

Ergonomic Assessment and Designing of Workstation for Bamboo and Cane Weaving Craftsmen of Assam

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1. INTRODUCTION

1.1. Introduction

Bamboo and cane crafts constitute an important component of sustainable material culture and rural livelihoods, particularly across tropical and subtropical regions. As fast-growing and renewable members of the grass family (Poaceae), bamboo and cane possess high tensile strength, flexibility, durability, and biodegradability, making them environmentally sustainable alternatives to synthetic materials **(Sharma et al., 2019; Nath and Das, 2020)**. Globally, the sector has gained prominence due to increasing demand for eco-friendly products and the growing transition toward green economies.

In India, bamboo and cane weaving represents one of the oldest traditional crafts, especially in the Northeastern region. States such as Assam, Manipur, and Tripura are well known for their intricate weaving techniques and diverse product ranges **(Das and Nath, 2018)**. Among them, Assam remains a leading producer and exporter of handcrafted bamboo and cane products, with Barpeta emerging as a prominent craft cluster **(NEHHDC, 2021; Singh et al., 2020)**. Despite abundant raw materials and skilled artisans, the sector largely operates within the informal economy, facing persistent challenges such as inadequate financial assistance, limited market access, lack of technological modernization, and poor ergonomic infrastructure **(Sharma et al., 2019; Bhattacharyya et al., 2018)**. The craft production process involves multiple labour-intensive stages, including harvesting, seasoning, splitting, weaving, chemical treatment, colouring, and finishing **(Bhattacharya, 2018)**. These processes demand high levels of manual dexterity, sustained concentration, and prolonged physical effort. Artisans typically work in home-based settings, often sitting or squatting for extended periods in awkward postures while performing repetitive hand and arm movements. Such working conditions significantly increase the risk of work-related musculoskeletal disorders (MSDs), repetitive strain injuries, respiratory problems due to dust exposure, skin irritation, eye strain, and accidental injuries from sharp tools **(Gupta et al., 2020; Bhattacharya, 2019)**.

Musculoskeletal disorders are globally recognized as a leading cause of disability, with approximately 149 million years of living with disabilities (YLDs), accounting for 17 percent of all YLDs worldwide (World Health Organization, 2021). Work-related MSDs commonly arise from repetitive motions, forceful exertions, prolonged static postures, vibration exposure, and poorly designed workstations (**Armstrong et al., 1993; National Research Council & Institute of Medicine, 2001**). Conditions such as cumulative trauma disorders (CTDs) and carpal tunnel syndrome (CTS) are strongly associated with repetitive hand-intensive work and inadequate ergonomic design (**Silverstein et al., 1986; Atroshi et al., 2009**). In the informal bamboo and cane sector, where human labour remains the primary production mechanism, the prevalence of awkward postures and repetitive tasks further intensifies these risks (**Lop et al., 2019**). Recognizing the socio-economic significance of bamboo and cane crafts, several initiatives have been undertaken by the Government of India and the Government of Assam. National programs such as the National Bamboo Mission, Khadi and Village Industries Commission, North Eastern Handicrafts and Handloom Development Corporation, and Skill India aim to promote bamboo cultivation, skill development, financial inclusion, and market expansion (**National Bamboo Mission, 2006; KVIC, 2020; NEHHDC, 2021; Skill India, 2015**). At the state level, the Assam Bamboo and Cane Policy (2019) and initiatives by the Assam State Bamboo Development Agency seek to enhance resource management, enterprise development, and artisan welfare (**Government of Assam, 2019; Government of Assam, 2021**). Despite these policy efforts, gaps remain in effective implementation, ergonomic intervention, and access to credit and infrastructure at the grassroots level. Though, bamboo, and cane crafts offer substantial environmental, cultural, and economic benefits, but the occupational health risks and structural limitations faced by craftsmen demand urgent attention. Integrating ergonomic workstation design, human factors engineering, technological upgradation, and strengthened policy support is essential to reduce musculoskeletal risks, improve productivity, and enhance overall artisan well-being (**Choobineh et al., 2004; Motamedzade et al., 2007**). Sustainable development of the bamboo and cane sector requires a balanced approach that simultaneously preserves traditional craftsmanship and promotes health-conscious, economically viable production systems.

1.2. Justification of the study

Bamboo and cane weaving is a traditional craft that has been practiced for generations and forms an integral part of the cultural and economic fabric of Assam. Despite its significance, the craft involves labour-intensive activities characterized by repetitive hand movements, prolonged bending, and awkward working postures. These conditions expose craftsmen to various work-related musculoskeletal disorders, resulting in discomfort, fatigue, reduced productivity, and a diminished long-term work capacity. Hence, an ergonomically supportive working environment is essential to improve comfort, reduce physical strain, and promote occupational health. A review of national and international literature reveals that several studies have addressed ergonomic risks, postural assessment, and musculoskeletal problems in craft-based and manual occupations. However, a dearth was found in research focusing specifically on the ergonomic assessment and workstation design for bamboo and cane weaving craftsmen of Assam, despite the state being one of the major bamboo-producing regions of the country. This indicates a significant research gap in the context of regional craft practices and occupational health. In view of this gap, the present study aims to assess the postures adopted during bamboo and cane weaving, identify the type and extent of musculoskeletal discomfort experienced by the craftsmen, and develop an ergonomic workstation based on the working requirements of craftsmen engaged in the bamboo and cane weaving process.

The outcomes of the study will be beneficial for multiple stakeholders. For craftsmen in the unorganized sector, the findings provide insights into ergonomic hazards and occupational health, thereby supporting SDG 3: Good Health and Well-being. For product designers, the results offer guidelines for creating sustainable, ergonomic solutions that enhance productivity and align with SDG 8: Decent Work and Economic Growth and SDG 9: Industry, Innovation, and Infrastructure. For policymakers and government agencies, the research offers evidence that can inform welfare schemes, skill-development initiatives, and infrastructure improvements aimed at supporting bamboo and cane craftsmen, contributing to SDG 1: No Poverty and SDG 10: Reduced Inequalities.

1.3. Statement of problem

The present study aimed to assess the extent of perceived musculoskeletal discomfort among craftsmen engaged in the bamboo and cane weaving process and to design a need-based ergonomic workstation to reduce work-related musculoskeletal discomfort and physical injuries among the selected craftsmen of Assam engaged in Bamboo and Cane weaving Process.

1.4. Objectives of the study

1. To collect the personal and occupational information of the selected craftsmen of Assam engaged in Bamboo and Cane weaving Process.
2. To assess the duration of adopted postures, repetition of task, and rest pauses taken by the selected craftsmen engaged in Bamboo and Cane weaving Process.
3. To determine the prevalence of perceived work-related musculoskeletal discomfort, exertion, fatigue and physical injuries among the selected craftsmen engaged in Bamboo and Cane weaving Process.
4. To assess the anthropometric measurements, tools used and workspace arrangement of the selected craftsmen engaged in Bamboo and Cane weaving Process.
5. To design and develop a need-based ergonomic workstation and to propose coping strategies to reduce perceived work-related musculoskeletal discomfort and physical injuries encountered by the selected craftsmen engaged in Bamboo and Cane weaving Process.

1.5. Delimitations of the study

1. Bamboo and Cane weaving craftsmen registered under the North Eastern Handicrafts and Handlooms Development Corporation (NEHHDC) who were actively engaged in Micro, Small, and Medium Enterprises (MSME) clusters with the highest number of craftsmen (both male and female) and the greatest annual production.
2. The craftsmen aged above 18 years, who were willing to participate in the study.
3. The craftsmen who have been engaged in Bamboo and Cane weaving for a minimum of two years
4. The craftsmen who were physically and mentally normal (not physically and mentally challenged), especially females not in the pregnancy stage.

1.6. Hypotheses of the study

1. There exists a variation in the selected situational variables (time spent on work, frequency of repetition of task, type of adopted posture) of the craftsmen engaged in the Bamboo and Cane weaving process due to their personal variables (age, gender, and work experience).
2. There exists a variation in the extent of perceived Musculoskeletal discomfort experienced by the craftsmen engaged in Bamboo and Cane weaving process due to their situational variables (time spent, frequency of repetition of task, type of posture adopted, tools used and workspace arrangement during Bamboo & Cane weaving process) and intervening variable (duration of maintaining a posture adopted by the craftsmen).
3. There exists a variation in the duration of maintaining the adopted posture due to the personal variables (age, gender and work experience) of the craftsmen engaged in the Bamboo and Cane weaving process.
4. The extent of physical injuries experienced by the Bamboo and Cane weaving craftsmen varies with the selected situational variable (tools used and workspace arrangement) of the craftsmen engaged in the Bamboo and Cane weaving process.

2. REVIEW OF LITERATURE

The review of literature chapter was divided into two parts, namely Theoretical Orientation and Empirical Studies.

2.1. Theoretical Orientation:

The theoretical orientation of the study focuses on indigenous bamboo and cane weaving crafts, covering global and Indian perspectives, their historical significance in Assam, material properties, traditional weaving techniques, and production processes. Emphasis is placed on work postures, human–work interaction, occupational health risks, and sustainability in craft-based workstation design, highlighting the role of ergonomics in reducing musculoskeletal discomfort and enhancing productivity.

2.2. Empirical Studies:

This sub-section of the review of literature consisted of researches conducted in India and abroad related to bamboo and cane weaving, occupational health, ergonomics, and work posture assessment.

3. METHODOLOGY

3.1. Research Design

The present study aimed to analyze work postures and assess perceived drudgery, exertion, fatigue, musculoskeletal discomfort, and physical injuries among selected bamboo and cane weaving craftsmen of Assam. Furthermore, the study aimed to design a need-based ergonomic workstation and propose coping strategies to reduce work-related musculoskeletal discomfort and physical injuries. Therefore, a descriptive research design was considered most appropriate for the study.

3.2. Locale of the Study

The present study was conducted in the Barpeta District of Assam.

3.3. Sampling Procedure, Sample Size, and Unit of Inquiry

The unit of inquiry for the present study comprised craftsmen engaged in the bamboo and cane weaving process from the Barpeta cluster of Assam. The sampling followed clearly defined inclusion and exclusion criteria. Out of a total population of 828 craftsmen, a sample of 260 craftsmen (130 male and 130 female) was selected using a multistage sampling technique. In the first stage, the Barpeta cluster was purposively selected due to its high concentration of bamboo and cane weaving craftsmen. In the second stage, stratified random sampling was used to ensure proportional representation of male and female craftsmen.

For detailed postural analysis, a subsample of 60 craftsmen, representing over 20 percent of the total sample, was selected using stratified random sampling. Craftsmen were categorized into three groups based on the nature of their work: bamboo weaving, cane weaving, and combined bamboo and cane weaving.

