts-assam.html
30. www.yatraindia.com/assam-tourism/assam-art-craft.html

Annexure

- Table
- Chart
- Evaluation spreadsheet
- Questionnaire
- Checklist
- Field study photos

Publication

Annexure - I Personal details of cane crafts artisans

Name	Age (Years)	Sex	Height (cm)	Weight (Kg)	Right handed (RH)/Left handed (LH)	Daily working hours	Working days per week	Years in this profession
GOPAL DAS	55	M	171	68	RH	5 HOURS	7 DAYS	40 YEARS
NILKAMAL DAS	54	M	163	64	RH	6 HOURS	7 DAYS	35 YEARS
MANTU DAS	52	M	168	61	RH	5 HOURS	7 DAYS	40 YEARS
RAGHU DAS	35	M	166	55	RH	4 HOURS	7 DAYS	15 YEARS
HIREN DAS	55	M	174	67	RH	5 HOURS	7 DAYS	25 YEARS
NIRMAL DAS	32	M	169	62	RH	6 HOURS	7 DAYS	15 YEARS
SANTOSH DAS	34	M	172	64	RH	4 HOURS	7 DAYS	16 YEARS
TAPAN MALLICK	37	M	167	59	RH	10 HOURS	7 DAYS	20 YEARS
SOHIDUL HOQUE	40	M	166	56	RH	10-12 HOURS	6 DAYS	20 YEARS
CHANDRA OJA	28	M	170	61	RH	12 HOURS	6 DAYS	16 YEARS
DILIP DAS	35	M	166	55	RH	4 HRS	7 DAYS	15 YRS
BIMAL BISWAS	30	M	167	59	RH	5 HRS	7 DAYS	10 YRS
MAHESH PATHAK	25	M	165	61	RH	8-10 HRS	7 DAYS	4 YRS
SONARUDDIN SHEIKH	44	M	168	64	RH	10 HRS	7 DAYS	25 YRS
TAPAN MALLICK	37	M	163	61	RH	10 HRS	7 DAYS	20 YRS

Annexure - II Personal details of brass metal artisans

Name	Age (Years)	Sex	Height (cm)	Weight (Kg)	Right handed (RH)/Left handed (LH)	Daily working hours	Working days per week	Years in this profession
MD. MAJIBUR RAHAMAN	23	M	168	64	RH	7 HRS	7 DAYS	7 YRS
KISIM ALI	45	M	171	67	RH	6 HRS	7 DAYS	30 YRS
MD. ROSAN ALI	25	M	162	59	RH	5-6 HRS	6 DAYS	13 YRS
MD. AKBAR ALI	31	M	163	62	RH	8 HRS	6 DAYS	20 YRS
MD. ABU BAKKAR ALI	20	M	167	64	RH	9 HRS	6 DAYS	3 YRS
MUKSOOD ALI	40	M	166	59	RH	8 HRS	6 DAYS	20 YRS
AIJOR RAHAMAN	26	M	168	61	RH	8 HRS	6 DAYS	12 YRS
MD. SHER ALAM	30	M	169	64	LH	7 HRS	6 DAYS	13 YRS
NIZAM ALI	38	M	166	68	RH	8 HRS	6 DAYS	20 YRS
AMJAD KHAN	20	M	167	60	RH	7 HRS	6 DAYS	6 YRS
MD. AZIZ ALI	30	M	172	68	RH	6-7 HRS	6 DAYS	5 YRS
RAHAMAN ALI	35	M	168	61	RH	7 HRS	6 DAYS	20 YRS
AYUB KHAN	36	M	166	58	RH	7 HRS	6 DAYS	25 YRS
DILDAR ALI	19	M	169	61	RH	8 HRS	6 DAYS	5 YRS
AKIMUDDIN ALI	30	M	168	62	RH	8 HRS	6 DAYS	20 YRS

Annexure - III Joint angles and range of joint motion values of different joints for carrying out different crafts making activities in most commonly adopted postures

Adopted posture	Angle values (in degrees) R = Right
 Cane sharpening activity	NECK: 14- 16 (flexed); TRUNK: 13 (flexed); UPPER ARM(R): 16(flexed), abducted; LOWER ARM(R): 69-82 (flex) ; WRIST(R): 13 (Radial deviation); LEGS AT KNEES: Straight
 Cane straightening activity	NECK: 11(flexed); TRUNK: 11 (flexed); UPPER ARM(R): 8-14(flexed), abducted; LOWER ARM(R): 84-97 (flexed); WRIST(R): 10 (Radial deviated) 34 (extension.); LEGS AT KNEES: 90+ (flexed)
 Fiber making activity	NECK: 14(flexed) TRUNK: 13 (flexed) UPPER ARM(R): 5-7 (flexed) LOWER ARM(R): 57(flexed) WRIST(R): 11 (Ulnar deviation) 14 (extension);LEGS AT KNEES: 12 (flexed)
 Cane bending activity	NECK: 17 (flexed) TRUNK: 15 (flexed) UPPER ARM(R): 8 (flexed), abducted LOWER ARM(R): 67 (flexed) WRIST(R): 11 (Ulnar deviation), 28(extension.); LEGS AT KNEES: 90+ (flexed)

 Cane sharpening after bending	NECK: 18 (flexed); TRUNK:17 (flexed) UPPER ARM(R): 4 (flexed); LOWER ARM(R): 44-58 (flexed); WRIST(R): 4-11 (Ulnar deviation); KNEES: 90+ (flexed)
 Cane cutting activity	NECK: 24 (flexed); TRUNK: 14 (flexed) UPPER ARM(R): 4-18 (flexion to extension); LOWER ARM(R): 68-84 (flexed); WRIST(R): 7 (radial deviation);
 Knitting activity	NECK: 17 (flexed); TRUNK: 19 (flexed) UPPER ARM(R): 3 (flexed); LOWER ARM(R): 76 (flexed); WRIST(R): 4 (radial deviation); KNEES: 90+ (flexed)

Annexure - IV Joint angles and range of joint motion values of different joints for carrying out different brass metal activities in most commonly adopted postures

Adopted posture	Angle values R = Right, U = Ulnar
 Sheet cutting activity	NECK: 23 (flexed); TRUNK: 11 (flexed); UPPER ARM(R): 17(flexed); LOWER ARM(R):36(flexed); WRIST(R):11(Ulnar deviation); LEG AT KNEE(R): 90+ (flexed)
 Shape making through hammering	NECK: 9-11 (flexed); TRUNK: 14 (flexed) UPPER ARM(R): 3 (flexed); LOWER ARM(R): 94-107 (flexed) ; WRIST(R): 13 (U), 9 (R) (deviated) LEG AT KNEE(R): 54 (flexed)
 Shape making through hammering	NECK: 13 (flexed) TRUNK: 11 (flexed) UPPER ARM(R): 4(flexed), abducted, shoulder raised; LOWER ARM(R): 92-114 (flexed) WRIST(R): 18 (U),10 (R) (deviated); LEG AT KNEE(R): 90+ (flexed)

 Shape making through hammering	NECK: 9-11 (flexed) ; TRUNK: 14 (flexed) UPPER ARM(R): 3 (flexed); LOWER ARM(R): 94-107 (flexed) ; WRIST(R): 13 (U), 9 (R) (deviated) LEG AT KNEE(R): 54 (flexed)
 Brazing activity	NECK: 12(flexed) ; TRUNK: 14 (flexed) UPPER ARM(R): 5-15(flexed); LOWER ARM(R): 69(flexed) ; WRIST(R): 12(R) deviation ; LEG AT KNEE(R): 90+ (flexed)
 Polishing activity	NECK: 12(flexed) ; TRUNK: 11 (flexed) UPPER ARMS: 7-35(flexed); LOWER ARMS: 34(flexed) WRISTS(R): 26(flexed) deviation
 Polishing activity	NECK: 16(flexed) ; TRUNK: 15 (flexed) UPPER ARMS: 17(flexed) ; LOWER ARMS: 48(flexed) ; WRISTS(R):25(R) deviation ; LEGS AT KNEES(R): 90+ (flexed)

Annexure - V Postural adoption time for making different crafts items, N=15

Fig- 1

Fig- 2

Fig- 3

Fig – 4

Fig – 5

Fig – 6

Fig – 7

Fig- 8

Fig- 9

Name	Activity (Adopted posture fig-)	Maximum duration of particular posture adopted
KAMALESWER DAS	Cane sharpening (Fig- 1) Cane sharpening (Fig- 2)	= 29 minutes = 47 minutes

	Cane straightening (Fig- 3) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 19 minutes = 21 minutes = 24 minutes = 35 minutes
TAPAN MALLICK	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 26 minutes = 22 minutes = 22 minutes = 28 minutes = 28 minutes
RAGHUNATH DAS	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 39 minutes = 32 minutes = 24 minutes = 54 minutes = 27 minutes
NIRMAL DAS	Cane sharpening (Fig- 1) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 6)	= 41 minutes = 27 minutes = 31 minutes = 55 minutes = 61 minutes
SANTOSH DAS	Cane sharpening (Fig- 2) Cane straightening (Fig- 9)	= 46 minutes = 43 minutes

	Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 22 minutes = 53 minutes = 47 minutes
SOHIDUL HOQUE	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 28 minutes = 47 minutes = 36 minutes = 48 minutes = 26 minutes
CHANDRA OJA	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 39 minutes = 36 minutes = 38 minutes = 47 minutes = 28 minutes
PRABIN GOALA	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 46 minutes = 42 minutes = 34 minutes = 38 minutes = 28 minutes
CHANDRA KR. DAS	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4)	= 34 minutes = 40 minutes = 38 minutes

	Fiber making (Fig- 5)	= 34 minutes
	Knitting (Fig – 7)	= 42 minutes
MD. GULZAR HOSSAIN	Cane sharpening (Fig- 2)	= 44 minutes
	Cane straightening (Fig- 9)	= 38minutes
	Cane bending (Fig – 4)	= 36 minutes
	Fiber making (Fig- 5)	= 50 minutes
	Knitting (Fig – 7)	= 23 minutes
AKBAR ALI	Cane sharpening (Fig- 2)	= 48 minutes
	Cane straightening (Fig- 9)	= 36 minutes
	Cane bending (Fig – 4)	= 34 minutes
	Fiber making (Fig- 5)	= 50 minutes
	Knitting (Fig – 7)	= 36 minutes
SOHIDUL ISLAM	Cane sharpening (Fig- 2)	= 40 minutes
	Cane straightening (Fig- 9)	= 38 minutes
	Cane bending (Fig – 4)	= 36 minutes
	Fiber making (Fig- 5)	= 48 minutes
	Knitting (Fig – 7)	= 44 minutes
MONIMOHAN DAS	Cane sharpening (Fig- 2)	= 48 minutes
	Cane straightening (Fig- 9)	= 36 minutes
	Cane bending (Fig – 4)	= 38 minutes
	Fiber making (Fig- 5)	= 54 minutes

	Knitting (Fig – 7)	= 42 minutes
PAPPU RAJMUMAR	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 54 minutes = 42 minutes = 38 minutes = 48 minutes = 44 minutes
HARADHAN DAS	Cane sharpening (Fig- 2) Cane straightening (Fig- 9) Cane bending (Fig – 4) Fiber making (Fig- 5) Knitting (Fig – 7)	= 48 minutes = 38 minutes = 36 minutes = 48 minutes = 44 minutes

