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Development and Validation of Composite Ergonomic Analysis Module Applicable to Fabric Embellishment Workers

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ABSTRACT India is a country known for its culture and traditions all over the world. Handicrafts sector plays a significant and important role in the country's economy. Among several embroidery works *aari* is traditional hand embroidery carried out on a wooden cot like frame with *aar* needle. embellishment workers for long hours sitting on without any seating aids, and are prone to developing musculoskeletal symptoms. A survey was carried out to identify the need to develop the ergonomic analysis module. The literature search on ergonomic evaluation tools, revealed the availability of about 12 qualitative, 9 quantitative tools and 10 ergonomic analysis modules mostly in the form of software packages. Among them, Ergomaster module was selected as a frame of reference as it covered all the aspects of analyzing any work environment. A total of seven tools including four ergonomic checkpoints formats, five rating scales on degree of difficulty were developed using the Likert scale method of summated ratings. The constructed analysis module was analyzed by thirty experts of various research and technical experts for its content validation in terms of four qualities and was found consistent. The tool was also tested for reliability with p value above 0.9 confirming the tool for its dependability in eliciting the needed data from the subjects.

INTRODUCTION

India is a hub for its distinctive traditional crafts, from enriching the hand sculpture to hand woven textiles. The sector is thus creating employment opportunity for over 130 lakh workers and artisans, a large percentage of them hailing from the marginalized sections of the society (Yojana 2011). India is estimated to have around 2682 handicrafts and 491 handlooms clusters. In both cases, around 10 states cover two-third of these clusters. The report of a review workshop in 2011-12 by The Department of Office of The Development Commissioner (Handicrafts) Ministry of Textiles, Hyderabad, revealed that there are considerable clusters working on handicrafts in and around Hyderabad, mostly working on *aari* embroidery.

Embellishment is a value adding property to the fabric or garment. Among several embroidery works *aari* embroidery is one of hand embroidery carried out on a wooden frame with *aar* needle. *Aari* work is done with a large range of embellishing materials available in the market. *Aari* embroidery is done while sitting in kneeling position or cross-legged position on the floor around the '*Adda'* the wooden frame. The main tools used in *aari* work are curved hooks and needles for stitching purpose.

Aari workers working for long hours sitting on floor in prolonged kneeling or cross legged postures without any seating aids, and are also prone to developing musculoskeletal symptoms. A survey conducted in Rajasthan reported that there is a need for good infrastructure and development of ergonomically suitable *adda* where four artisans can sit and work at a time on a long fabric along with standardization of tool kit (Gupta 2007).

As it is imperative that ergonomic research tools need to be employed considering the various factors that need analysis in the study context, evolving a composite ergonomic analysis module for assessing the fabric embellishment workers (*aari* workers) was felt necessary by the investigator. In addition examining the applicability of available modular tools was felt needed for the purpose.

METHODOLOGY

The methodology is presented under the following heads:

Selection of Area

A preliminary survey was conducted in two small scale commercial *aari* units at Dilsukhnagar and Charminar by selecting one unit from each area purposively.

Selection of Sample

A total of six subjects, three from each unit were interviewed to understand their work and to trace the issues needing design solutions.

Development of Survey Tool

A brief interview schedule was prepared with open ended questions on general profile of workers, work profile, work productivity and problems faced by the workers. This was followed by observing the workers at their work.

Secondary Literature Search

The literature search was carried out to bring forth the qualitative and quantitative tools available for administering or adapting in the context of *aari* work tasks. Modular tools available in the form of software packages were also examined for the purpose. The tools in the form of scales, checklists, questionnaires available in the library, public domain of web search were examined (Table 1).

Among the available modular tools, Ergomaster module was selected as a frame of reference for developing the composite modular tool by making necessary adaptations and modifications. The tools used in Ergomaster modules were critically examined to understand the applicability to the present situation.

Development of the Tool

A comprehensive and integrated tool was felt necessary after examining 13 qualitative tools and 9 quantitative tools. Therefore modular tool was developed after evaluation of work process and conductions of *aari* workers. in the following way.

a. Each module after a thorough examination was reframed by integrating tools in the form of checklists, perception scales, rating scales and observations by the investigator in support of the data. Four ergonomic checkpoint schedules were constructed by incorporating the data needed as essential for the general profile of workers, materials and tool handling, work postures, work profile, repetitive motions and work station analysis.
b. Five rating scales were developed formulating statements by following the Likert scale method of summated ratings where number of statements to be judged with respect to favorableness or unfavorableness in comparison to others (Kothari 2011).