3.4. Selection, Development and Description of Tools

For the present study, the data were collected using the following three tools:

- i.** Structured Interview Schedule
- ii.** Observation Sheet
- iii.** Feedback Form

The present study incorporated five standardized and pre-validated instruments within the interview schedule and observation sheet.

The description of each tool is as follows:

3.4.1. Interview Schedule:

The interview schedule consisted of two sections designed to gather information from the bamboo and cane weaving craftsmen. The first section focused on personal and occupational details of the respondents. The second section assessed musculoskeletal discomfort, exertion, fatigue, and hand-related discomfort, incidence and nature of physical injuries experienced by the craftsmen during the weaving process.

Section I: Personal and Occupational Profile of the Bamboo and Cane Weaving Craftsmen of Assam

This section focused on collecting two categories of information:

- A.** Personal profile, which included variables such as age, gender, educational qualification, monthly family income, hand dominance, and the presence of any self-reported co-morbidities; and
- B.** Occupational profile, which encompassed details on type of weaving activity involved, work experience, daily working hours, and the quantity of craft production of the respondents.

Section II: Frequency and Severity of Perceived Work-Related Body Discomfort, Discomfort in Right and Left hand, Exertion, Fatigue, and Physical Injuries experienced by the Craftsmen during Bamboo and Cane Weaving Process

This section of the interview schedule focused on assessing the ergonomic and physiological challenges experienced by the respondents during the bamboo and cane weaving process.

Part A focused on body and hand discomfort, wherein;

- A1:** This section captured the frequency, severity and interference of body discomfort across 20 distinct body regions using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) for both male and female craftsmen (Hedge, Morimoto, & McCrobie, 1999).

A2: This section captured the frequency, severity and interference of discomfort in the left and right hands through the Cornell Hand Discomfort Questionnaire (CHDQ) (Hedge, Morimoto, & McCrobie, 1999).

Part B assessed the perceived exertion by the craftsmen during the Bamboo and Cane weaving process was assessed using the Borg Category-Ratio Scale (CR10, 0–10), which enable respondents to subjectively rate the level of physical effort involved.

Part C examined perceived fatigue by the craftsmen during the Bamboo and Cane weaving process using the Multidimensional Fatigue Inventory (MFI-20), which evaluates fatigue across five dimensions: general fatigue, physical fatigue, reduced activity, reduced motivation, and mental fatigue.

Part D documented the physical injuries encountered by the craftsmen during the Bamboo and Cane weaving process, providing insights into the immediate risks associated with their occupational tasks.

3.4.2. Observation sheet:

For the present study, the observation sheet comprised two distinct sections. The first section focused on recording anthropometric measurements, tools used, and the workspace sitting arrangement of the craftsmen. The second section documented the postures adopted, duration and frequency of repetitive tasks, and rest pauses taken during the bamboo and cane weaving process.

Section I: Anthropometric Measurements, Frequency of Tool used and Workspace Sitting Arrangement adopted by the Craftsmen during Bamboo and Cane weaving Process

This section focused on collecting detailed information related to the anthropometric measurement, tool usage, and workspace sitting arrangement of the craftsmen engaged in the Bamboo and Cane weaving Process.

Part A covered the anthropometric measurements, where body weight (kg) was recorded using a digital weighing scale and knee height, arm span, hip width, thigh clearance, horizontal maximum reach and horizontal minimum reach were measured using a non-stretchable measuring tape.

Part B involved documenting the frequency and type of tools used during various activities of the Bamboo and Cane weaving process.

Part C involved systematic observations of the workspace sitting arrangement adopted by the craftsmen, with a focus on examining how the layout, seating practices, and placement of tools and materials affect their working posture and contribute to potential ergonomic risks during the bamboo and cane weaving process.

Section II: Posture Analysis, Time Spent and Rest Pause Taken by the craftsmen during Bamboo and Cane Weaving Process

This section focused on evaluating the postures adopted by the craftsmen during various weaving activities, along with the time spent in each posture and the rest pauses taken as follows-

Part A documented the primary and transitional postures adopted by the craftsmen during various activities of the bamboo and cane weaving process, along with the time spent in each activity and the frequency and duration of rest pauses taken. Digital videography using a GoPro HERO 13 camera was employed to record the sequence of work activities.

Part B involved analyzing the recorded footage to assess the ergonomic risks associated with the adopted postures. The postural assessment was carried out using the Rapid Entire Body Assessment (REBA) tool (Hignett & McAtamney, 2000), enabling a systematic evaluation of the craftsmen's working postures and related work practices.

3.4.3. Feedback Form

For obtaining feedback on the developed need-based ergonomic workstation, the selected bamboo and cane weaving craftsmen were requested to use the workstation for a period of one week during their routine craft activities. After the trial period, a structured feedback form was administered to assess the perceived improvement in comfort, posture, and work efficiency. The feedback was collected under three major parameters, namely improvement in comfort and reduction of fatigue, ease of use and posture maintenance, and improvement in efficiency across various weaving activities such as splitting, stripping, bending, weaving, and finishing.

3.5. Establishment of Content Validity and Reliability of the Tools

The present study utilized five standardized and pre-validated instruments, namely the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), Cornell Hand Discomfort Questionnaire (CHDQ), Borg Category-Ratio Scale (CR10), Multidimensional Fatigue Inventory (MFI-20), and Rapid Entire Body Assessment (REBA). Content validity of the interview schedule and observation sheet was established through expert review by eleven specialists from the fields of Ergonomics and Family and Community Resource Management, and necessary modifications were made based on their suggestions. Reliability of the tools was supported by strong psychometric evidence reported in earlier studies, including satisfactory test–retest reliability and high internal consistency for CMDQ and CHDQ, strong correlation of the Borg CR10 scale with physiological indicators of exertion, high reliability coefficients for MFI-20, and acceptable inter-rater reliability for REBA. Thus, the tools employed were considered valid and reliable for the present study.

3.6. Data Collection

Data for the present study were collected by the researcher during May–June 2024. A structured interview schedule was administered to obtain information on demographic profile, perceived musculoskeletal and hand discomfort, physiological fatigue, and physical injuries among bamboo and cane weaving craftsmen. Posture adopted, duration of postures, task time, repetitive movements, tools used, and workspace sitting arrangements were documented using an observation sheet supported by digital videography with a GoPro HERO 13 camera. The recorded data were analyzed for postural risk using the Rapid Entire Body Assessment (REBA) tool. Anthropometric measurements were taken by the researcher for female respondents and by a male assistant for male respondents to ensure cultural appropriateness. Ethical approval was obtained from the Institutional Ethics Committee of The Maharaja Sayajirao University of Baroda, and informed consent was secured from all participants in English and Assamese. The study adhered strictly to ethical guidelines, ensuring voluntary participation, confidentiality, and the safety and well-being of the respondents.

3.7. Data analysis

For the present study, the collected data were systematically analyzed by employing categorization, coding, tabulation, and statistical analysis. These methods allowed for the systematic organization and interpretation of the collected data, ensuring accurate and reliable results of the study. Statistical analysis involved systematic coding and tabulation of data, followed by the application of relational statistical techniques. Responses obtained from the interview schedule and observation sheet were coded and entered into Microsoft Excel to ensure accuracy. The categorized data were then tabulated for clear presentation. Relational statistics, including Spearman Rank Correlation, Chi-square Test of Independence, and One-way ANOVA, were applied to examine relationships among independent variables, the intervening variable, and dependent variables of perceived musculoskeletal discomfort and physical injuries.

3.8. Development of Need-based Ergonomically Designed Workstation

For the present study, a need-based ergonomically designed workstation was developed for selected bamboo and cane weaving craftsmen by integrating essential anthropometric measurements of the respondents with standard Indian anthropometric data and findings on postural discomfort and musculoskeletal problems. The development process was carried out in three phases: Phase I, assessment of essential anthropometric measurements using standard measuring tools; Phase II, design of the ergonomic workstation keeping in mind the raw bamboo and cane materials, prepared through AutoCAD 2024, SketchUp 2024, and Lumion 2024; and Phase III, development of the workstation prototype along with cost estimation.

3.9. Development of Informative Pamphlet on Coping Strategies for prevention of Musculoskeletal discomfort and Physical Injuries experienced by the respondents at workplace

An informative pamphlet was developed in both English and Assamese to propose need-based coping strategies for reducing musculoskeletal discomfort and the risk of physical injuries among bamboo and cane weaving craftsmen. The content was formulated based on findings from body and hand discomfort assessments and

postural analysis, and was validated through consultation with an ergonomics expert and a physiotherapist to ensure scientific accuracy and practical relevance. The pamphlet included ergonomic interventions, stretching exercises, correct working postures, and appropriate rest–work schedules tailored to weaving tasks.

The finalized pamphlet was distributed among the respondents to enhance awareness and encourage adoption of the recommended strategies. Additionally, a set of recommendations was submitted to the North Eastern Handicrafts and Handloom Development Corporation (NEHHDC), emphasizing the provision of essential safety and comfort-enhancing resources to improve craftsmen’s occupational health and well-being.

3.10. Feedback on the Comfort Level of the Developed Need-based Ergonomic Workstation

To obtain feedback on the developed need-based ergonomic workstation, selected bamboo and cane weaving craftsmen were asked to use the workstation for one week. Thereafter, a structured feedback form was administered to assess perceived improvements in comfort, posture, and work efficiency during routine weaving activities. The feedback was evaluated under three parameters:

- (i) Improvement in comfort and reduction of fatigue,
- (ii) Ease of use and posture maintenance, and
- (iii) Improvement in efficiency across work activities such as splitting, stripping, bending, weaving, and finishing.

4. KEY FINDINGS OF THE STUDY

The major findings of the present study, derived from the systematic analysis of the collected data, are presented below:

4.1. Personal and Occupational Profile of the Respondents engaged in the Bamboo and Cane Weaving Process

4.1.1. Personal Profile of the Respondents

The personal profile of the respondents engaged in bamboo and cane weaving were analyzed in terms of age, gender, educational qualification, monthly family income,

prevalence of self-reported co-morbidities, and hand dominance. The age-wise distribution showed distinct trends across weaving categories. Among bamboo craftsmen, 76.29 per cent were in the 20–35 years age group, while 100 per cent of cane craftsmen belonged to the 36–51 years category. Respondents engaged in both bamboo and cane weaving were comparatively older, with 53.45 per cent in the 52–68 years age group. Overall, 47.69 per cent of the respondents were aged 36–51 years, and the mean age was 42.88 years, indicating predominance of middle-aged craftsmen (**Figure 1**).