Annexure - VI Postural adoption time for different brass metal activities, N=15

Fig-1

fig-2

fig-3

fig-4

fig-5

Fig-6

fig-7

fig-8

fig-9

Fig-10

fig-11

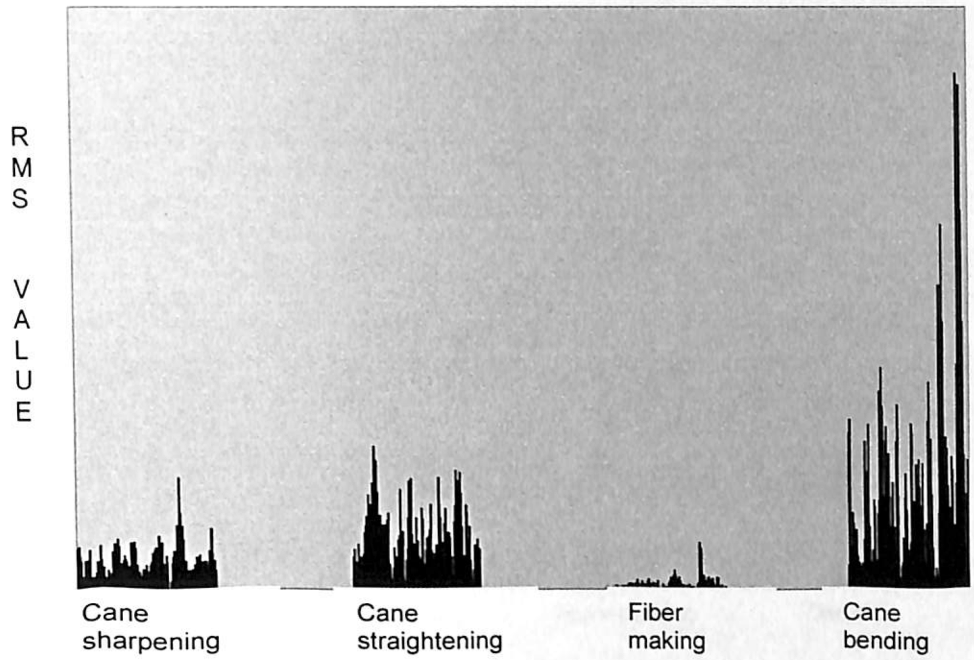
Name	Activity (Adopted posture fig-)	Maximum duration of particular posture adopted
MD. MAJIBUR RAHAMAN	Sheet cutting (fig-3)	= 12 minutes
	Shape making through hammering (fig- 7)	= 7 minutes
	Brazing (fig-9)	= 13 minutes
	Polishing (fig-11)	= 9 minutes
AMJAD KHAN	Sheet cutting (fig-2)	= 12 minutes
	Shape making through hammering (fig- 5)	= 8 minutes
	Brazing (fig-9)	= 14 minutes

	Polishing (fig-12)	= 7 minutes
MD. AZIZ ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 6) Brazing (fig-10) Polishing (fig-12)	= 10 minutes = 10 minutes = 15 minutes = 8 minutes
RAHAMAN ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 4) Brazing (fig-9) Polishing (fig-12)	= 10 minutes = 18 minutes = 13 minutes = 8 minutes
AYUB KHAN	Sheet cutting (fig-2) Shape making through hammering (fig- 6) Brazing (fig-9) Polishing (fig-11)	= 12 minutes = 11 minutes = 13 minutes = 9 minutes
AMJAD KHAN	Sheet cutting (fig-2) Shape making through hammering (fig- 4) Brazing (fig-10) Polishing (fig-12)	= 12 minutes = 19 minutes = 15 minutes = 7 minutes
MD. AZIZ ALI	Sheet cutting (fig-2) Shape making through hammering (fig- 4) Brazing (fig-10) Polishing (fig-12)	= 13 minutes = 20 minutes = 14 minutes = 9 minutes

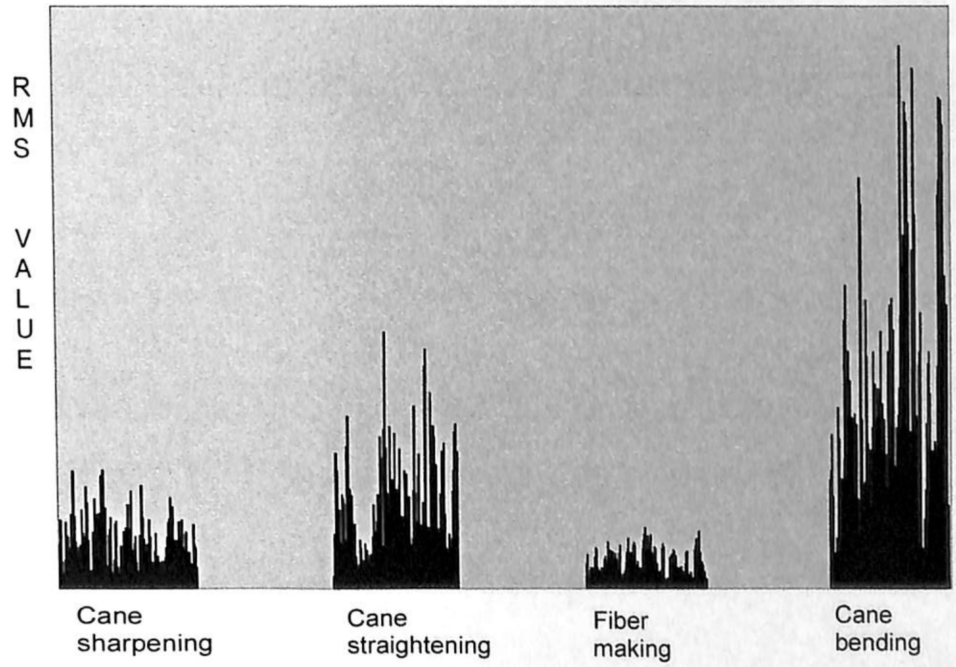
RAHAMAN ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 5) Brazing (fig-9) Polishing (fig-11)	= 9 minutes = 18 minutes = 14 minutes = 12 minutes
DILDAR ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 5) Brazing (fig-9) Polishing (fig-11)	= 9 minutes = 21 minutes = 14 minutes = 11 minutes
AKIMUDDIN ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 4) Brazing (fig-9) Polishing (fig-12)	= 9 minutes = 22 minutes = 17 minutes = 9 minutes
KISIM ALI	Sheet cutting (fig-1) Shape making through hammering (fig- 4) Brazing (fig-9) Polishing (fig-11)	= 15 minutes = 16 minutes = 15 minutes = 11 minutes
ROSAN ALI	Sheet cutting (fig-2) Shape making through hammering (fig- 6) Brazing (fig-10) Polishing (fig-12)	= 12 minutes = 11 minutes = 15 minutes = 9 minutes
AKBAR ALI	Sheet cutting (fig-1)	= 12 minutes

	Shape making through hammering (fig- 5) Brazing (fig-9) Polishing (fig-11)	= 18 minutes = 15 minutes = 11 minutes
NIZAM ALI	Sheet cutting (fig-2) Shape making through hammering (fig- 4) Brazing (fig-9) Polishing (fig-11)	= 11 minutes = 15 minutes = 14 minutes = 9 minutes
SHER ALAM	Sheet cutting (fig-1) Shape making through hammering (fig- 5) Brazing (fig-9) Polishing (fig-11)	= 9 minutes = 21 minutes = 17 minutes = 9 minutes

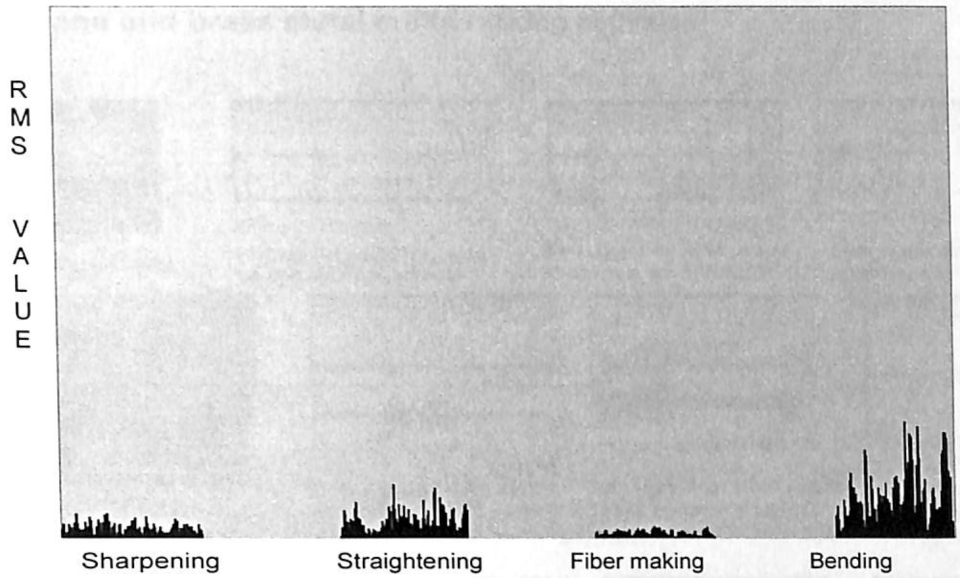
Annexure VII RMS of trapezius muscle for different cane activities



Annexure VIII RMS of pectoralis major muscle for different cane activities

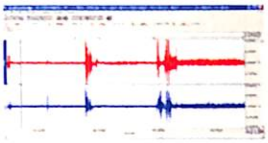


Annexure IX RMS of erector spinae muscle for different cane activities

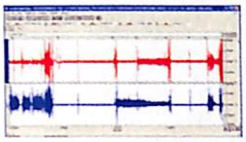


Annexure X Sample signals of EMG recorded from Erector Spinae, Upper Trapezius and Pectoralis major muscles for performance of major cane and brass metal crafts making activities

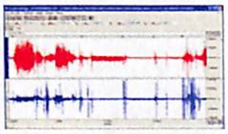
Cane bending activity



EMG signal from ES muscle left and right side of body



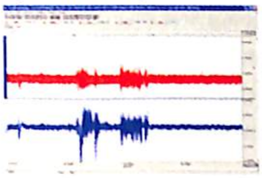
EMG signal from TRAP muscle left and right side of body



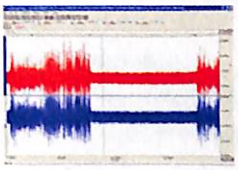
EMG signal from PM muscle left and right side of body