Content Validation of the Constructed Tool

The constructed tool was given for validation of content to thirty experts in field of specialization of research, scientists, teachers, technical experts, trainers and tool designers for its content validation. Sample of experts were drawn from national institutes, universities, central government tool design institutes apart from the faculty of Home Science. Each of the developed modules was analyzed in terms of four qualities viz., content relevance, information adequacy, statement completeness and statement clarity. Scores were assigned for rating on each of the quality.

The Reliability of the Developed Composite Tool

The developed research tools were checked for their reliability. Thirty subjects were selected

Table 1: List of available ergonomic tools and modules

Qualitative research tools	*Quantitative research tools*	*Software modules*
a. Rapid upper limb assessment	a. Centre of gravity	a. Ergomaster
b. Rapid entire body assessment	b. Electro Myo Graph	b. Ergomix
c. Job strain index	c. Stadiometer	c. Ergowatch
d. ART HSE	d. Heart rate monitor	d. Harbo
e. QEC	e. Grip dynamometer	e. Job evaluation tool kit
f. Rodgers muscle fatigue	f. Body fat analyzer	f. MVTA
g. Ovako work posture assessment	g. Back leg dynamometer	g. PEO
h. NORDIC musculoskeletal	h. Goniometer	h. Posture program
i. HAMA	i. Flexicurve	i. VIDAR
j. PLIBEL		
k. Body mapping		
l. Rate of perceived exertion		

from the areas of Dilsukhnagar for assessing reliability by test that re- test method with a gap of 10 days. Scores obtained on both the tests were analyzed for their significance on 't'-test. The scores, opinions and the suggestions were taken into consideration while bringing out the final composite ergonomic evaluation tool for the study of fixed frame workstation for fabric embellishment workers.

RESULTS

The results of the preliminary survey and development of composite ergonomic tool for conducting the study on the embellishment workers are presented under the following heads:

Subjects Profile

The study revealed that workers belonged to the age range of 20 – 50 years. This indicates that it is necessary to incorporate question on age as category based on large age variation. As factors like reduction in muscle strength, physical strength and physiological work load are associated with age (Sinaki et al. 2001), any intervention planned has to be relevant to the varied age group of the population in *aari* work.

The selected *aari* work units had only men working on fabric embellishment and the units are maintained as small enterprise units away from home.

There was large variation in the experience. The years of experience ranged from 2 – 30 years. This result shows that the variation of experience was because of the age the workers take up this work. This also has impact on the division of labour based on experience. The more the experience, more is the productivity.

Physical Characteristics

The stature ranged between 155cms-170cms. The average height was 161.7cms which was falling between 25th to 50th percentiles of Indian population. Therefore anthropometric data of the reference group can be used to compare the design of workstation, equipment, furniture, to identify any mismatching between worker and work environment.

Weights of the population ranged from 45 kgs-70 kgs. The average weight was 59.5kgs. Their BMI ranged from 19-25, indicating the subjects were of normal weight for height (WHO 2004).

The workers observed were right handed. They were stitching the embellishment material using their right hand.

Socio-economic Condition

The workers in this work mostly belonged to Muslim cobbler community and this was like a family occupation. They did not belong to any organized unions since this is considered as unorganized sector.

The workers were being paid on the basis of the work they carried out. Therefore their income was much dependent on the productivity. On an average their monthly income ranged between Rs. 9000 – 10,000. Wages also varied on the basis of the embellishing work, materials used and the type of garment, indicating economic condition as low.

Work Profile

The nature of work observed was continuous and repetitive. They were found working from one end on repetitive motions till it is completed. The motifs of the design are continuous and repeat in their pattern. The workers carried out the embellishment work for 8 hours a day and for about 10 hrs at peak time sitting at floor level positions without any seating aids.

They were found working from 9:30 AM till 6:00 PM, with a break of 40 to 60 minutes for lunch in the afternoon. The rest or breaks taken were of long duration of 40 minutes for lunch and short breaks of 5-10 minutes per hour to make them comfortable.

A discussion with the workers helped out to understand the different steps involved in fabric embellishment task on a fixed frame workstation. The lists of tasks are given in Table 2.