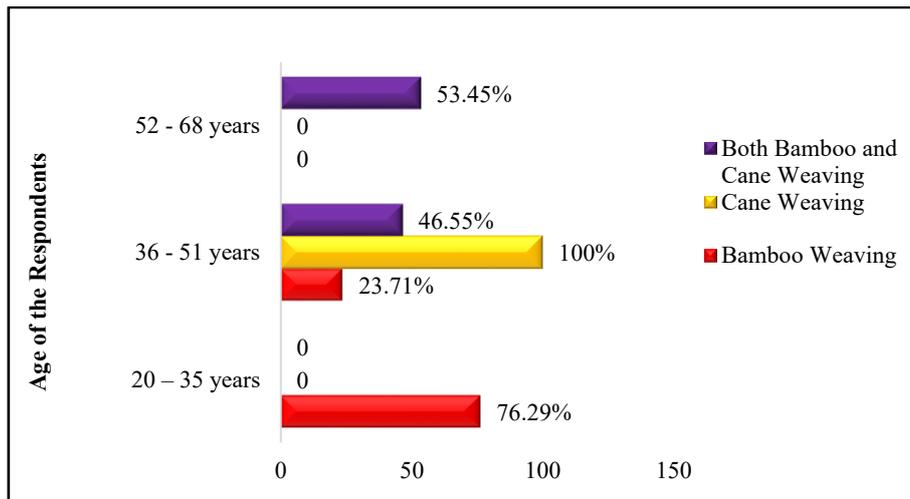


Figure 1: Percentage distribution of Respondents according to their Age

Gender-wise distribution revealed an overall equal representation of males and females. Bamboo weaving showed fairly balanced participation, cane weaving was predominantly male-oriented, whereas a higher proportion of females (59.48 per cent) were involved in both bamboo and cane weaving, indicating gender-based task specialization within the craft (**Figure 2**).

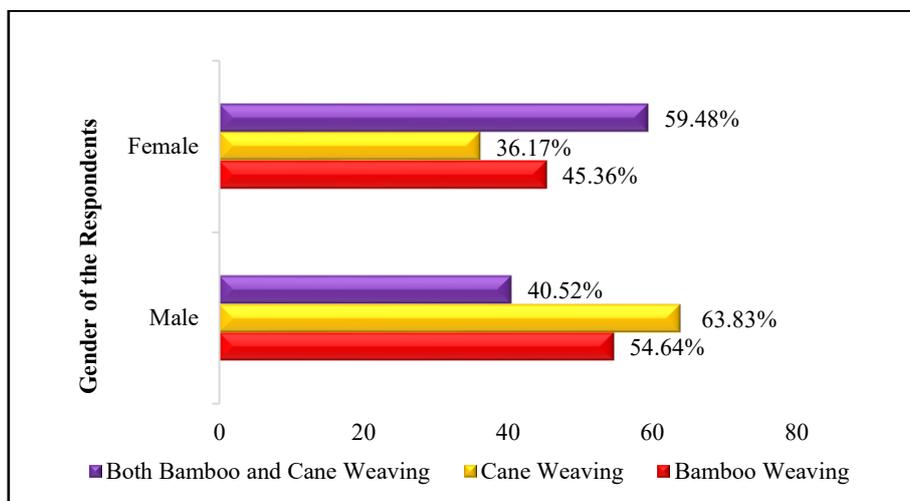


Figure 2: Percentage distribution of the respondents according to their Gender

Educational qualification analysis indicated that 41.15 per cent of the respondents had completed secondary-level education, followed by diploma holders (23.86 per cent) and graduates (12.69 per cent). Craftsmen engaged in both bamboo and cane weaving exhibited comparatively higher educational attainment, suggesting the requirement of broader skill sets for combined weaving activities. Overall, the findings indicate that formal education is not a prerequisite for participation in bamboo and cane crafts, as skills are primarily acquired through traditional and experiential learning (**Figure 3**).

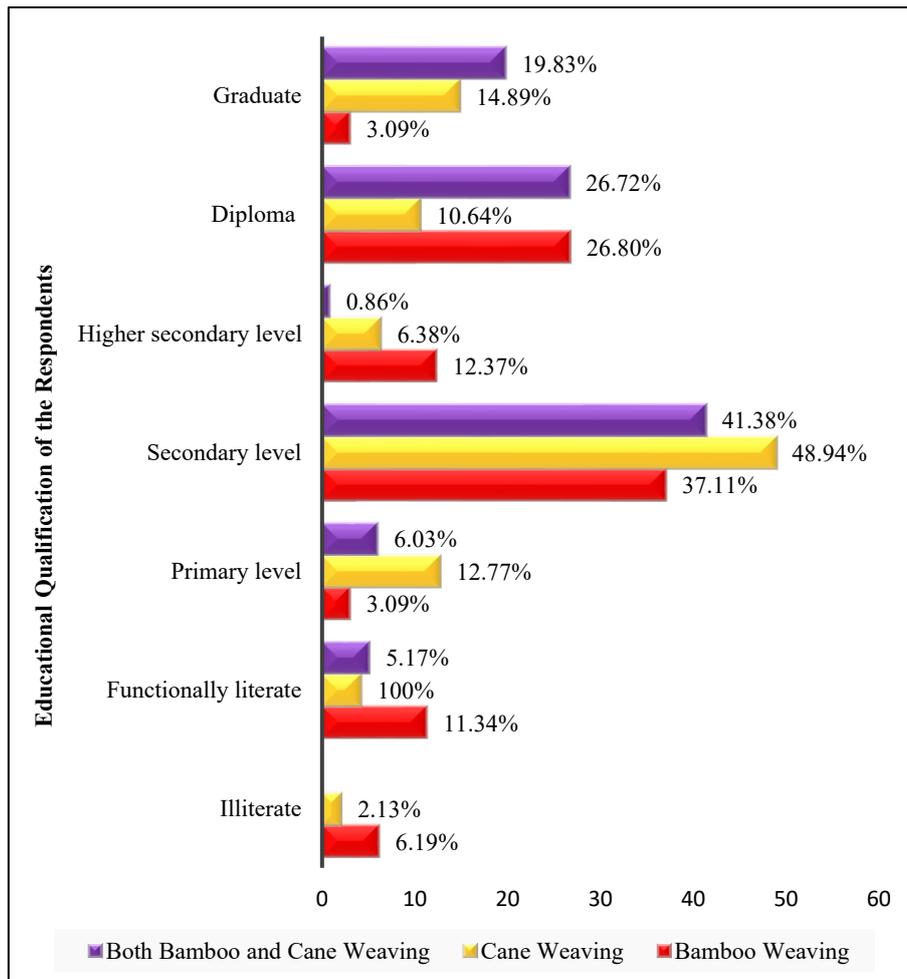


Figure 3: Percentage distribution of the respondents according to their Educational Qualification

The monthly family income profile reflected a modest economic status of the respondents. Nearly half (48.08 per cent) reported a monthly family income between ₹10,000 and ₹27,000, with a mean income of ₹29,157.95. Almost all bamboo craftsmen (98.97 per cent) belonged to the lowest income group. In contrast, respondents engaged in both bamboo and cane weaving reported relatively higher income levels, highlighting the economic advantage of diversified craft engagement (**Figure 4**).

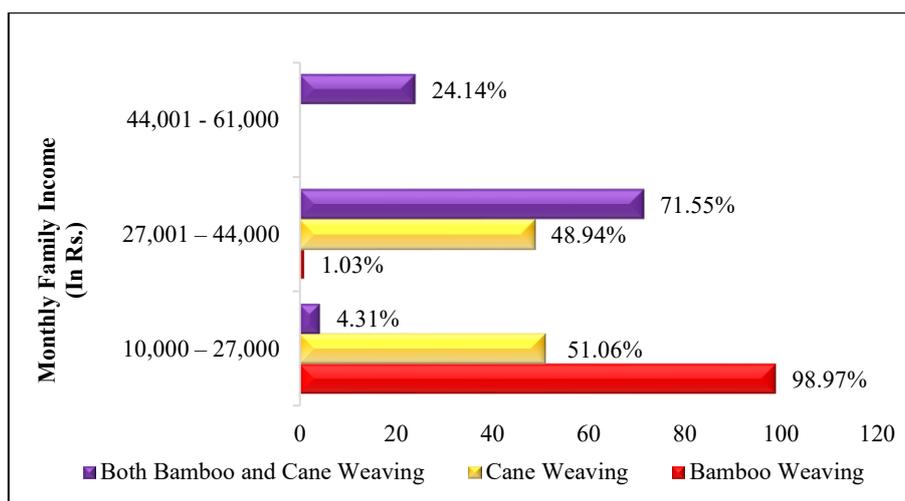


Figure 4: Percentage distribution of the respondents according to their Monthly Family Income

Regarding health status, 68.46 per cent of the respondents reported no co-morbidities. Among those with health issues, eye strain (11.54 per cent) and hypertension (6.92 per cent) were the most commonly reported conditions, indicating emerging occupational health concerns among craftsmen (Table 1).

Table 1: Frequency and percentage distribution of the Respondents according to the Prevalence of Self-Reported Co-morbidities n=260

Sr. no.	Co-morbidities	Bamboo Weaving		Cane Weaving		Both Bamboo & Cane Weaving		Total	
		<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
1.	Diabetes	06	6.19	-	0.00	02	1.72	08	3.08
2.	Hypertension	09	9.28	03	6.38	06	5.17	18	6.92
3.	Headache	02	2.06	05	10.64	06	5.17	13	5.00
4.	Skin Irritation	-	0.00	03	6.38	05	4.31	08	3.08
5.	Respiratory Problem	02	2.06	-	0.00	03	4.59	05	1.92
6.	Eye Strain	09	9.28	08	17.02	13	11.21	30	11.54
7.	None	69	71.13	28	59.58	81	69.83	178	68.46
Total		97	100	47	100	116	100	260	100

Hand dominance analysis showed that 84.23 per cent of the respondents exhibited ambiguous or mixed hand dominance, underscoring the bi-manual nature of bamboo and cane weaving activities. This pattern was most pronounced among craftsmen engaged in both bamboo and cane weaving, reflecting the high level of coordinated hand use required in the craft (Figure 5).