Cane Sharpening activity

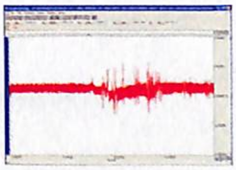
C



EMG signal from ES muscle left and right side of body

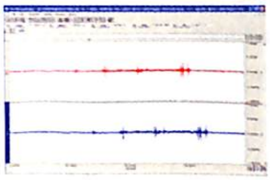


EMG signal from TRAP muscle left and right side of body

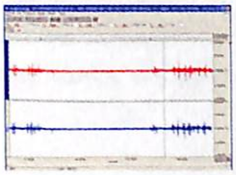


EMG signal from PM muscle left and right side of body

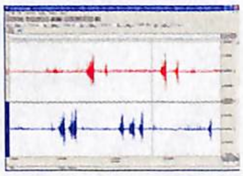
Fiber making activity



EMG signal from ES muscle left and right side of body

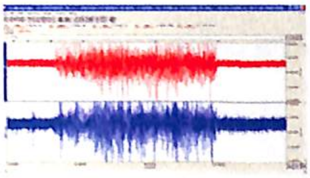


EMG signal from TRAP muscle left and right side of body

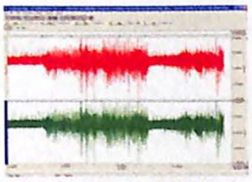


EMG signal from PM muscle left and right side of body

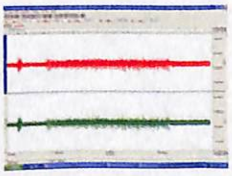
Polishing activity



EMG signal from ES muscle left and right side of body

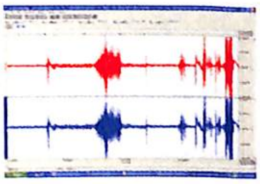


EMG signal from TRAP Muscle left and right side of body

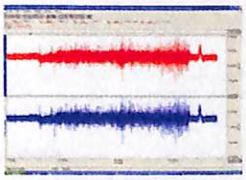


EMG signal from PM muscle left and right side of body

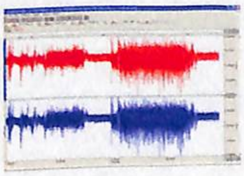
Sheet cutting activity



EMG signal from ES muscle left and right side of body



EMG signal from TRAP muscle left and right side of body



EMG signal from PM muscle left and right side of body

Annexure XI MATLAB code for integrated EMG

```
%%% returns Time Domain Parameters ,output variable name :—> %Time Average   ::
'time_avg'
clear all
clc
close all
%EMG Fatigue Analysis
%Initial Parameters
%% Changeable parameters ...
Fs = 1000;                      %%% Sampling freq
wintime = .05;                  %%% Window time in seconds
shift_in_samples = .05*Fs;      %%% Shift of samples in number of samples
int_win = 60;                   %%% Integration width in number of samples
%Integrated EMG
load('filt');
path = 'D:\MVC data\';          %%% Directory in which file is present
name = 'test';                  %%% File name (without extension)
totalchannel = 2;               %% total number of channels in the txt file
yourchannel = 1;                %% channel number you want to operate on
fid = fopen(strcat(path,name,'.txt'),'r');
data = fscanf(fid,'%f',[totalchannel inf]);
data = data(yourchannel,:)';
fclose(fid);
%load(name);
data = data(1:end,:);   %%% Limit the size of the data
channel = 1;
%Filtering 20 to 400Hz
%global filtered_data
filtered_data(:,channel) = filter(Num, Den, data(:,channel));
%HW Rectification
for i=1:length(filtered_data)
   if filtered_data(i,channel) < 0
      rectified_data(i,channel) = 0;
   else
      rectified_data(i,channel) = filtered_data(i,channel);
   end
%Integration over int_win samples
for i = int_win+1:length(rectified_data);
   iemg(i,channel) = mean(rectified_data(i-int_win:i-1,channel));
end;  t = 0:1/(Fs/shift_in_samples):length(iemg)/Fs - 1/Fs;
```

Annexure XII MAT LAB code for Time Domain parameters

```
%Time average
winsize = wintime*Fs;  %in samples
sample_count = 1;
for i = 1:shift_in_samples:length(iemg)
   time_avg(sample_count) = mean(iemg(max(1, i - winsize/2): min(i+winsize/2-1,
length(iemg))));
   sample_count = sample_count+1;
end
%subplot(6,1,3)
figure
plot(t, time_avg);
title('Electrical Activity: Time average')
clc
save([name 'TD'],'time_avg')
disp(['output stored in mat file: ' name 'TD'])
```

MATLAB code for frequency domain parameters (MPF, MDF, and High and low frequency ratio)

```
%%% returns Frequency Domain Parametres ,output variable name :—>
%Mean power freq    :: 'mpf'
%Median freq        :: 'mf'
%95 percentile Freq :: 'f95'
%Ratio of High and Low freq. energies :: 'ratio'
clear all
clc
close all
%EMG Fatigue Analysis
%Initial Parameters
%% Changeble parametres ...
Fs = 1000;                       %%% Sampling freq
wintime = .01;                     %%% Window time in seconds
shift_in_samples = .01*Fs;           %%% Shift of samples in number of samples
int_win = 60;                    %%% Interegation width in number of samples
%Integrated EMG
load('filt');
path = 'D:\experimentation on 26.5.2006\before lunch with free posture\DATA for MAT LAB\';
%%% Directory in which file is present
name = 'TRAP_LEFT_RAGHU_WITH FREE POSTURE _4TH';                    %%% File
name (without extension)
```

```
totalchannel = 1;                          %% total number of channels in the txt file
yourchannel = 1;                            %% channel number you want to operate on
fid = fopen(strcat(path,name,'.txt'),'r');
data = fscanf(fid,'%f',[totalchannel inf]);
data = data(yourchannel,:)';
fclose(fid);
%load(name);
data = data(141000:143000,:);     %%% Limit the size of the data
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%Dont change
here on%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
channel = 1;
%Filtering 20 to 400Hz
%global filtered_data
filtered_data(:,channel) = filter(Num, Den, data(:,channel));
%HW Rectification
for i=1:length(filtered_data)
    if filtered_data(i,channel) < 0
        rectified_data(i,channel) = 0;
    else
        rectified_data(i,channel) = filtered_data(i,channel);
    end
end

%Integration over int_win samples
for i = int_win+1:length(rectified_data);
    iemg(i,channel) = mean(rectified_data(i-int_win:i-1,channel));
end

t = 0:1/(Fs/shift_in_samples):length(iemg)/Fs - 1/Fs;
```

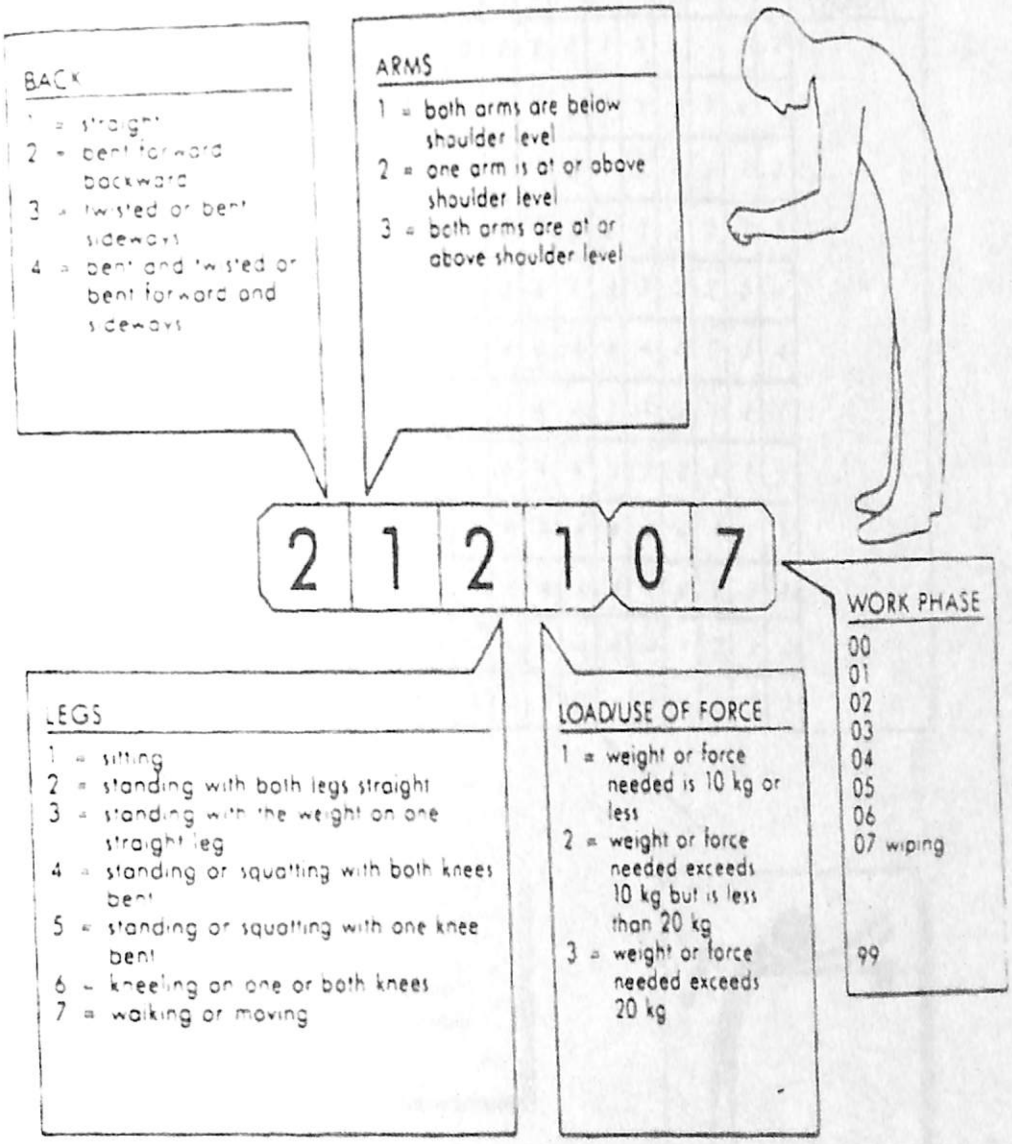
Annexure XIII MATLAB code for Frequency Domain parameters

```
winsize = wintime*Fs;   %in samples
%Mean Power Frequency
sample_count = 1;
for i = 1:shift_in_samples:length(iemg)
    current_sample = filtered_data(max(1, i - winsize/2): min(i+winsize/2-1, length(iemg)));
    [psd, f] = periodogram(current_sample, hamming(length(current_sample)), 2*winsize, Fs);
    mpf(sample_count) = psd'*f/sum(psd);
    cum_psd = cumsum(psd);
    temp = find (cum_psd/max(cum_psd) >= 0.5);
    mf(sample_count) = f(temp(1));
    temp = find (cum_psd/max(cum_psd) >= 0.95);
    f95(sample_count) = f(temp(1));
        %Dividing into 2 equal bands
%       low_energy = cum_psd(winsize/2);
%       high_energy = cum_psd(winsize) - cum_psd(winsize/2);
%       ratio(sample_count) = high_energy/low_energy;
    %Dividing into 3 equal bands
    low_energy = cum_psd(floor(winsize/3));
    high_energy = cum_psd(winsize) - cum_psd(floor(2*winsize/3));
    ratio(sample_count) = high_energy/low_energy;
        sample_count = sample_count+1;
end
figure
plot(t, mpf);
title('Freqeuncy domain paramters : Mean power frequency')
figure
plot(t, mf);
title('Frequency Domain parametres : 50 %ile frequency')
figure
plot(t, f95);
title('Frequency Domain parametres : 95 %ile frequency')
plot(t, ratio);
title('Frequency Domain parametres : high/low energy')
clc
save([name 'mpf'],'mpf')
save([name 'mf'],'mf')
save([name 'f95'],'f95')
save([name 'ratio'],'ratio')
disp(['output stored in respective mat files'])
```

Annexure XIV MATLAB code for RMS EMG

```
%%% returns IEMG of single channel ,output variable name :: '(filename)iemg'
clear all
clc
close all
%EMG Fatigue Analysis
%Initial Parameters
%% Changeble parametres ...
Fs = 1000;                    %%% Sampling freq
wintime = .5;                 %%% Window time in seconds
shift_in_samples = Fs*.5;          %%% Shift of samples in number of samples
int_win = 60;                 %%% Interegation width in number of samples
%Integrated EMG
load('filt');
path = 'D:\experimentation on 26.5.2006\after lunch with constraint posture\DATA for MAT
LAB analysis\';               %%% Directory in which file is present
name = 'ES_RIGHT_RAGHU_WITH CONSTRAINT POSTURE 3RD';                   %%%
File name (without extension)
totalchannel = 1;                  %% total number of channels in the txt file
yourchannel = 1;                   %% channel number you want to operate on
fid = fopen(strcat(path,name,'.txt'),'r');
data = fscanf(fid,'%f',[totalchannel inf]);
data = data(yourchannel,:)';
fclose(fid);
%load(name);
data = data(94000:115000,:);   %%% Limit the size of the data
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%Dont change
here on%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
channel = 1;
%Filtering 20 to 400Hz
%global filtered_data
filtered_data(:,channel) = filter(Num, Den, data(:,channel));
rectified_data = filtered_data;
%Integration over int_win samples
for i = int_win+1:length(rectified_data);
   rms(i,channel) = sqrt(((rectified_data(i-int_win:i-1,channel))'*(rectified_data(i-int_win:i-
1,channel)))/int_win);
end
plot(rms)
clc save([name 'rms'],'rms'), disp(['output stored in : ' name 'rms'])
```