Table 2: List of observed tasks in fabric embellishment work

S.No.	*List of tasks in embellishment work*	*Nature of task*
1	Setting up the frame	Single time
2	Fixing the fabric	Single time
3	Tightening the fabric to create tension in the fabric	Single time
4	Stitching the embellishment materials	Repetitive task
5	Rolling the embellished fabric	Single time

Work Postures

The workers were found sitting on the floor to carry out the embellishing task on a cot like frame workstation. Different postures adapted by the workers were studied through observation method and the postures were videotaped and photographs were taken. Apart from sitting postures adapted the neck, shoulder and trunk postures were also observed which were found adapted for long hours. The different seating postures, neck, shoulders and trunk positions observed are listed with illustrations in Table 3.

Table 3: Work Postures observed in the survey

Observed work postures			
Sitting cross legged	Kneeling	One leg stretched in sitting cross legged position	One leg folded vertically in kneeling position

Workstation and Tools Used

The workstation used was a fixed frame cot like structure where the fabric was fixed. The workstations observed were of square and rectangle in shape. The small square was used to embellish on blouse fabrics and the rectangle was used to embellish on *sarees* (Table 4).

Table 4: Fixed frame workstations observed in the survey

Fixed frame workstations observed	
Small for blouses	Big for *sarees* and *dupattas*

The tool used is an *aar* needle. This looks like a fine hook to pull the thread for creating a thread lock. Normal hand sewing needle is also used to stitch some of the embellishment materials. Details of embellishment material that they handle was also listed and included in the developed schedule.

Work Environment

The work environment observed had general lighting. The room space was also very less for their movement. One unit had three frames and the other has two frames. The necessity for making a quantitative evaluation of work space dimensions, lighting, work station dimensions in a sub sample study was noted from this.

Problems Faced

Opinion of workers was taken, and also the problems faced while working, with the workstation (Table 5).

Developed Composite Ergonomic Tool

The tool was developed adapting the Ergomaster module. As the available module was not designed to suit Indian occupaton, it was thus modified by incorporating the relevant ergonomic analysis tools applicable to fabric embellishment workers. The constructed module consisted of seven sub tools with addition of ergonomic checkpoints, rating scales on degree of difficulty and the repetitive motion analysis. A total of four ergonomic checkpoint formats were constructed by incorporating the data needed as essential with particular reference to materials and tool handling, work postures, work profile, repetitive motions and work station analysis on the basis of preliminary survey findings. Five rating scales were developed formulating statements by following the Likert scale method of summated ratings. The above were integrated and were developed as a composite ergonomic modular tool for complete analysis of fabric embellishment workers (Table 6).

Table 5: Problems faced by workers

S. No.	*Problems faced by workers*	*Task*
1	Pain in neck and shoulders	While stitching and supplying thread
2	Pain in back	Bending forward while stitching
3	Pain in legs	Sitting on floor for long hours
4	Less work area and lighting	Two or more workstations in a small room
5	Pain in wrist and arm	Repetitive motion while stitching
6	Working on Workstation	Mismatch of Dimensions of the workstation to the worker
7	Working with the tool	Pinch grip in holding the needle, slippery in nature

Table 6: List of existing Ergomaster sub tools along with the changed and incorporated tools