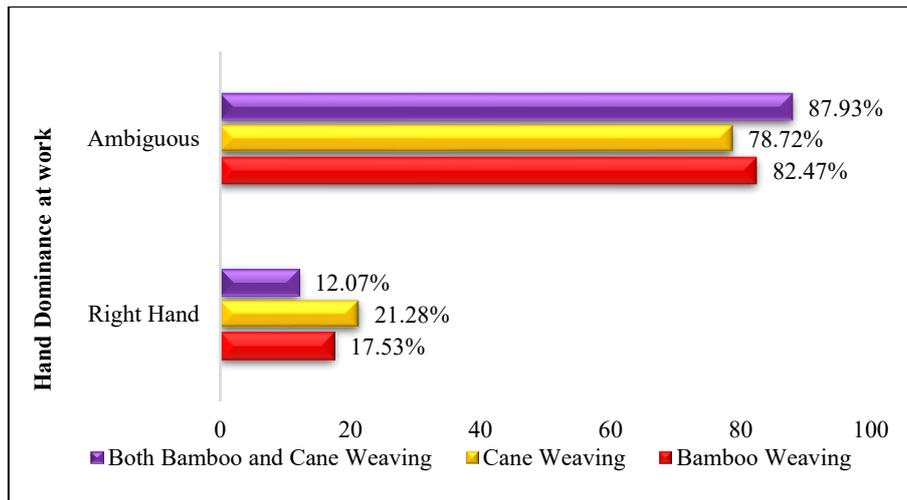


Figure 5: Percentage distribution of the respondents according to their Hand Dominance at work

4.1.2. Occupational Profile of the Respondents

The occupational profile of respondents engaged in bamboo and cane weaving was assessed, and the analysis of work experience revealed that respondents had experience ranging from 2 to 41 years, with a mean of 15.42 years, indicating long-term engagement in the craft. Overall, 57.69 per cent of the respondents had 2–14 years of experience, followed by 28.08 per cent with 15–27 years and 14.23 per cent with 28–41 years of experience. Among bamboo craftsmen, 45.36 per cent had 2–14 years of experience, while cane craftsmen (65.96 per cent) and those engaged in both bamboo and cane weaving (64.65 per cent) were largely concentrated in the early- to mid-experience category, reflecting the continued entry of relatively younger and moderately experienced craftsmen into the sector (**Figure 6**).

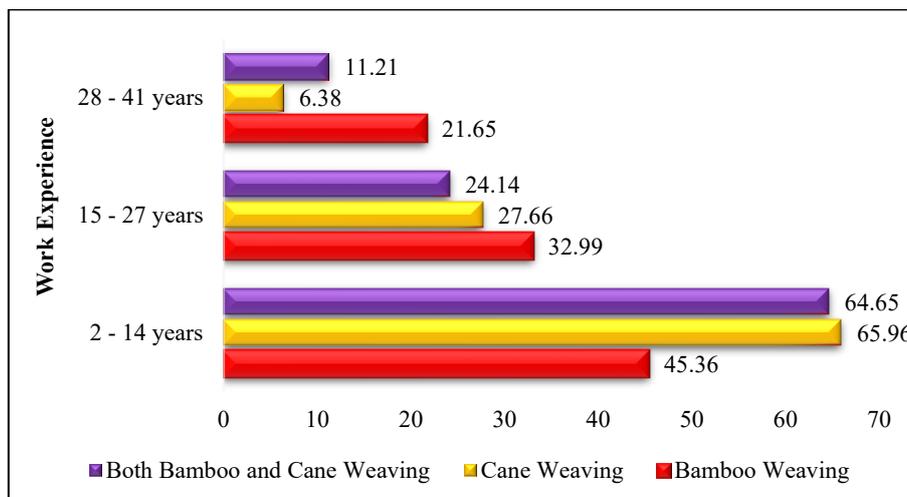


Figure 6: Percentage distribution of the respondents according to their Work Experience

With respect to working hours, the respondents worked an average of 7.48 hours per day. Bamboo craftsmen showed a higher proportion (49.48 per cent) working more than 8 hours per day, whereas respondents engaged in both bamboo and cane weaving predominantly worked for 6–8 hours daily (49.14 per cent), reflecting the sustained effort required for combined weaving activities (Figure 7).

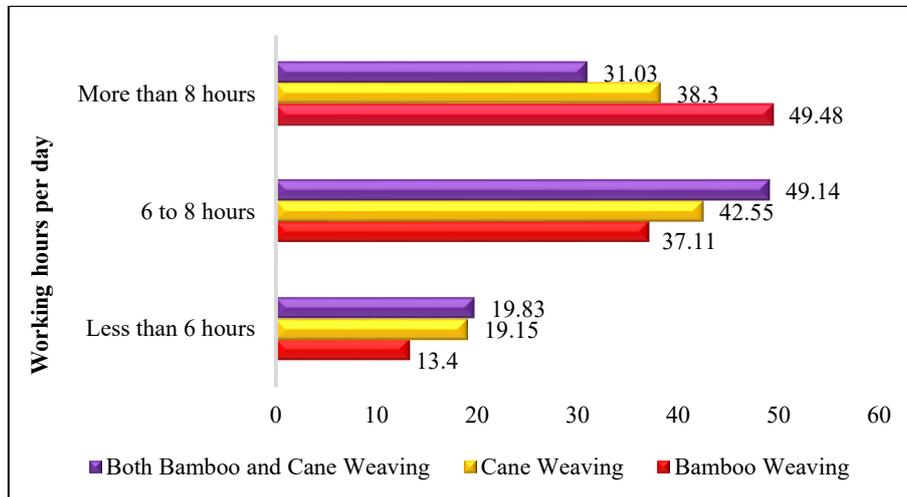


Figure 7: Percentage distribution of the respondents according to their Working Hours per Day

The assessment of daily production showed a mean daily output of 10.85 items. A higher proportion of bamboo craftsmen (80.40 per cent) were concentrated in the lowest production category, reflecting the physically demanding and time-intensive nature of bamboo weaving. Craftsmen engaged in both bamboo and cane weaving also predominantly produced 2–9 items per day (63.80 per cent), indicating moderate daily productivity due to increased task complexity (Figure 8).

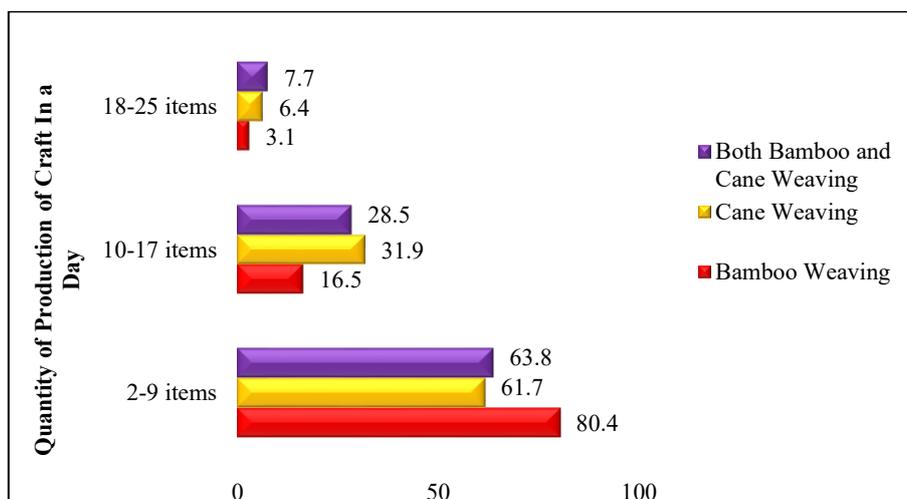


Figure 8: Percentage distribution of the respondents according to the Quantity of Production of craft in a Day

Monthly production analysis revealed that the respondents produced an average of 42.70 items per month. Overall, 46.54 per cent produced 36–51 items per month, followed by 29.61 per cent producing 20–35 items and 23.85 per cent producing 52–68 items. A distinct pattern emerged across weaving categories, wherein 76.29 per cent of bamboo craftsmen produced 20–35 items per month, cane craftsmen largely produced 36–51 items (93.62 per cent), and more than half of the craftsmen engaged in both bamboo and cane weaving (53.45 per cent) produced 52–68 items per month. This highlights the productivity advantage associated with diversified skill engagement and combined weaving practices (**Figure 9**).

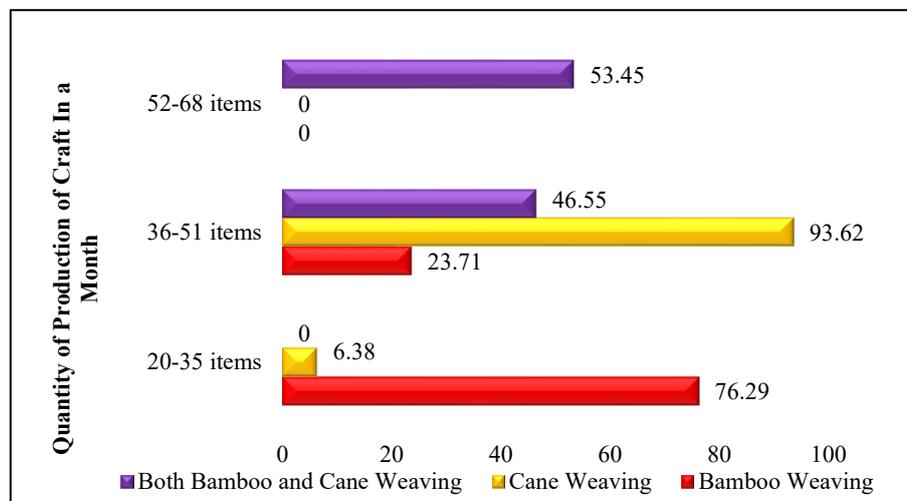


Figure 9: Percentage distribution of the respondents according to the Quantity of Production of craft in a Month

4.2. Workspace Sitting Arrangement and Tools Adopted by the Respondents during Bamboo and Cane Weaving Process

4.2.1. Workspace Sitting Arrangement adopted by the Respondents during Bamboo and Cane Weaving Process

The findings revealed that bamboo and cane weaving is predominantly carried out in informal and non-standardized workspaces, either within the craftsmen’s homes, shared work areas, or small workshops measuring approximately 10–15 m². These spaces provide only the minimum area required for materials, tools, and work activities. Four types of workspace sitting arrangements were identified: floor sitting, wooden low stool (Pidha), bamboo stool (Murha), and wooden bench, each varying in height and ergonomic suitability depending on the nature of the task.

The activity-wise analysis showed that the wooden low stool (Pidha) was the most preferred sitting arrangement across all stages of weaving. During splitting, 57.70 per cent of the respondents used a Pidha, followed by floor sitting (27.70 per cent). Stripping was also mainly performed on a Pidha (42.30 per cent), with notable use of Murha (25.00 per cent). For bending activities, 53.80 per cent preferred the Pidha, while 21.20 per cent worked on the floor. Weaving activities showed a more varied distribution, with 38.50 per cent using a Pidha and 32.70 per cent using a Murha. During finishing, 46.20 per cent preferred the Pidha, followed by Murha (34.60 per cent). Overall, the choice of sitting arrangement was closely linked to task requirements, with Pidha supporting activities demanding strength and stability, and Murha or slightly elevated surfaces preferred for precision-oriented tasks (Table 2).