Annexure XV OWAS CHART FOR POSTURE EVALUATION



BACK	ARMS	LEGS: 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
	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	3	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

ACTION CATEGORIES

1 *no corrective measures*
2 *corrective measures in the near future*
3 *corrective measures as soon as possible*
4 *corrective measures immediately*

Annexure XVI RULA CHART FOR POSTURE EVALUATION

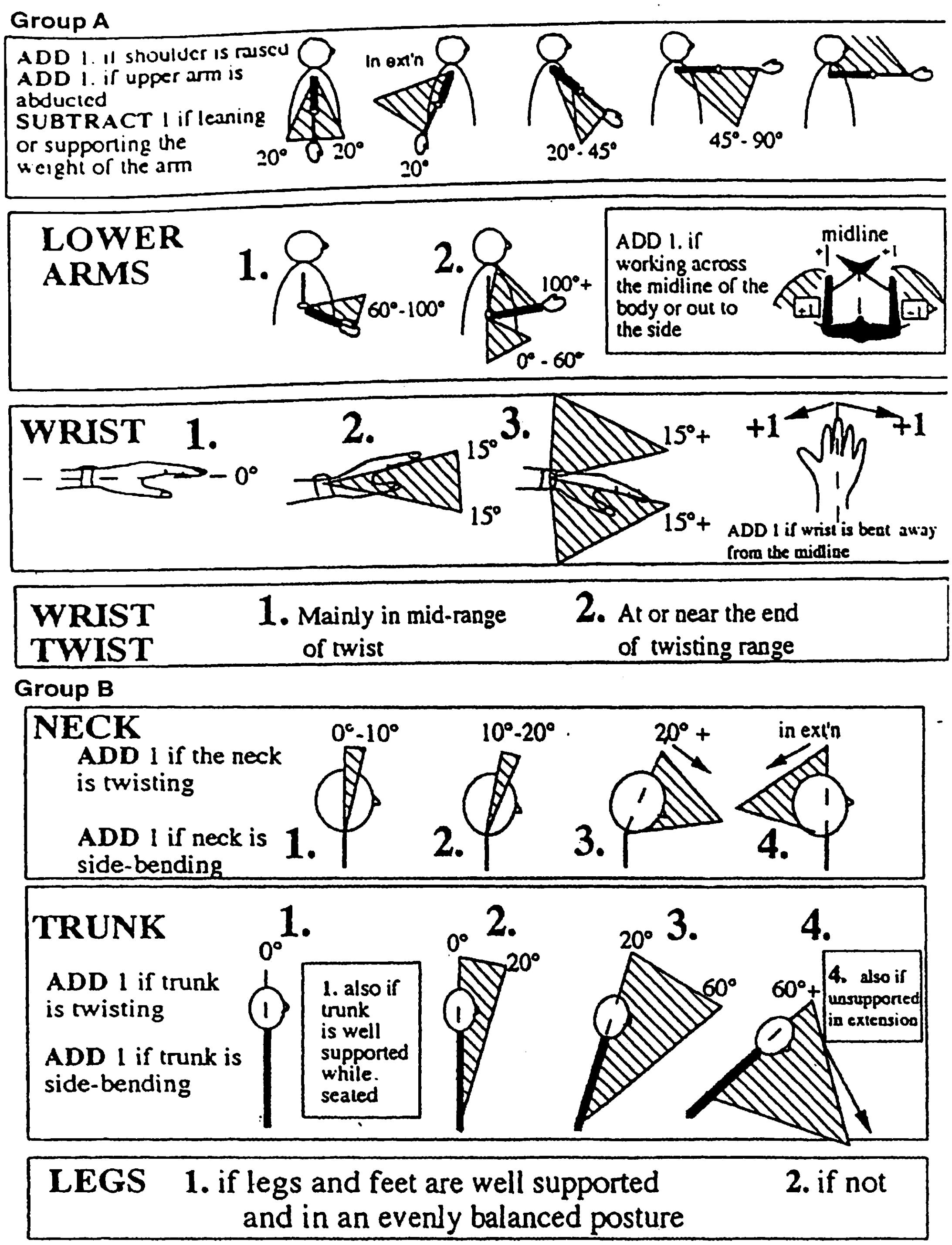


TABLE A Upper Limb Posture Score

UPPER ARM	LOWER ARM	WRIST POSTURE SCORE 1		2		3		4	
		TWIST 1	2	TWIST 1	2	TWIST 1	2	TWIST 1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	6	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

TABLE B Neck, Trunk, Legs Posture Score

NECK POSTURE SCORE	TRUNK POSTURE SCORE 1		2		3		4		5		6	
	LEGS 1	2	LEGS 1	2	LEGS 1	2	LEGS 1	2	LEGS 1	2	LEGS 1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

MUSCLE USE SCORE

Give a score of 1 if the posture is; mainly static, e.g. held for longer than 1 minute repeated more than 4 times/minute

FORCES OR LOAD SCORE

0.	1.	2.	3.
No resistance or less than 2kg intermittent load or force	2-10kg intermittent load or force	2-10kg static load 2-10kg repeated load or force	10kg or more static load 10kg or more repeated loads or forces. Shock or forces with a rapid buildup.

SCORE D (NECK, TRUNK, LEGS)

SCORE C (UPPER LIMB)	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

TABLE C Grand Score Table

ACTION LEVEL 1 A score of one or two indicates that posture is acceptable if it is not maintained or repeated for long periods.

ACTION LEVEL 2 A score of three or four indicates further investigation is needed and changes may be required.

ACTION LEVEL 3 A score of five or six indicates investigation and changes are required soon.

ACTION LEVEL 4 A score of seven or more indicates investigation and changes are required immediately.

Annexure XVII Questionnaire and checklists

PERSONAL DETAILS

Date:

Name:

Sex:

Date of birth: Age:

Weight:

Height:

Are you right or left handed?
Right handed Left handed Able to use both hands

When did you first join in this profession?

For how many years you are in this profession?

What is the average working day in a week?

What is the average working hour in a day?

What are your primary job activities?
a)
b)
c)
d)
e)
f)
g)
h)

What is the most physically demanded task on your current job?
a), b), c), d), e), f), g), h)

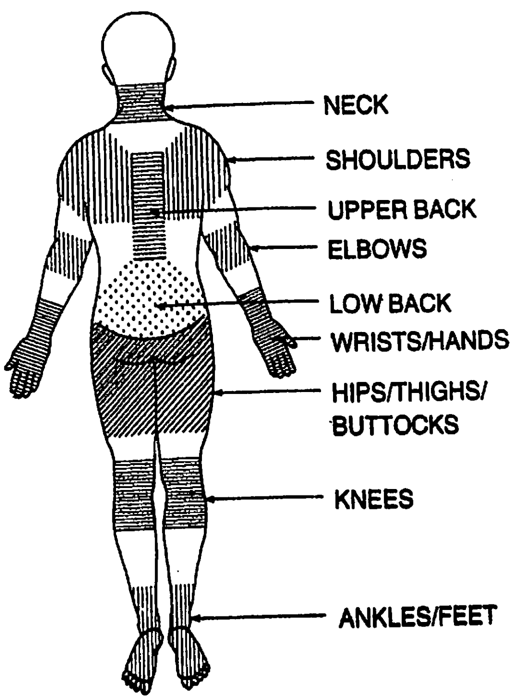
Rate the following on a 5 point scale

1= rarely
2= occasionally
3= Sometimes
4= Often
5= Very often

How often does the job require you to work very fast?

How often does the job require you to do work very hard?

How often are you physically exhausted at the end of the work day?



This picture shows how the body has been divided. Please answer the three questions shown opposite for each body area.
Body sections are not sharply defined and certain parts overlap. You should decide for yourself which part (if any) is or has been affected.

Please answer by using the tick boxes ☑
– *one tick for each question*

Please note that this part of the questionnaire should be answered, even if you have never had trouble in any parts of your body.

Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in:	Have you had trouble during the last 7 days:	During the last 12 months have you been prevented from carrying out normal activities (eg. job, housework, hobbies) because of this trouble:
1 ***Neck*** No 1☐ Yes 2☐	2 ***Neck*** No 1☐ Yes 2☐	3 ***Neck*** No 1☐ Yes 2☐
4 ***Shoulders*** No 1☐ Yes 2☐ in the right shoulder 3☐ in the left shoulder 4☐ in both shoulders	5 ***Shoulders*** No 1☐ Yes 2☐ in the right shoulder 3☐ in the left shoulder 4☐ in both shoulders	6 ***Shoulders (both/either)*** No 1☐ Yes 2☐
7 ***Elbows*** No 1☐ Yes 2☐ in the right elbow 3☐ in the left elbow 4☐ in both elbows	8 ***Elbows*** No 1☐ Yes 2☐ in the right elbow 3☐ in the left elbow 4☐ in both elbows	9 ***Elbows (both/either)*** No 1☐ Yes 2☐
10 ***Wrists/hands*** No 1☐ Yes 2☐ in the right wrist/hand 3☐ in the left wrist/hand 4☐ in both wrists/hands	11 ***Wrists/hands*** No 1☐ Yes 2☐ in the right wrist/hand 3☐ in the left wrist/hand 4☐ in both wrists/hands	12 ***Wrists/hands (both/either)*** No 1☐ Yes 2☐
13 ***Upper back*** No 1☐ Yes 2☐	14 ***Upper back*** No 1☐ Yes 2☐	15 ***Upper back*** No 1☐ Yes 2☐
16 ***Lower back (small of the back)*** No 1☐ Yes 2☐	17 ***Lower back*** No 1☐ Yes 2☐	18 ***Lower back*** No 1☐ Yes 2☐
19 ***One or both hips/thighs/buttocks*** No 1☐ Yes 2☐	20 ***Hips/thighs/buttocks*** No 1☐ Yes 2☐	21 ***Hips/thighs/buttocks*** No 1☐ Yes 2☐
22 ***One or both knees*** No 1☐ Yes 2☐	23 ***Knees*** No 1☐ Yes 2☐	24 ***Knees*** No 1☐ Yes 2☐
25 ***One or both ankles/feet*** No 1☐ Yes 2☐	26 ***Ankles/feet*** No 1☐ Yes 2☐	27 ***Ankles/feet*** No 1☐ Yes 2☐

 Rec [0|3]

How to answer the questionnaire:

By neck trouble we mean pain, ache or discomfort in the shaded area only.

Please answer by using the tick boxes ☑ – **one tick for each answer.**

1 Have you ever had any neck trouble (ache, pain, numbness or discomfort)?

Yes 1☐ No 2☐ — If you have answered **NO** to this question, do not answer questions 2-12 but please go to the section on **shoulder trouble page 6.**

2 Have you ever hurt your neck in an **accident?**

Yes 1☐ No 2☐

If the answer is **NO,** please go on to Question 3.

If **YES:**

2a Was the accident at work?