S.No.	*Module*	*Tools available*	*Modifications*	
1	*General Information*	General project information	Adapted	Interview schedule with general profile details of the worker
		Discomfort survey	Taken as such	Adapted Verghese (1994) 5 – point scale was taken
		Rate of perceived exertion		
2	*Lift Analyst*	Materials handling assessment	Adapted	Checklist on material handled, tools used ergonomic checkpoints with 21 items and rating scale on difficulty (3 – point rating scale) with 21 items was developed newly.
		Biomechanical prediction	- -	
		Revised NIOSH lifting equation	- -	
		NIOSH multi task lift	- -	
		Discomfort survey	Taken as such	-
		Rate of perceived exertion	Adapted	Verghese (1994) 5 – point scale was taken
3	*2D Biomechanics Analyst*	-	- -	
4	*Task Analyst*	Task assessment	Adapted	Checklist on type of embroidery, interview schedule on work process chart, ergonomic checkpoints with 16 items and rating scale on difficulty (3 – point rating scale) with 10 items was developed newly.
		RULA	Taken as such	-
		Work/rest cycles	Adapted	Newly developed work / rest cycles sheet
		Tool/ product assessment	Adapted	Combined with task assessment module
		Discomfort survey	Taken as such	
		Rate of perceived exertion	Adapted	Verghese (1994) 5 – point scale was taken
5	*Posture Analyst*	Posture assessment	Adapted	Ergonomic checkpoints and rating scale on difficulty (3 – point rating scale) with 18 items was developed newly.
		RULA	Taken as such	-
		Discomfort survey	Taken as such	-
		Dimensional assessment	- -	
		Rate of perceived exertion	Adapted	Verghese (1994) 5 – point scale was taken
6	*Workstation Analyst*	Workstation assessment	Adapted	Checklist on type of workstation frames used, ergonomic checkpoints with 10 items and rating scale on difficulty (3 – point rating scale) with 8 items was developed newly.
		Video display assessment	- -	
		Discomfort survey	Taken as such	-
		Tool/ product assessment	Adapted	-
		Rate of perceived exertion	Adapted	Verghese (1994) 5 – point scale was taken
7	*Ergo Product Base*	-	- -	

Validated Composite Ergonomic Tool

The constructed tool was validated for its content in terms of four qualitiesviz; content relevance, information adequacy, statement completeness and statement clarity and was found consistent. The tool was also tested for reliability and was found as reliable with p value above 0.9 confirming the tool for its dependability in eliciting the needed data from the subjects.

Reliability of Developed Composite Ergonomic Tool

The study concluded the scope of using this tool for a large sample survey of fabric embellishment workers.

DISCUSSION

Evolving a composite ergonomic analysis module for assessing the fabric embellishment workers was felt necessary by the researchers to understand the needs of fabric embellishment workers. After the critical analysis of the research tools, with reference to modular tools, it can be concluded that Ergomaster module has the potential to serve as a frame of reference on the basis of applicability.

Ergonomic research tools create a path to examine the existing situations of *aari* workers and to analyze their design needs for a safe, comfortable environment. Few ergonomic research tools are available and administered to examine aspects such as posture (Baker et al. 2002, 2003), musculoskeletal disorders (Spielholz et al. 2001), repetitive motions (Keyserling et al. 1993), lifting (Granata 1997), material handling (Denis 2005), and physical and psychological strain (Layn 2001) and work place (Kroemer 2000).

A total of four ergonomic checkpoints formats were constructed by incorporating the data needed as essential with particular reference to materials and tool handling, work postures, work profile, repetitive motions and work station analysis on the basis of preliminary survey findings. Five rating scales were developed formulating statements by following the Likert scale method of summated ratings. The above were integrated into Ergo master and were developed as a composite modular tool for fabric embellishment workers.

The constructed tool was validated for its content in terms of four qualities viz; content relevance, information adequacy, statement completeness and statement clarity and was found consistent. The tool was also tested for reliability and was found as reliable with p value above 0.9 confirming the tool for its dependability in eliciting the needed data from the subjects.

CONCLUSION

The results conclude that mostly men were found carrying out the fabric embellishment task. There was large age variation among the embellishment workers. Their height was found to be between the 25th and 50th percentiles with a normal weight for height. There was a large variation in their experience. They belonged to the category of lower income group. The work profile was observed with work duration of 8 hours and 8 – 10 hours at peak season. The type of work was repetitive. They work in static seating postures at floor level with hands in dynamic motions. Four types of work postures were observed – sitting cross legged, kneeling, one leg stretched in sitting cross legged and one leg vertical in kneeling position. The workstation observed was of two types, one small for embellishing blouse and the other big for *sarees*. The work environment was found to have general lighting with very less space. The problems faced were reported as pain in legs, back, legs, wrist and arm, working with workstation and tool. The tool was developed adapting the Ergomaster module and the required aspects were modified constructing the composite ergonomic analysis module applicable to fabric embellishment workers. The constructed module consisted of seven modules with new addition of ergonomic checkpoints, rating scales on degree of difficulty and the repetitive motion analysis. Thirty experts validated the tool and the results showed no significant difference. A test, re- test for reliability of the tool also revealed no significant difference. It can be concluded that the scope of using this tool for a large sample survey of fabric embellishment workers and similar other occupations like embroidery, handicraft making, bangle making etc.

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