Table 2: Frequency and percentage distribution of the respondent based on Workspace Arrangements adopted during Bamboo and Cane Weaving Process n=260

Activity	Workspace Sitting Arrangement								Total	
	On the Floor		Wooden low Stool/ Pidha		On a Wooden Bench		Bamboo stool/ Murha			
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
1. Splitting	72	27.70	150	57.70	18	6.90	20	7.70	260	100
2. Stripping	45	17.30	110	42.30	40	15.40	65	25.00	260	100
3. Bending	55	21.20	140	53.80	20	7.70	45	17.30	260	100
4. Weaving	65	25.00	100	38.50	10	3.80	85	32.70	260	100
5. Finishing	30	11.50	120	46.20	20	7.70	90	34.60	260	100

4.2.2. Tools Adopted by the Respondents during Bamboo and Cane Weaving Process

The respondents predominantly used traditional, manually operated tools that were locally made or procured from nearby markets. Core tools included the knife, dao, chisel/boti, hand saw, measuring tape, and scissors, which were essential for cutting, splitting, shaping, and measuring bamboo and cane materials.

Tool usage analysis indicated that the knife was the most frequently used tool, with 88.50 per cent of respondents reporting it as always used (W.M.S. = 2.87), followed by the dao (84.60 per cent; W.M.S. = 2.81) and chisel/boti (80.80 per cent; W.M.S. = 2.75). Measuring tape, hand saw, and scissors also recorded high frequency of use, reflecting their importance in ensuring accuracy and precision during weaving

activities. Tools such as the hacksaw, fire gun, bending lever, and nail plier were used occasionally, indicating task-specific application. The random orbital sander showed minimal usage (W.M.S. = 1.52), highlighting the limited mechanization and continued reliance on manual craftsmanship in the bamboo and cane weaving process (**Figure 10**).

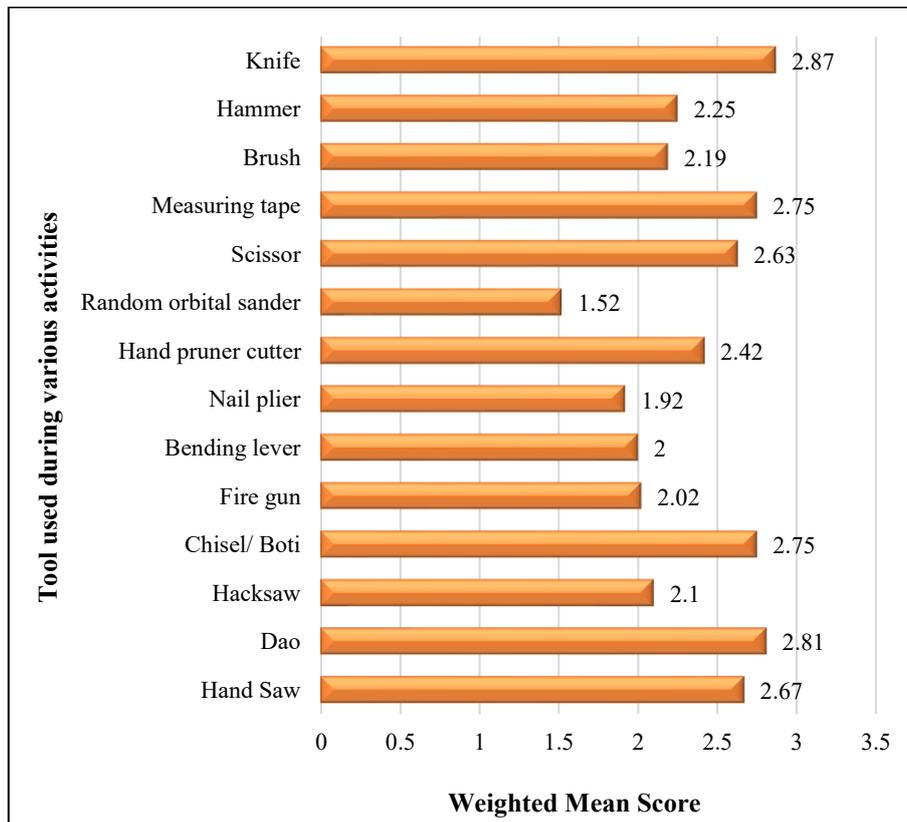


Figure 10: Distribution of the respondents according to tool used

4.3. Posture Analysis, Frequency of Repetition of Task, Time Spent, and Rest Pauses Taken by the Respondents during Bamboo and Cane Weaving Process

4.3.1. Analysis of Postures Adopted by the Respondents during Bamboo and Cane Weaving Process

Observation revealed that bamboo and cane craftsmen adopted squatting, sitting with crossed legs, one leg folded with one leg extended, sitting upright, and one leg crossed with the other in a squatting position, depending on the activity performed. These postures were predominantly floor-based and involved prolonged static loading of the trunk and lower limbs. Rapid Entire Body Assessment (REBA) was conducted on more than 20 per cent of the sample, indicating that most primary postures across all

activities fell under medium to very high-risk categories, necessitating ergonomic intervention as discussed below. During splitting, craftsmen adopted squatting and one leg crossed with one leg squatting postures. REBA analysis showed that a large proportion of respondents across bamboo, cane, and combined weaving groups experienced high ergonomic risk on both left and right sides of the body. High-risk scores were consistently observed among both male and female craftsmen, indicating substantial biomechanical strain during splitting. Stripping was mainly performed in cross-leg sitting, one leg folded with one leg extended, and sitting upright postures. REBA results revealed that cross-leg and one-leg-folded postures were associated with high risk levels, whereas sitting upright generally resulted in medium risk. However, overall, stripping activity imposed considerable ergonomic stress, especially in non-upright postures. Bending activities were performed either in cross-leg sitting (water spray method) or squatting posture (fire gun and lever method). REBA analysis demonstrated cent per cent high-risk scores across all groups, genders, and postures, indicating that bending is the most ergonomically hazardous activity in the bamboo and cane weaving process. Weaving was mainly carried out in cross-leg sitting, one leg folded with one leg extended, and squatting postures. REBA assessment showed that all commonly adopted postures during weaving were associated with high risk levels, irrespective of craft type or gender, due to prolonged static sitting, repetitive upper limb movement, and asymmetric loading. Finishing activities involved cross-leg sitting (sandpaper, varnish, glue) and squatting posture (orbital sander and fire gun use). REBA findings indicated that both postures consistently resulted in high ergonomic risk, highlighting significant musculoskeletal strain during finishing tasks. The findings also revealed that splitting was generally performed once per day by 65–80 per cent of craftsmen, reflecting batch preparation of raw materials. In contrast, stripping, bending, weaving, and finishing were repeated multiple times per day. Weaving and finishing were the most frequently repeated tasks, with 40–60 per cent of respondents performing them more than four times daily, indicating a high repetitive workload and elevated ergonomic risk.

4.3.2. Time Spent, Duration of Adopted Posture, and Rest Pauses Taken

Across all craft groups, weaving emerged as the most time-consuming activity, with craftsmen spending over 2–3 hours per day in sustained postures. The duration of adopted posture accounted for more than 70–80 per cent of total task time, indicating

prolonged static loading. Rest pauses were infrequent and short, typically less than two breaks per activity, lasting approximately 5–10 minutes, which was insufficient for physiological recovery. Overall daily work analysis showed that craftsmen spent 5.6–6.9 hours per day engaged in weaving-related activities, while rest periods remained limited (**Table 3**). The imbalance between prolonged work duration and inadequate rest highlights high cumulative physical strain, underscoring the urgent need for ergonomic workstation design and structured rest interventions.

Table 3: Distribution of the Respondents based on Overall Time Spent on Activity, Duration of Spontaneous Rest Pause taken and Duration of Actual Work Performed in a Day

Sr. No.	Activity	Gender	Total Time Spent on the Task in a Day (hours)	Total Time Spent on the Activity in a Day (min) (A)	Total Duration of Spontaneous Rest Pause in a Day (min) (B)	Total Duration of Actual Work in a Day (min) (A - B)
1.	Bamboo Weaving	Male	6.13±0.92	367.8±55.05	51.5±30.67	316.3±62.53
		Female	6.55±0.69	392.8±41.58	60±21.25	332.8±44.54
2.	Cane Weaving	Male	6.91±0.59	414.8±35.56	51.6±13.16	363.2±29.69
		Female	6.64±0.19	398.2±11.32	66±16.48	332.2±19.36
3.	Both Bamboo and Cane Weaving	Male	5.92±0.42	355.09±25.15	61.09±18.78	294.00±30.17
		Female	5.65±0.46	338.82±27.73	52.64±15.65	286.18±26.24

4.4. Prevalence of Perceived Work-Related Musculoskeletal Discomfort, Hand Discomfort, Exertion, Fatigue, and Physical Injuries by the Respondents engaged in the Bamboo and Cane Weaving Process

4.4.1. Prevalence of Perceived Work-Related Musculoskeletal Discomforts by the Respondents

A. Overall Distribution of the Respondents Based on Frequency of Perceived Musculoskeletal Discomfort (CMDQ Score 0–10)

Table 4 represents the overall frequency of perceived musculoskeletal discomfort among the respondents as follows-

Upper Body Parts: Among bamboo and cane craftsmen, the right and left wrists exhibited the highest CMDQ scores, indicating that these regions were most frequently affected. For bamboo craftsmen, the right wrist recorded the highest

mean score (4.26 ± 2.89), closely followed by the left wrist (4.22 ± 2.90). Similarly, for both bamboo and cane craftsmen, the right and left wrists showed elevated scores of 4.25 ± 2.81 each, reflecting substantial repetitive strain in these joints. Additionally, the right and left forearms also exhibited relatively high CMDQ scores for all groups, with both weaving types scoring 3.90 ± 2.72 (right forearm) and 3.90 ± 2.73 (left forearm), suggesting frequent use and strain during the weaving process. The neck was another commonly affected region, with both weaving types reporting 3.89 ± 2.64 , indicating significant postural stress.