Yes 1☐ No 2☐

2b What was the approximate date of the accident? Month Year ☐☐☐☐

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

Yes 1☐ No 2☐

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

1 Accident☐ 2 Sporting Activity☐ 3 Activity at Home☐

4 Activity at Work☐ 5 Other☐ **(please specify)** ______

5a What year did you **first** have neck trouble? [19__]

5b What year was your **worst** neck trouble? [19__]

6 How bad was the pain during the **worst** episode? Mild 1☐ Severe 2☐ Very, Very Severe 3☐

7 Have you ever been absent from work because of neck trouble?

Yes 1☐ No 2☐

If the answer is **NO,** please go on to Question 8.

If **YES:**

How many **times?**

7a ☐☐

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

7b ☐☐ days

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

7c ☐☐ days

8 How often do you get or have you had **neck trouble?**

daily 1☐
one or more times a week 2☐
one or more times a month 3☐
one or more times a year 4☐
one or more times every few years 5☐
one episode of trouble only 6☐

---

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

0 days 1☐
1 - 7 days 2☐
8 - 30 days 3☐
More than 30 days, but not every day 4☐
Every day 5☐

---

10 Has neck trouble caused you to **reduce** your activity during the **last 12 months?**

10a Work activity (at home or away from home)

Yes 1☐ No 2☐

10b Leisure activity

Yes 1☐ No 2☐

---

11 What is the **total length of time** that neck trouble has prevented you from doing your normal work (at home or away from home) during the **last 12 months?**

0 days 1☐
1 - 7 days 2☐
8 - 30 days 3☐
More than 30 days 4☐

---

12 Have you been seen by a doctor, physiotherapist, chiropractor, or other such person because of neck trouble during the **last 12 months?**

Yes 1☐ No 2☐

If the answer is NO, please go on to the next section.

If YES:

12a Where? (more than one box can be ticked)

Medical centre at work 1☐
GP 2☐
Hospital 3☐
Private doctor 4☐
Osteopath or chiropractor 5☐
Other* 6☐

* If you have ticked *Other* please give details ☐

Rec [0|4]

How to answer the questionnaire:

By shoulder trouble we mean pain, ache or discomfort in the shaded area only.

Please answer by using the tick boxes ☑ – **one tick for each answer.**

1 Have you **ever** had any shoulder trouble (ache, pain, numbness or discomfort)?

Yes 1☐ No 2☐

If you have answered **NO** to this question, do not answer questions 2-12 but please go to the section on **low back trouble** page 8.

2 Have you **ever** hurt your shoulder in an **accident**?

No 1☐ Yes 2☐ my right shoulder
3☐ my left shoulder
4☐ both shoulders

If the answer is **NO**, please go on to Question 3.

If **YES**:

2a Was the accident at work?

Yes 1☐ No 2☐

2b What was the approximate **date** of the accident? Month Year ☐☐☐☐

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

Yes 1☐ No 2☐

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

1 Accident☐ 2 Sporting Activity☐ 3 Activity at Home☐
4 Activity at Work☐ 5 Other☐ **(please specify)** ☐

5a What year did you **first** have shoulder trouble? 19__

5b What year was your **worst** shoulder trouble? 19__

6 How bad was the pain during the **worst** episode? Mild 1☐ Severe 2☐ Very, Very Severe 3☐

7 Have you **ever** been absent from work because of shoulder trouble?

Yes 1☐ No 2☐

If the answer is **NO**, please go on to Question 8.

If **YES**:

How many **times**?

7a ☐☐

How many **days** have you been absent from work with shoulder trouble **in total?**

7b ☐☐ days

How many **days** have you been absent from work with shoulder trouble in the **last 12 months?**

7c ☐☐ days

8 How often do you get or have you had shoulder trouble?

- daily 1☐
- one or more times a week 2☐
- one or more times a month 3☐
- one or more times a year 4☐
- one or more times every few years 5☐
- one episode of trouble only 6☐

---

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

- 0 days 1☐
- 1 - 7 days 2☐
- 8 - 30 days 3☐
- More than 30 days, but not every day 4☐
- Every day 5☐

---

10 Has shoulder trouble caused you to **reduce** your activity during the **last 12 months?**

10a Work activity (at home or away from home)

Yes 1☐ No 2☐

10b Leisure activity

Yes 1☐ No 2☐

---

11 What is the **total length of time** that shoulder trouble has prevented you from doing your **normal work** (at home or away from home) during the **last 12 months?**

- 0 days 1☐
- 1 - 7 days 2☐
- 8 - 30 days 3☐
- More than 30 days 4☐

---

12 Have you been seen by a doctor, physiotherapist, chiropractor, or other such person because of shoulder trouble during the **last 12 months?**

Yes 1☐ No 2☐

If the answer is **NO**, please go on to the next section.

If **YES:**

12a Where? (more than one box can be ticked)

- Medical centre at work 1☐
- GP 2☐
- Hospital 3☐
- Private doctor 4☐
- Osteopath or chiropractor 5☐
- Other* 6☐

* If you have ticked *Other* please give details ☐

How to answer the questionnaire:

By low back trouble we mean pain, ache or discomfort in the shaded area whether or not it extends from there to one or both legs (sciatica).

Please answer by using the tick boxes ☑ – **one tick for each answer.**

1 Have you **ever** had any low back trouble (ache, pain, numbness or discomfort)?

Yes 1☐ No 2☐

If you have answered **NO** to this question, do not answer questions 2-12 but please go to the section on **wrist/hand trouble** page 10.

2 Have you **ever** hurt your low back in an **accident**?

Yes 1☐ No 2☐

If the answer is **NO**, please go on to Question 3.

If **YES**:

2a Was the accident at work?

Yes 1☐ No 2☐

2b What was the approximate **date** of the accident? Month Year ☐☐☐☐

3 Have you **ever** had to **change duties** or **jobs** because of low back trouble?

Yes 1☐ No 2☐

4 What do you think brought on this problem with your back?

1 Accident☐ 2 Sporting Activity☐ 3 Activity at Home☐

4 Activity at Work☐ 5 Other☐ **(please specify)**☐

5a What year did you **first** have low back trouble? [19]

5b What year was your **worst** low back trouble? [19]

6 How bad was the pain during the **worst** episode? Mild 1☐ Severe 2☐ Very, Very Severe 3☐

7 Have you **ever** been absent from work with low back trouble?

Yes 1☐ No 2☐

If the answer is **NO**, please go on to Question 8.

If **YES**:

How many **times**?

7a ☐☐

How many **days** have you been absent from work with low back trouble **in total?**

7b ☐☐ days

How many **days** have you been absent from work with low back trouble in the **last 12 months?**

7c ☐☐ days

8 How **often** do you get or have you had low back trouble?

daily	1☐
one or more times a week	2☐
one or more times a month	3☐
one or more times a year	4☐
one or more times every few years	5☐
one episode of trouble only	6☐

---

9 What is the **total length of time** that you have had low back trouble during the **last 12 months**?

0 days	1☐
1 - 7 days	2☐
8 - 30 days	3☐
More than 30 days, but not every day	4☐
Every day	5☐

---

10 Has low back trouble caused you to **reduce** your activity during the **last 12 months?**

10a Work activity (at home or away from home)

Yes	No
1☐	2☐

10b Leisure activity

Yes	No
1☐	2☐

---

11 What is the **total length of time** that low back trouble has prevented you from doing your **normal work** (at home or away from home) during the **last 12 months?**

0 days	1☐
1 - 7 days	2☐
8 - 30 days	3☐
More than 30 days	4☐

---

12 Have you been seen by a doctor, physiotherapist, chiropractor, or other such person because of low back trouble during the **last 12 months?**

Yes	No
1☐	2☐

If the answer is NO, please go on to the next section.

If YES:

12a Where? (more than one box can be ticked)

Medical centre at work	1☐
GP	2☐
Hospital	3☐
Private doctor	4☐
Osteopath or chiropractor	5☐
Other*	6☐

* If you have ticked *Other* please give details ☐

Wrist or hand trouble

Rec [0|6]

How to answer the questionnaire:

By wrist or hand trouble we mean pain, ache or discomfort in the shaded area only.

Please answer by using the tick boxes ☑ – **one tick for each answer.**

1. Have you **ever** had any wrist or hand trouble (ache, pain, numbness or discomfort) ?

Yes 1. ☐ No 2. ☐

If you have answered NO to this question, do not answer questions 2-12 but please go to General health questionnaire on page 12.

2 Have you **ever** hurt your wrist or hand in an **accident**?

No 1☐ Yes 2☐ my right wrist or hand
3☐ my left wrist or hand
4☐ both wrists or hands

If the answer is **NO, please go on to Question 3.**

If **YES:**

2a Was the accident at work?

Yes 1☐ No 2☐

2b What was the approximate **date** of the accident? Month Year ☐☐☐☐

3 Have you ever had to **change duties** or **jobs** because of wrist or hand trouble?

Yes 1☐ No 2☐

4 What do you think brought on this problem with your wrists or hands?

1 Accident☐ 2 Sporting Activity☐ 3 Activity at Home☐
4 Activity at Work☐ 5 Other☐ **(please specify)** ☐

5a What year did you **first** have wrist or hand trouble? [19]

5b What year was your **worst** wrist or hand trouble? [19]

6 How bad was the pain during the **worst** episode? Mild 1☐ Severe 2☐ Very, Very Severe 3☐

7 Have you **ever** been absent from work with wrist or hand trouble?

Yes 1☐ No 2☐

If the answer is **NO, please go on to Question 8.**

If **YES:**

How many **times**?

7a ☐☐

How many **days** have you been absent from work with wrist or hand trouble **in total?**

7b ☐☐ days

How many **days** have you been absent from work with wrist or hand trouble in the **last 12 months?**

7c ☐☐ days

8 How **often** do you get or have you had wrist or hand trouble?

daily	1☐
one or more times a week	2☐
one or more times a month	3☐
one or more times a year	4☐
one or more times every few years	5☐
one episode of trouble only	6☐

---

9 What is the **total length of time** that you have had wrist or hand trouble during the **last 12 months?**

0 days	1☐
1 - 7 days	2☐
8 - 30 days	3☐
More than 30 days, but not every day	4☐
Every day	5☐

---

10 Has wrist or hand trouble caused you to **reduce** your activity during the **last 12 months?**

10a Work activity (at home or away from home)

Yes	No
1☐	2☐

10b Leisure activity

Yes	No
1☐	2☐

---

11 What is the **total length of time** that wrist or hand trouble has prevented you from doing your **normal work** (at home or away from home) during the **last 12 months?**

0 days	1☐
1 - 7 days	2☐
8 - 30 days	3☐
More than 30 days	4☐

---

12 Have you been seen by a doctor, physiotherapist, chiropractor, or other such person because of wrist or hand trouble during the **last 12 months?**

Yes	No
1☐	2☐

If the answer is **NO, please go on to the next section.**

If YES:

12a Where? (more than one box can be ticked)

Medical centre at work	1☐
GP	2☐
Hospital	3☐
Private doctor	4☐
Osteopath or chiropractor	5☐
Other*	6☐

* If you have ticked *Other* please give details ☐

Checklist for seating device features:

Seat height above the floor	Too high	Correct	Too low
Seat length	Too long	Correct	Too short
Seat width	Too narrow	Correct	Too Wide

Slope of seat provided or not:

If provided, is it	Too far towards back	Correct	Too far towards front
Seat Shape	Poor	Adequate	Good

Please rate your seating device:

11---1

11= I feel completely relaxed
10= I feel perfectly comfortable
9= I feel quite comfortable
8= I feel barely comfortable
7= I feel uncomfortable
6= I feel restless and fidgety
5= I feel cramped
4= I feel stiff
3= I feel numb(or pins and needles)
2= I feel sore and tender
1= I feel unbearable pain

Questionnaire for field study (General)