Table 4: Overall Distribution of the Respondents based on Frequency of Perceived Musculoskeletal Discomfort (CMDQ Score 0–10)

Body Part	Bamboo Craftsmen (n=97)	Cane Craftsmen (n=47)	Both Bamboo & Cane Craftsmen (n=116)
UPPER BODY PARTS			
1. Neck	3.80 ± 2.60	3.67 ± 2.72	3.89 ± 2.64
2. Right Shoulder	3.16 ± 2.54	3.41 ± 2.54	3.64 ± 2.66
3. Left Shoulder	3.10 ± 2.58	3.60 ± 2.73	3.69 ± 2.74
4. Right Upper Arm	2.62 ± 2.26	3.19 ± 2.63	3.52 ± 2.70
5. Left Upper Arm	2.83 ± 2.62	3.19 ± 2.67	3.55 ± 2.72
6. Right Forearm	3.53 ± 2.49	3.66 ± 2.71	3.90 ± 2.72
7. Left Forearm	3.53 ± 2.61	3.51 ± 2.76	3.90 ± 2.73
8. Right Wrist	4.26 ± 2.89	3.95 ± 2.82	4.25 ± 2.81
9. Left Wrist	4.22 ± 2.90	3.90 ± 2.84	4.25 ± 2.82
10. Upper Back	3.52 ± 2.60	3.41 ± 2.78	3.81 ± 2.77
LOWER BODY PARTS			
11. Lower Back	3.65 ± 2.54	3.64 ± 2.71	3.94 ± 2.79
12. Hip/Buttock	3.23 ± 2.49	3.45 ± 2.83	3.81 ± 2.86
13. Right Thigh	2.01 ± 2.13	2.36 ± 2.60	2.87 ± 2.77
14. Left Thigh	2.04 ± 2.13	2.43 ± 2.60	2.94 ± 2.84
15. Right Knee	2.94 ± 2.44	3.23 ± 2.66	3.41 ± 2.77
16. Left Knee	2.97 ± 2.43	3.23 ± 2.70	3.53 ± 2.82
17. +Right Lower Leg	2.92 ± 2.56	3.01 ± 2.73	3.35 ± 2.79
18. Left Lower Leg	2.99 ± 2.55	3.19 ± 2.71	3.53 ± 2.90
19. Right Foot	2.63 ± 2.37	2.89 ± 2.77	1.98 ± 2.20
20. Left Foot	2.72 ± 2.50	3.04 ± 2.74	2.09 ± 2.22

Lower Body Parts: In the lower extremities, the lower back consistently displayed the highest CMDQ scores across all weaving categories, with both weaving types showing a mean of 3.94 ± 2.79 , highlighting its susceptibility to prolonged static posture and bending during work. The left and right knees also reported relatively higher discomfort scores, particularly among both weaving types, with the left knee

at 3.53 ± 2.82 and the right knee at 3.41 ± 2.77 , suggesting the impact of sustained kneeling or squatting postures. Similarly, the left lower leg demonstrated elevated scores (3.53 ± 2.90) for respondents involved in both types of weaving. Among the hip and buttock region, both weaving types registered a mean CMDQ score of 3.81 ± 2.86 , indicating frequent musculoskeletal stress due to prolonged sitting and working postures.

B. Overall Distribution of the Respondents Based on Severity of Perceived Musculoskeletal Discomfort (CMDQ Score 1–3)

Table 5 represents the overall severity of perceived musculoskeletal discomfort among the respondents as follows-

Upper Body Parts: Among cane craftsmen, the left and right shoulders displayed the highest severity scores, with the right shoulder registering 2.07 ± 0.73 and the left shoulder 1.90 ± 0.66 . The neck also exhibited elevated severity (2.00 ± 0.71), indicating considerable postural strain in these regions. For respondents engaged in both bamboo and cane weaving, the right shoulder showed the highest severity (2.04 ± 0.68), followed by the left shoulder (1.99 ± 0.65) and the neck (1.92 ± 0.66), suggesting that sustained repetitive motions and awkward postures contributed to moderate discomfort in these areas. Additionally, left and right upper arms also recorded relatively higher severity scores among both weaving groups, with 1.96 ± 0.66 for the right upper arm and 1.92 ± 0.65 for the left upper arm in respondents performing both weaving types.

Lower Body Parts: In the lower body, the left lower leg exhibited the highest severity among cane craftsmen (2.64 ± 1.13), indicating pronounced musculoskeletal strain likely due to prolonged kneeling, squatting, or static postures during weaving. The right thigh also showed relatively higher severity (2.03 ± 0.70) among cane craftsmen, whereas hip/buttock regions reported elevated scores (2.00 ± 0.65) in cane craftsmen and 1.95 ± 0.68 in bamboo craftsmen. For respondents engaged in both weaving types, the lower back emerged as a body part with comparatively higher severity (1.90 ± 0.65), followed by the right foot (1.84 ± 0.67) and left foot (1.87 ± 0.65), reflecting the cumulative impact of prolonged sitting, bending, and static postures.

Table 5: Overall Distribution of the Respondents based on Severity of Perceived Musculoskeletal Discomfort (CMDQ Score 1–3)

Body Part	Bamboo Craftsmen	Cane Craftsmen	Both Bamboo & Cane Craftsmen
UPPER BODY PARTS			
1. Neck	1.91 ± 0.66	2.00 ± 0.71	1.92 ± 0.66
2. Right Shoulder	1.95 ± 0.70	2.07 ± 0.73	2.04 ± 0.68
3. Left Shoulder	1.95 ± 0.67	1.90 ± 0.66	1.99 ± 0.65
4. Right Upper Arm	1.84 ± 0.68	1.95 ± 0.68	1.96 ± 0.66
5. Left Upper Arm	1.84 ± 0.68	2.00 ± 0.65	1.92 ± 0.65
6. Right Forearm	1.84 ± 0.64	1.90 ± 0.70	1.89 ± 0.63
7. Left Forearm	1.76 ± 0.64	1.98 ± 0.72	1.94 ± 0.63
8. Right Wrist	1.97 ± 0.68	1.83 ± 0.65	1.89 ± 0.62
9. Left Wrist	1.90 ± 0.64	1.86 ± 0.63	1.83 ± 0.62
10. Upper Back	1.90 ± 0.68	2.14 ± 0.71	1.90 ± 0.64
LOWER BODY PARTS			
11. Lower Back	1.86 ± 0.67	1.83 ± 0.65	1.90 ± 0.65
12. Hip/Buttock	1.95 ± 0.68	2.00 ± 0.65	1.89 ± 0.63
13. Right Thigh	1.88 ± 0.72	2.03 ± 0.70	1.59 ± 0.65
14. Left Thigh	1.88 ± 0.73	1.88 ± 0.66	1.55 ± 0.64
15. Right Knee	1.81 ± 0.65	2.00 ± 0.69	1.66 ± 0.64
16. Left Knee	1.73 ± 0.62	2.08 ± 0.69	1.62 ± 0.62
17. Right Lower Leg	1.67 ± 0.66	1.97 ± 0.68	1.70 ± 0.65
18. Left Lower Leg	1.70 ± 0.66	2.64 ± 1.13	1.66 ± 0.64
19. Right Foot	1.71 ± 0.66	1.94 ± 0.67	1.84 ± 0.67
20. Left Foot	1.62 ± 0.61	1.84 ± 0.62	1.87 ± 0.65

C. Overall Distribution of the Respondents Based on Extent of Perceived Work Interference (CMDQ Score 1–3)

Table 6 represents the overall extent of perceived work interference due to musculoskeletal discomfort among the respondents as follows-

Upper Body Parts: Among bamboo craftsmen, the right wrist displayed the highest interference (2.06 ± 0.57), followed closely by the neck (2.03 ± 0.51) and the left wrist (2.02 ± 0.55). These results suggest that prolonged repetitive hand movements and awkward postures during weaving contribute significantly to interference in upper limb functions. Similarly, the upper back (2.00 ± 0.54), hip/buttock (2.00 ± 0.54), and left upper arm (1.91 ± 0.54) also exhibited notable interference among bamboo craftsmen. For cane craftsmen, the left lower leg, left foot, left knee, left upper arm, and right wrist all recorded elevated interference scores ($1.95\text{--}1.94 \pm 0.51\text{--}0.52$), indicating that both lower and upper body parts are

affected due to prolonged kneeling, bending, and sustained hand activity during cane weaving. Additionally, the right thigh (1.94 ± 0.50) and right lower leg (1.94 ± 0.51) were also affected, highlighting ergonomic challenges in lower limb postures. Among respondents performing both bamboo and cane weaving, the right foot (2.03 ± 0.61) and left foot (2.00 ± 0.60) were the most prominently affected regions, reflecting cumulative stress on the lower limbs. Other upper body regions such as the right wrist, left wrist, and neck demonstrated moderate interference ($1.94\text{--}1.98 \pm 0.49\text{--}0.51$), suggesting that prolonged repetitive hand and arm movements impacted work efficiency and functional performance.

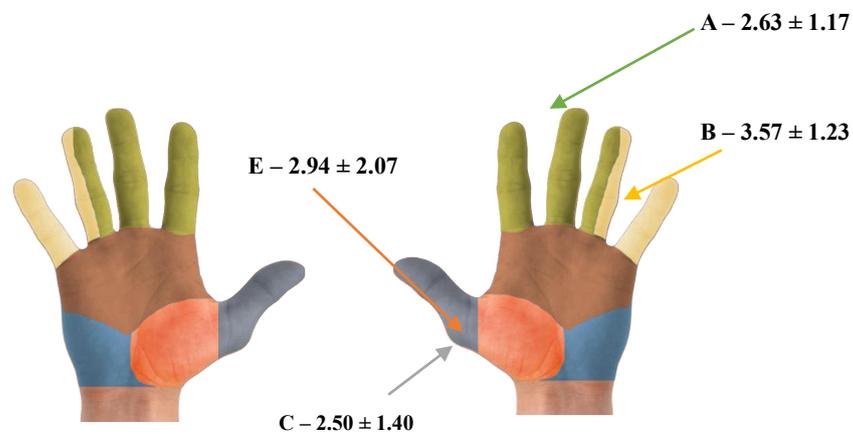
Lower Body Parts: The data indicate that lower body interference is particularly notable among both cane and dual weaving craftsmen. In addition to the feet, the left lower leg (1.95 ± 0.51) and left knee (1.95 ± 0.51) for cane craftsmen also showed significant interference, suggesting that extended periods of kneeling or squatting during weaving tasks impose a higher functional burden.