Photo

1. Name:
2. Age:
3. Height:
4. Weight:
5. Right/left sided:
6. Sex:

7. How many years and months have you been doing your present type of work ?

8. Have you been in any other jobs earlier?

9. On average how many hours a week do you work?

10. How many days a week do you work?

11. On average how many breaks do you have in each working days?

12. How long each of your breaks on average?

13. Do you enjoy your job?

Questionnaire for field study (Posture)

1. Task is performed under which of the following condition(s)
   floor seating/ground seating,
   stooping
   kneeling
   seating on chairs,
   standing

2. Whether any seating or body supportive device are used? If yes, types of seating /body supportive devices?

3. How often individual changes his/her posture? (average time)

4. Conditions/activities under which postures are adopted?

5. Relative position of body parts/joints under various postural condition?

   Back Shoulder Neck Forearm Elbow Wrist Leg

Questionnaire for field study (seating/body supportive device)

1. Do you think your seating/body supportive devices are appropriate and why?

2. Whether seat height above the floor is appropriate ?

   (Too High-------- Correct------Too Low)

3. Whether seat length is appropriate?

   (Too long-------- Correct------Too short)

4. Whether seat width is appropriate?

   (Too narrow-------- Correct------Too wide)

5. Whether seat shape is appropriate?

   (Poor-------- adequate------good)

6. Slope of the seat is

   (slopes too far towards
   Back--------------------------correct..................slopes too far towards front

7. Seat shape

   (poor------------------------adequate.....................good

8. Back rest(position)

   (too high....................correct......................too low

9. Cushioning of the seat surface

   (good----------------------appropriate-------------bad)

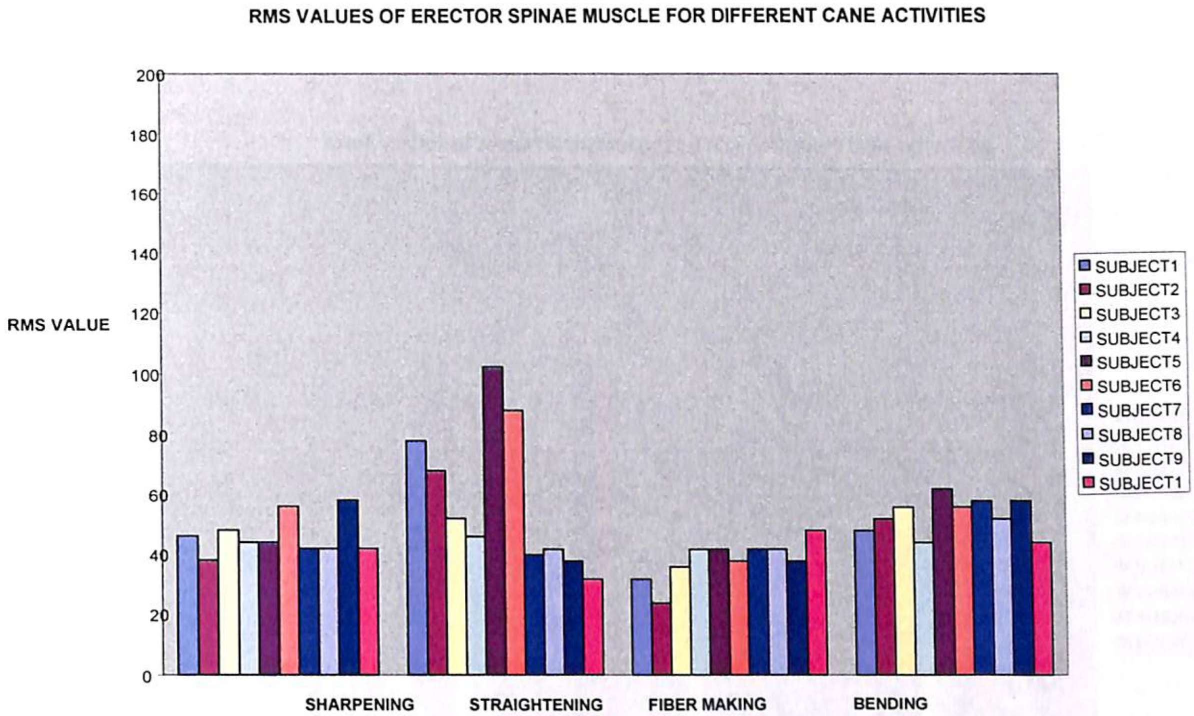
Questionnaire for field study (hand tools)

1. How many type of hand tools are used to do a particular job?
2. Weight of the hand tool(s)?
3. Does it match with body size and the strength of the operator?
4. If the force is required, can the tool be grasped in a power grip?
5. Can this be used keeping wrist straight?
6. Can this tool be used in either hand?
7. What is the tool grip diameter (for power work)?
8. What is the tool grip diameter (for precision work)?
9. What is tool handle length?

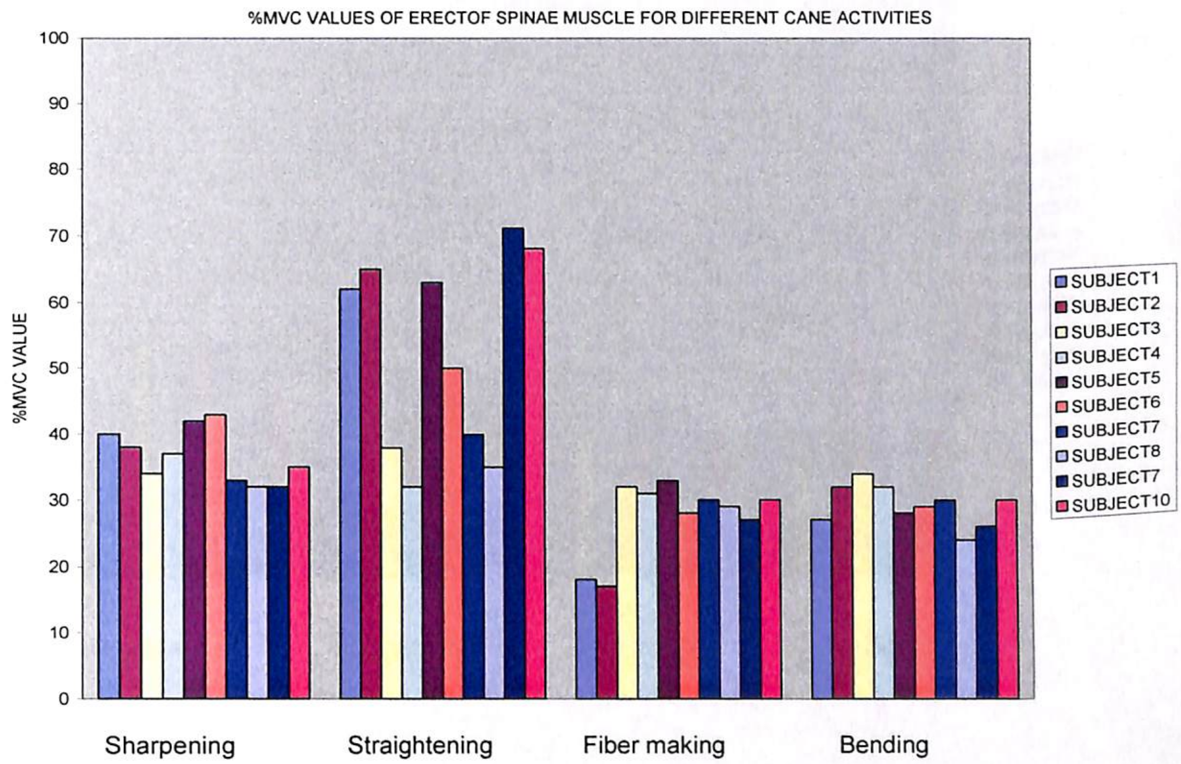
Questionnaire for field study (Products)

1. Details about the type of products?
2. Price details?
3. Average weight of the products?

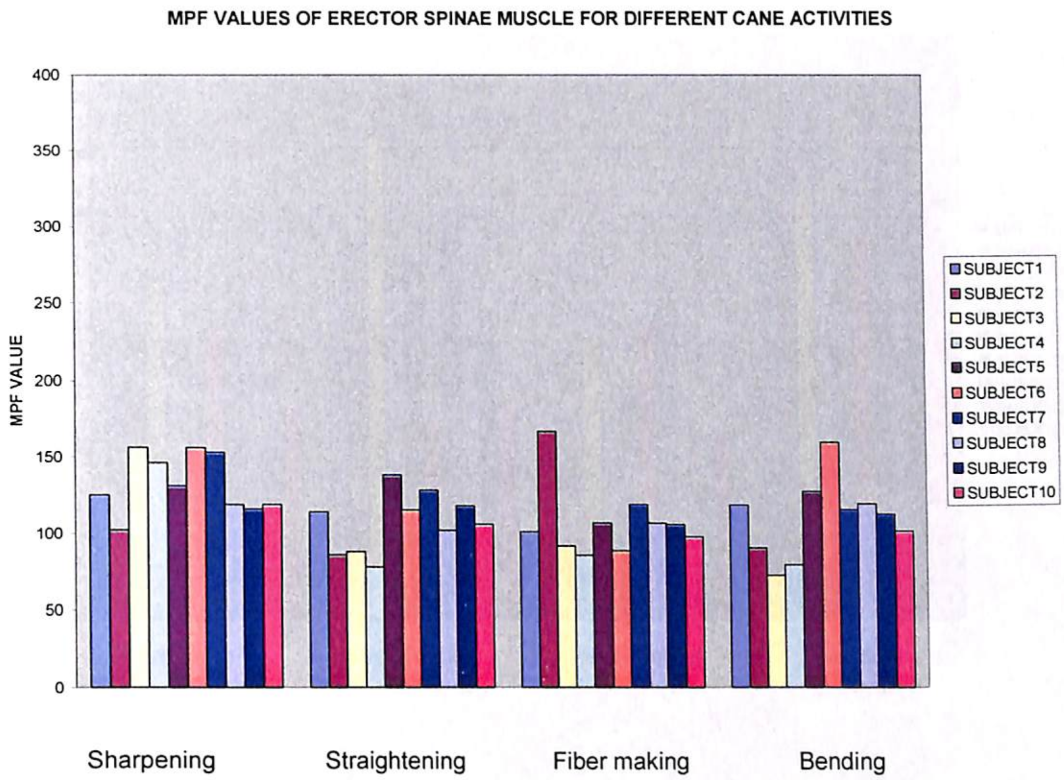
Annexure XVIII **RMS values of Erector Spinae muscle recorded from 10 professional crafts artisans indicate all cane performing activities require almost same level of muscle force except cane straightening activity**



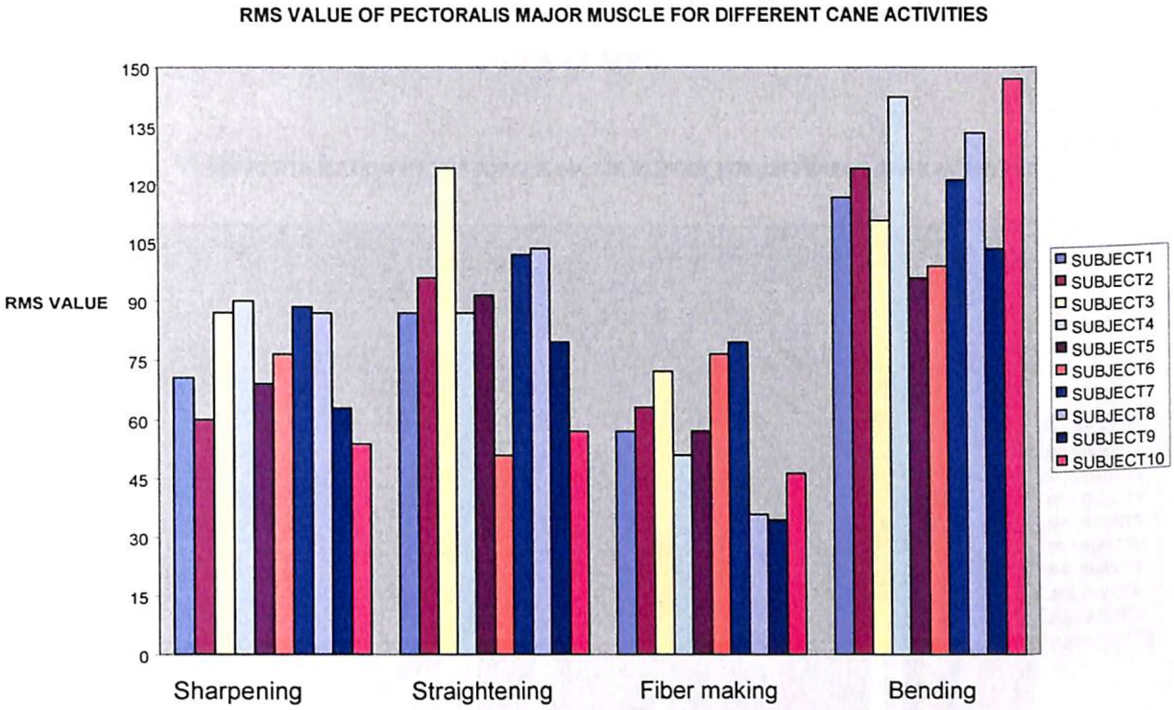
Annexure XIX, Percentage of MVC (Maximum voluntary contraction) utilization by Erector spinae muscle for performing different cane activities remains below 45% except cane straightening activity for some crafts artisans who utilizes 65%-70% of MVC.



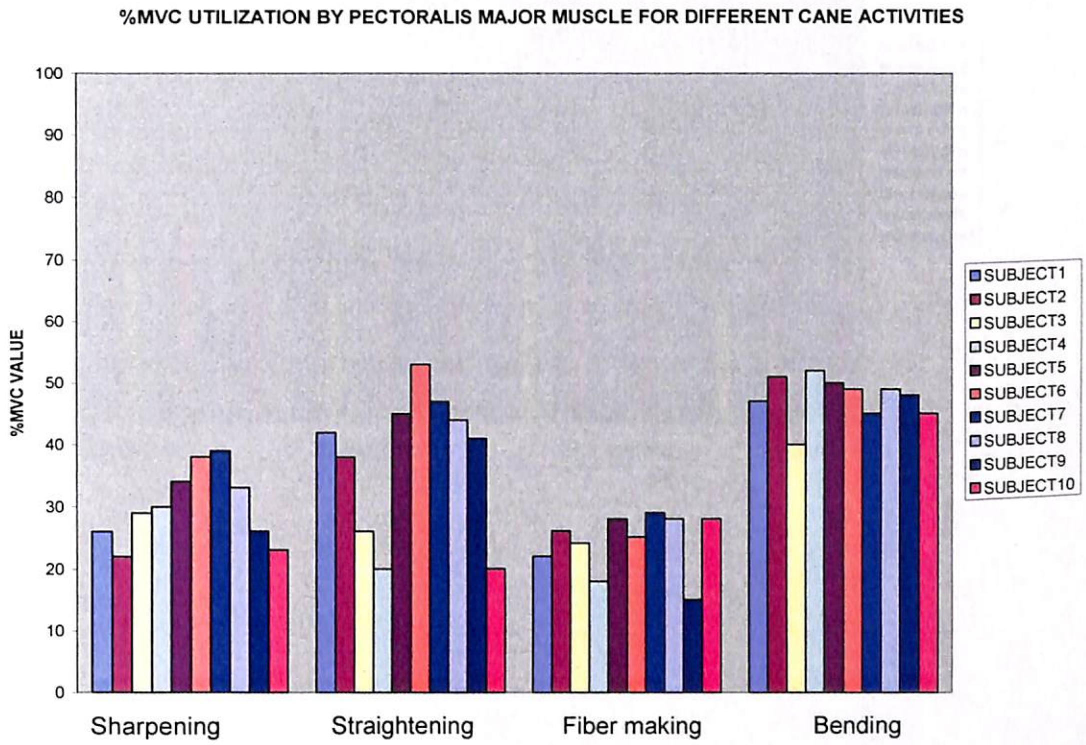
Annexure XX Mean power frequency (MPF) values of ES muscle for performing different cane activities lies within a range of 80-160 Hz.



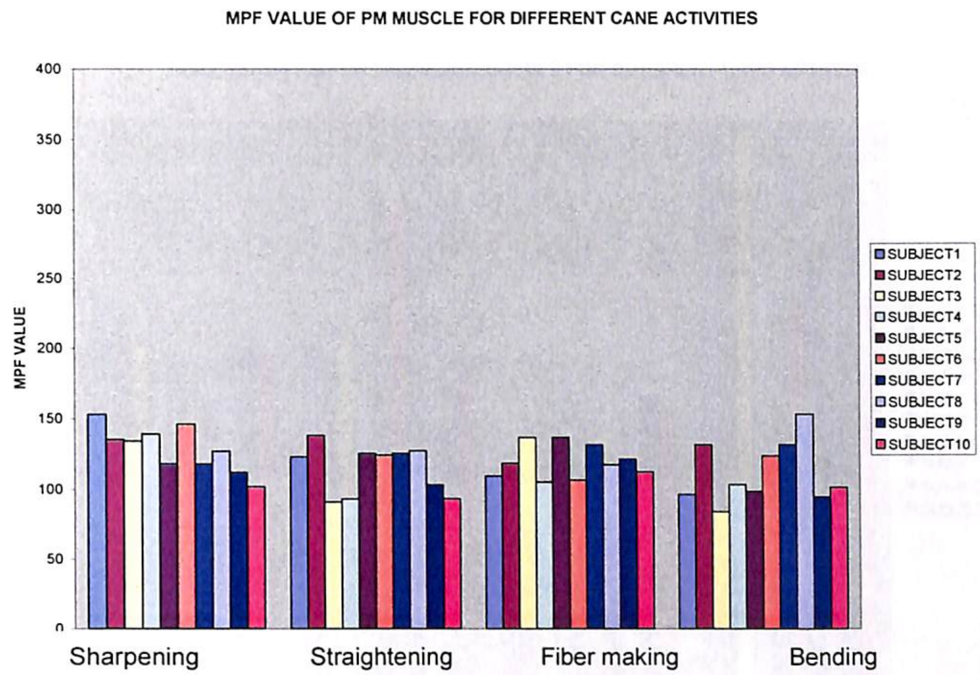
Annexure XXI **RMS values of pectoralis major muscle is highest for cane bending activity followed by cane straightening and sharpening. Fiber making activity shows lowest RMS value for all crafts artisans.**



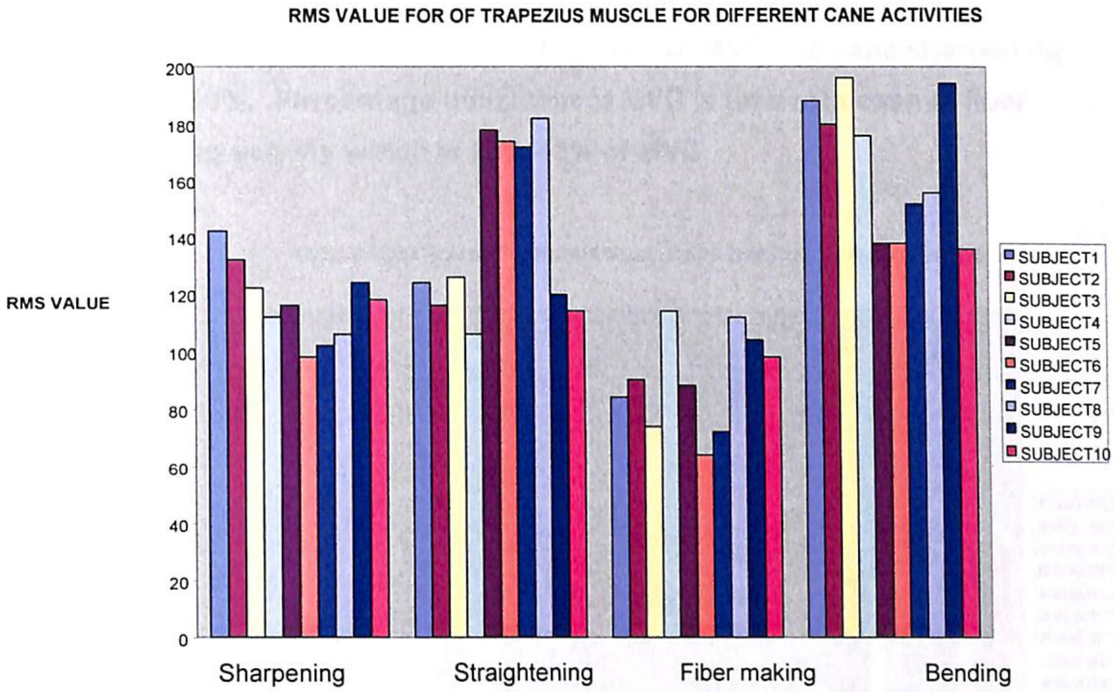
Annexure XXII Percentage of MVC utilization by Pectoralis major muscle is highest for cane bending activity and it lies in a range of 45-50%, followed by cane straightening and cane sharpening. Cane straightening activity utilizes 30%-45% of MVC and cane sharpening 25%-35%. Percentage utilization of MVC is lowest in case of fiber making activity which is 15%-25% of MVC.



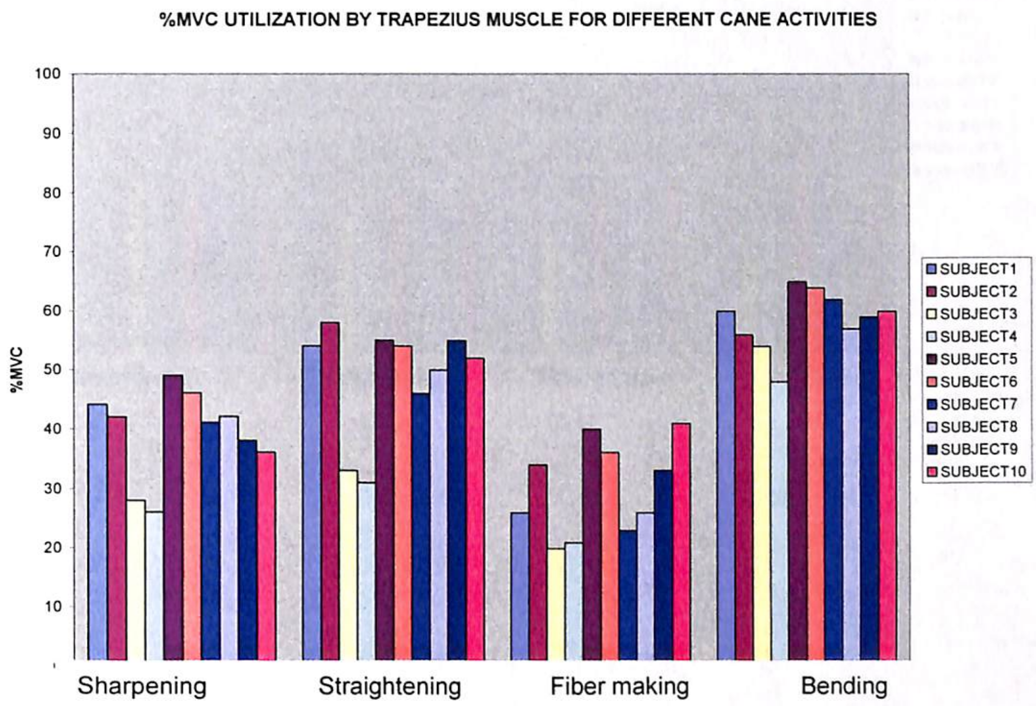
Annexure XXIII MPF value of pectoralis major muscle lies in a range of 90 to 155 Hz for different cane activities.