Table 6: Overall Distribution of the Respondents based on Extent of Perceived Work Interference (CMDQ Score 1–3)

Body Part	Bamboo Craftsmen	Cane Craftsmen	Both Bamboo & Cane Craftsmen
UPPER BODY PARTS			
1. Neck	2.03 ± 0.51	1.95 ± 0.49	1.98 ± 0.51
2. Right Shoulder	1.99 ± 0.54	2.00 ± 0.56	1.97 ± 0.51
3. Left Shoulder	1.99 ± 0.52	1.93 ± 0.50	1.94 ± 0.49
4. Right Upper Arm	1.85 ± 0.56	1.93 ± 0.50	1.93 ± 0.53
5. Left Upper Arm	1.91 ± 0.54	1.95 ± 0.51	1.93 ± 0.52
6. Right Forearm	1.98 ± 0.52	1.95 ± 0.50	1.91 ± 0.48
7. Left Forearm	1.96 ± 0.53	1.98 ± 0.54	1.94 ± 0.51
8. Right Wrist	2.06 ± 0.57	1.95 ± 0.50	1.94 ± 0.50
9. Left Wrist	2.02 ± 0.55	2.00 ± 0.52	1.94 ± 0.49
10. Upper Back	2.00 ± 0.54	1.95 ± 0.51	1.92 ± 0.50
LOWER BODY PARTS			
11. Lower Back	1.99 ± 0.52	1.90 ± 0.47	1.96 ± 0.51
12. Hip/Buttock	2.00 ± 0.54	1.95 ± 0.50	1.93 ± 0.49
13. Right Thigh	1.81 ± 0.56	1.94 ± 0.50	1.84 ± 0.53
14. Left Thigh	1.84 ± 0.55	1.95 ± 0.51	1.86 ± 0.53
15. Right Knee	1.91 ± 0.52	1.93 ± 0.50	1.88 ± 0.50
16. Left Knee	1.89 ± 0.52	1.95 ± 0.51	1.88 ± 0.49
17. Right Lower Leg	1.87 ± 0.52	1.94 ± 0.51	1.91 ± 0.50
18. Left Lower Leg	1.90 ± 0.53	1.95 ± 0.51	1.91 ± 0.50
19. Right Foot	1.82 ± 0.56	1.94 ± 0.51	2.03 ± 0.61
20. Left Foot	1.77 ± 0.51	1.95 ± 0.52	2.00 ± 0.60

4.4.2. Prevalence of Perceived Work-Related Hand Discomforts by the Respondents

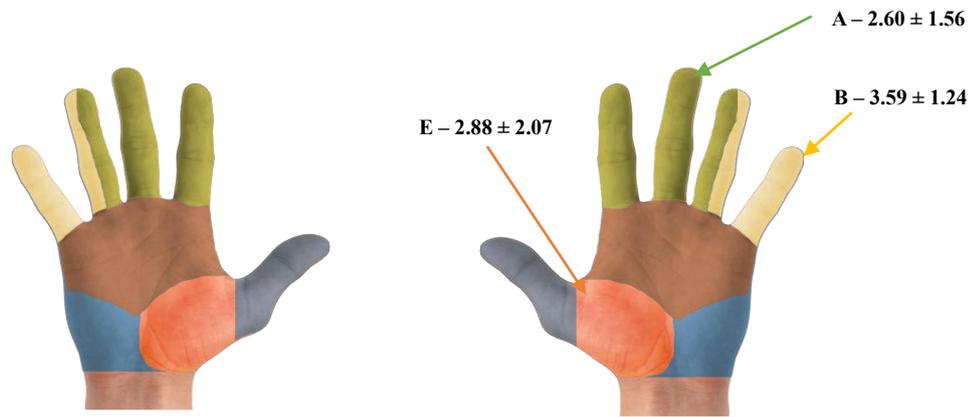
In the bamboo weaving process, the right hand exhibited higher discomfort scores than the left hand across all anatomical regions. The hypothenar eminence (B) recorded the highest discomfort score of 3.57 ± 1.23 , followed by the distal interphalangeal joints (E) at 2.94 ± 1.24 . The left hand's discomfort scores were lower, with the hypothenar eminence (B) at 2.39 ± 0.86 and the distal interphalangeal joints (E) at 2.42 ± 0.89 . These findings suggest that the right hand bears a greater share of the physical load during the bamboo weaving process, potentially due to the dominance of right-hand use in manual tasks. **(Figure 11)**



LEFT HAND		RIGHT HAND
A – 2.15 ± 0.90		A – 2.63 ± 1.17
B – 2.39 ± 0.86		B – 3.57 ± 1.23
C – 2.14 ± 0.83		C – 2.50 ± 1.40
D – 2.04 ± 0.80		D – 2.32 ± 1.34
E – 2.42 ± 0.89		E – 2.94 ± 2.07
F – 1.98 ± 0.79		F – 2.26 ± 1.56

Figure 11: Perceived Hand Discomfort by the Bamboo Craftsmen

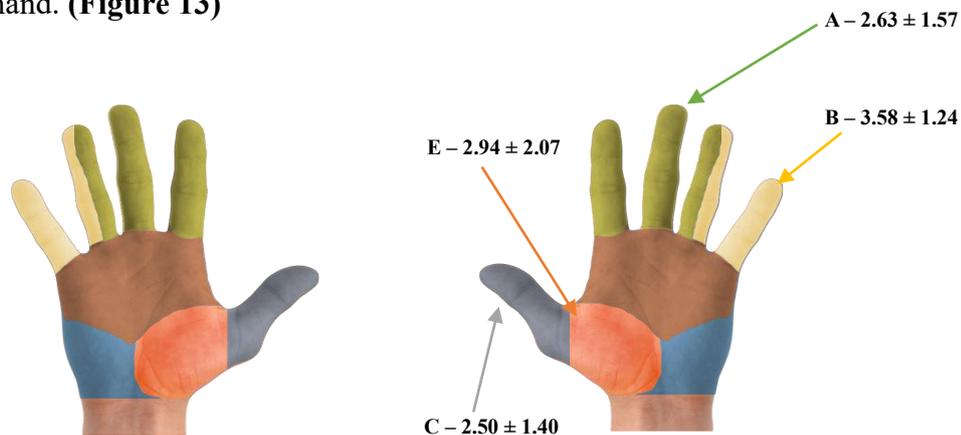
During cane weaving, the discomfort levels in both hands were slightly lower compared to bamboo weaving. The right hand's highest discomfort score was recorded in the hypothenar eminence (B) at 3.59 ± 1.24 , and the left hand's highest score was in the same region at 2.40 ± 0.86 . The distal interphalangeal joints (E) discomfort scores were 2.88 ± 1.23 for the right hand and 2.41 ± 0.89 for the left hand. These results indicate a reduction in discomfort levels in both hands during cane weaving, which may be attributed to differences in the physical demands and techniques employed in cane weaving compared to bamboo weaving. **(Figure 12)**



LEFT HAND		RIGHT HAND	
A	2.14 ± 0.91	A	2.60 ± 1.56
B	2.40 ± 0.86	B	3.59 ± 1.24
C	2.14 ± 0.83	C	2.49 ± 1.40
D	2.04 ± 0.80	D	2.34 ± 1.34
E	2.41 ± 0.89	E	2.88 ± 2.07
F	1.99 ± 0.79	F	2.26 ± 1.57

Figure 12: Perceived Hand Discomfort by the Cane Craftsmen

When combining both bamboo and cane weaving processes, the discomfort levels in the right hand remained the highest across all regions, with the hypothenar eminence (B) at 3.58 ± 1.24 and the distal interphalangeal joints (E) at 2.94 ± 1.24 . The left hand's discomfort scores were slightly lower, with the hypothenar eminence (B) at 2.38 ± 0.86 and the distal interphalangeal joints (E) at 2.41 ± 0.89 . These findings suggest that the cumulative effect of both weaving processes leads to sustained discomfort, particularly in the right hand. (Figure 13)



LEFT HAND		RIGHT HAND	
A	2.16 ± 0.90	A	2.63 ± 1.57
B	2.38 ± 0.86	B	3.58 ± 1.24
C	2.13 ± 0.83	C	2.50 ± 1.40
D	2.03 ± 0.79	D	2.33 ± 1.34
E	2.41 ± 0.89	E	2.94 ± 2.07
F	1.98 ± 0.64	F	2.26 ± 1.58

Figure 13: Overall Perceived Hand Discomfort by the Craftsmen Engaged in Both Bamboo and Cane Weaving Process

Note: Area A-Thenar Eminence, Area B- Hypothenar Eminence, Area C- Metacarpophalangeal Joints, Area D- Proximal Interphalangeal Joints, Area E- Distal Interphalangeal Joints, Area F- Carpal Region

A comparative analysis of discomfort levels across the three weaving processes indicates that bamboo weaving induces the highest discomfort in both hands, followed by cane weaving, with combined weaving resulting in intermediate discomfort levels. The right hand consistently reported higher discomfort scores than the left hand across all regions and weaving processes. This pattern aligns with previous study by Pawar et al. (2022), which reported significant discomfort in the palm and fingers among bamboo craftsmen in North Karnataka.

4.4.3. Perceived Exertion by the Respondents

Figure 14 depicts the perceived exertion levels of bamboo, cane, and combined bamboo–cane craftsmen during major weaving activities using the Borg CR-10 scale. Across all categories, splitting emerged as the most physically demanding activity, followed by stripping and bending, while weaving and finishing required comparatively lower exertion. Among bamboo craftsmen, splitting recorded a very strong exertion level (WMS = 6.9), with a high proportion reporting strong to very strong effort due to repetitive forceful cutting and sustained grip. Stripping also reflected strong exertion (WMS = 5.7), associated with continuous wrist and thumb movements. Bending showed moderately strong exertion (WMS = 5.3), whereas weaving (WMS = 4.5) and finishing (WMS = 3.6) were categorized under moderate exertion, though prolonged static postures contributed to cumulative fatigue. Cane craftsmen similarly perceived splitting as the most strenuous task (WMS = 6.6), attributed to the denser nature of cane material requiring greater cutting force. Stripping and bending reflected strong to moderate exertion levels (WMS = 5.3 and 5.0), while weaving (WMS = 4.3) and finishing (WMS = 3.5) involved moderate exertion with notable postural strain. Among craftsmen engaged in both bamboo and cane weaving, splitting again showed very strong exertion (WMS = 6.8), with reports extending to extremely strong effort. Stripping (WMS = 5.8) and bending (WMS = 5.4) were rated as strong exertion, while weaving (WMS = 4.6) and finishing (WMS = 3.8) remained within the moderate range.