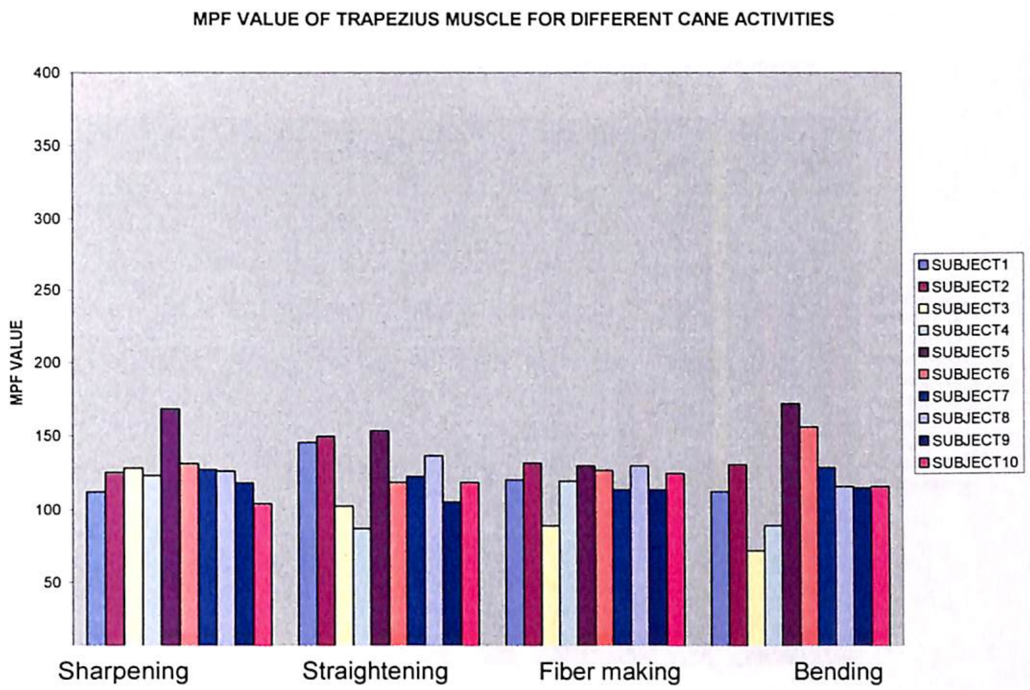
Annexure XXIV Highest RMS value of trapezius muscle is found for cane bending activity followed by straightening and sharpening. Fiber making activity shows lowest RMS value for trapezius muscle



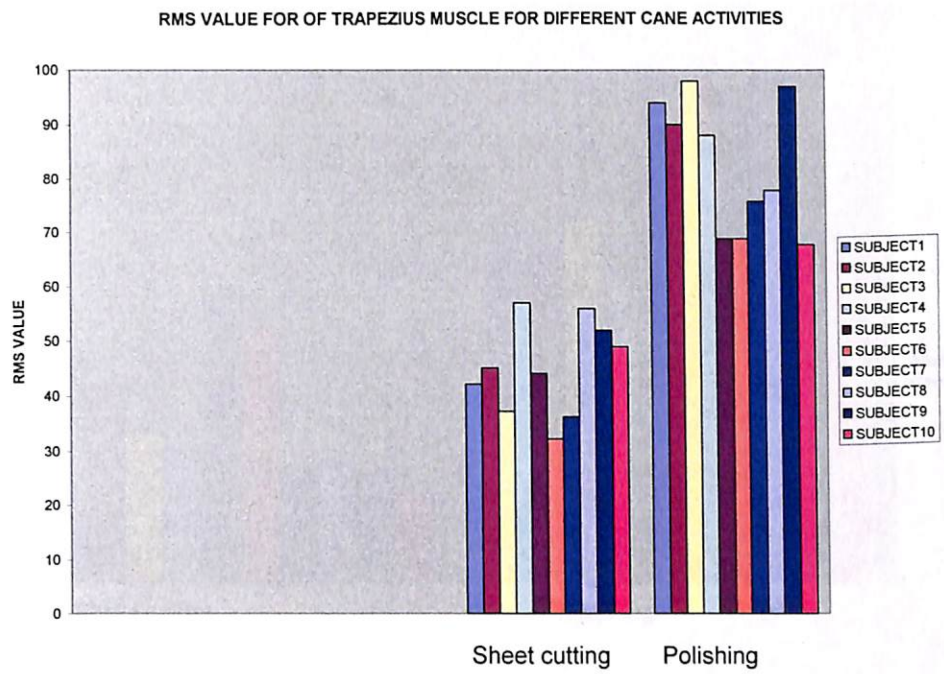
Annexure XXV, Percentage of MVC utilization by trapezius muscle is highest for cane bending activity which lies in a range of 55-65%, followed by cane straightening and cane sharpening. Cane straightening activity utilizes 45%-60% of MVC and cane sharpening 30%-50%. Percentage utilization of MVC is lowest in case of fiber making activity which is 20%-45% of MVC



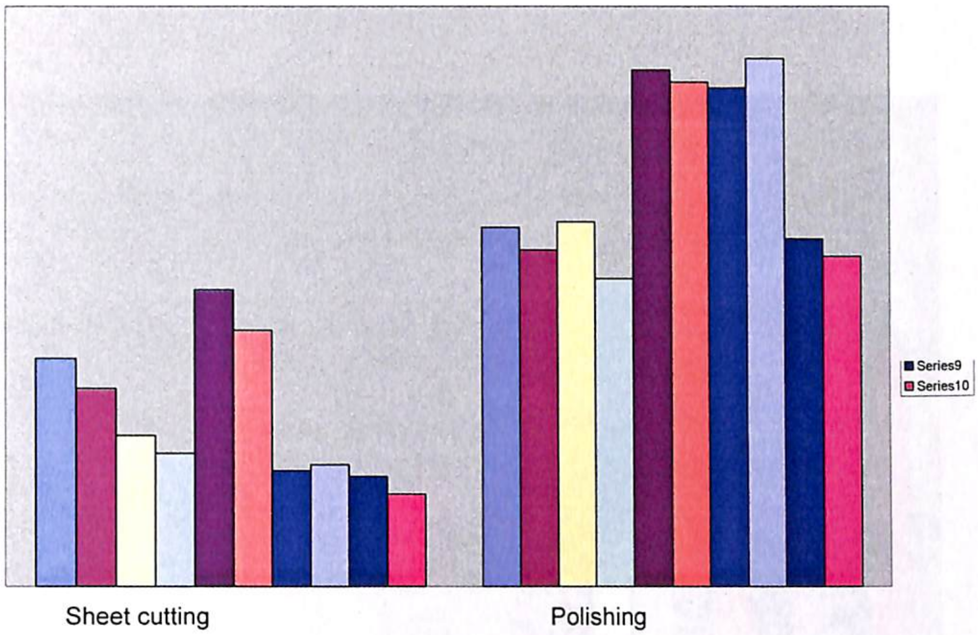
Annexure XXVI MPF values of Trapezius muscle for different cane activities



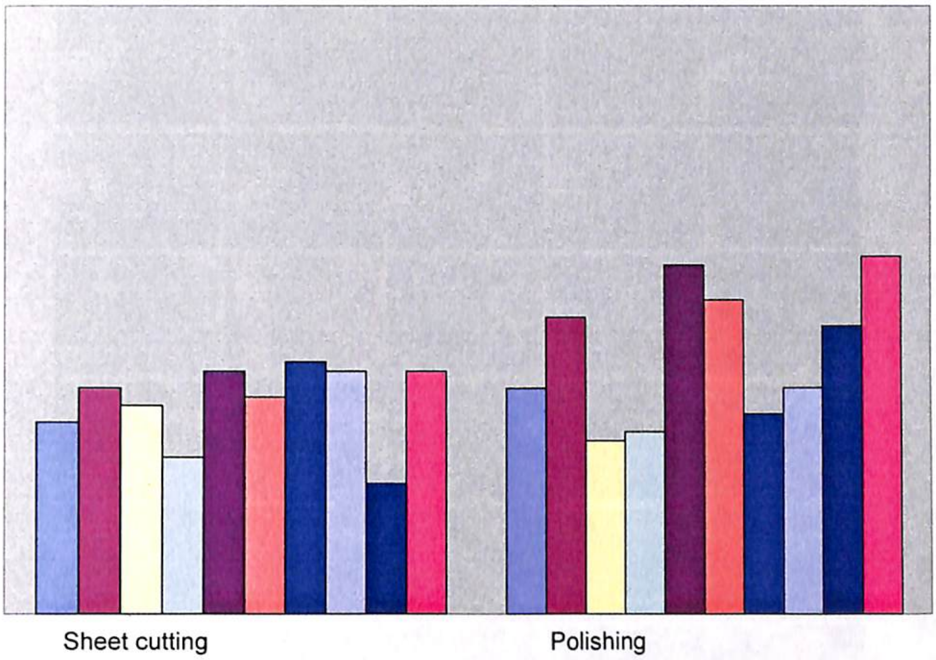
Annexure XXVII, RMS values of Trapezius muscle recorded from 10 professional brass metal artisans indicate polishing activity utilizes greater muscle force in comparison to sheet cutting activity



Annexure XXVIII RMS values of Pectoralis Major muscle recorded from 10 professional brass metal artisans indicate polishing activity utilizes greater muscle force in comparison to sheet cutting activity



Annexure XXIX RMS values of Erector Spinae muscle recorded from 10 professional brass metal artisans indicate both sheet cutting and polishing activity utilizes same muscle force level



Annexure XXX Field study photos (of artisans adopting various floor sitting posture)

Posture adopted by brass artisans

Posture adopted by cane artisans

Annexure XXXI

International Journal publication

1. "A study on upper extremity cumulative trauma disorder in different unorganized sectors of West Bengal, India", Journal of Occupational Health (Japan), Gangopadhyay, A.Ray, A.Das, 2003,Volume 45, Page 351-357

National Journal publication

2. "Evaluation of posture and joint angles of craftsperson (Cane and Brass-metal) of Assam during performance of different activities"; Journal of Applied Physiology and Allied Sciences, India (in press), Abhijit Das and Debkumar Chakrabarti

International Conference publication

3. "Participatory Interventions to reduce occupational stress in small scaled brass metal sectors of North-East India with development of ergonomically designed polish machine"; International Conference on Frontier researches in Integrative Physiology (ICFRIP), Abhijit Das and Debkumar Chakrabarti

4. "An Approach to Specify Informal Sitting In Classroom", International conference on Humanizing Work and Work Environment, IIIT Guwahati, December 10-12, 2005, Sharmistha Banerjee, Kirti Meera Goel, Debkumar Chakrabarti and Abhijit Das, 144-148

National conference publication

5. "Role Of Free Postural Adoption On Performance and Informal Workplace Design", National conference on Humanizing Work and Work Environment, NITIE, Mumbai, April 22-24, 2004, Abhijit Das and Debkumar Chakrabarti, 72-76

6. "Design Development of a new Seat-Desk Unit Suitable for Indian School Children, National conference on Humanizing Work and Work Environment, NITIE, Mumbai, April 22-24, 2004, Debkumar Chakrabarti and Abhijit Das, 131-136