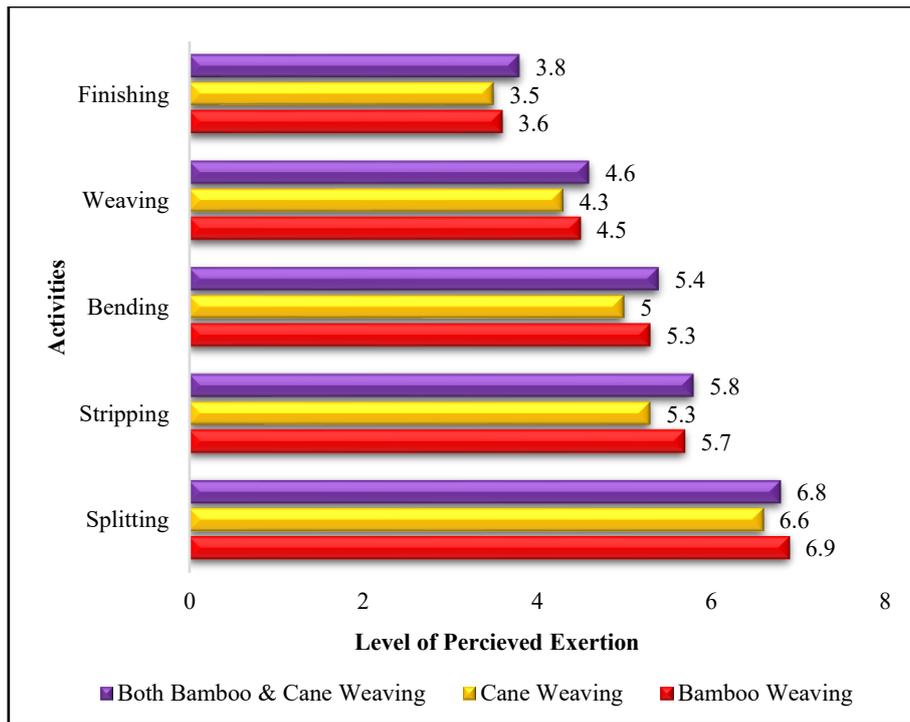


Figure 14: Distribution of the Respondents according to their Level of Perceived Exertion during Various Activities

Overall analysis (Table 38) revealed splitting as the most strenuous activity (WMS = 6.7), followed by stripping (WMS = 5.6) and bending (WMS = 5.1). Weaving (WMS = 4.3) and finishing (WMS = 3.5) involved lower exertion but contributed to cumulative musculoskeletal strain due to repetitive fine motor activity and prolonged sitting.

4.4.4. Perceived Fatigue by the Respondents

Figure 15 illustrates fatigue levels across five MFI-20 domains. General fatigue was highest among bamboo craftsmen (WMS = 3.6), followed by combined craftsmen (3.5) and cane craftsmen (3.4). Physical fatigue emerged as the most prominent dimension across all groups (WMS = 3.6–3.7), reflecting repetitive muscular activity, static working postures, and prolonged work duration. Mental fatigue showed moderate levels (WMS = 3.2–3.4), linked to sustained attention and precision during weaving. Reduced activity and reduced motivation also recorded moderate scores (WMS = 2.9–3.4), indicating cumulative occupational fatigue. Overall, physical fatigue predominated, emphasizing the need for ergonomic interventions, task variation, and scheduled rest breaks.

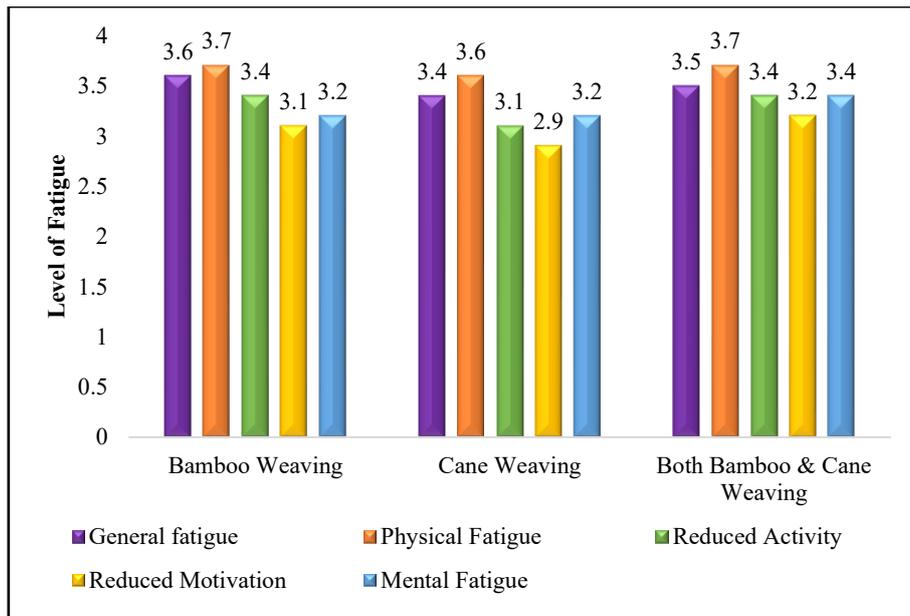


Figure 15: Distribution of Respondents According to the Multidimensional Fatigue Inventory (MFI-20) Score during Bamboo and Cane Weaving Process

4.4.5. Physical Injuries Encountered by the Respondent

Figure 16 reveals a high prevalence of work-related physical injuries among the respondents. Splinters embedded in the skin were the most commonly reported injury (88.5%), followed by cuts on fingers, hands, or arms (84.6%) and lacerations (75.0%), primarily due to manual handling of raw materials and sharp tools. Puncture wounds (64.6%) and pinch injuries (54.6%) were also frequently reported, indicating repeated exposure to sharp implements and manual weaving processes. Eye injuries affected 37.7% of respondents, mainly due to airborne particles and lack of protective gear, while slip and fall injuries were reported by 32.7%, largely due to cluttered workspaces.

Lower but notable incidences were recorded for piercing injuries (46.2%), twist or torque injuries (28.5%), crush injuries (25.0%), and skin burns (21.5%), associated with heavy material handling and heat-assisted bending. Bamboo craftsmen reported comparatively higher injury prevalence across most categories. The total of 1,453 multiple responses indicates frequent exposure to multiple occupational hazards, underscoring the need for improved safety measures, ergonomic tools, and organized work environments.

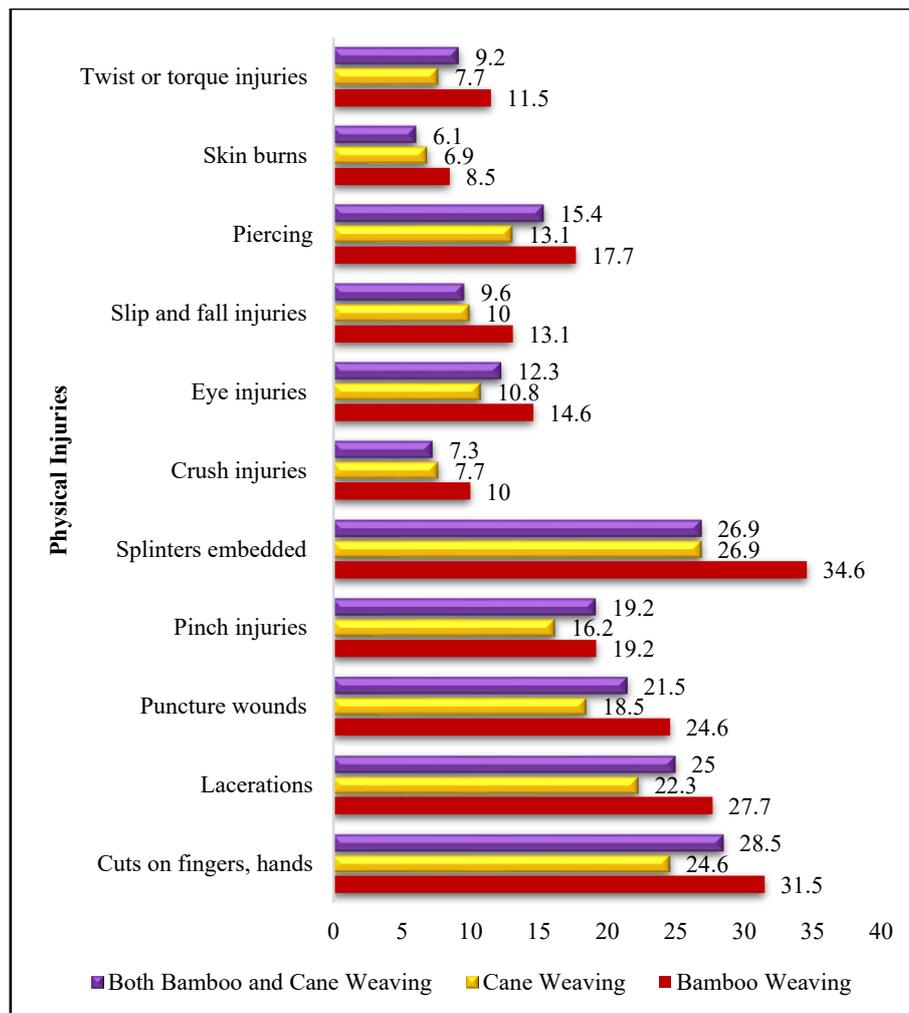


Figure 16: Distribution of Respondents according to Physical Injuries Encountered during Bamboo and Cane Weaving Process

4.5. Testing of Hypotheses

This section systematically describes the statistical procedures adopted for testing the hypotheses of the present study. The relational statistical analyses employed comprised the Chi-square test, Spearman’s Rank Correlation Coefficient, and One-way Analysis of Variance (ANOVA).

- For H_{01} , sub-hypotheses were formulated-
 - For $H_{01.1}$, the chi-square test results indicated that time spent on weaving did not differ significantly with respect to the personal variables age and gender, while a significant association was observed with work experience. The craftsmen with 2–15 years of experience contributed significantly to the association, as their Z-value exceeded the critical value of ± 1.96 . Thus, $H_{01.1}$ was partially accepted.

- For **H_{01.2}**, the chi-square test results indicated that the frequency of task repetition did not differ significantly with the personal variables age, gender, and work experience. Thus, **H_{01.2}** was accepted.
- For **H_{01.3}**, the chi-square test results indicated that the type of posture adopted during bamboo and cane weaving differed significantly with respect to age, while no significant variation was observed with gender and work experience. The post-hoc analysis using adjusted residuals (*Z*-score) revealed that squatting was the most frequently adopted posture among craftsmen aged 20–35 years, as the adjusted residual value (+2.34) exceeded the critical value of ±1.96. Thus, **H_{01.3}** was partially rejected.
- For **H₀₂**, sub-hypotheses were formulated-
 - For **H_{02.1}**, the Spearman’s rank-order correlation results indicated that perceived musculoskeletal discomfort and duration of maintaining the adopted posture differed significantly with respect to time spent on weaving activities. A significant positive relationship was observed between time spent on weaving and both musculoskeletal discomfort and duration of posture maintenance. Thus, **H_{02.1}** was rejected.
 - For **H_{02.2}**, the Spearman’s rank-order correlation results indicated that perceived musculoskeletal discomfort and duration of maintaining the adopted posture differed significantly with respect to the frequency of task repetition. A significant positive relationship was observed between the frequency of task repetition and both musculoskeletal discomfort and duration of posture maintenance. Thus, **H_{02.2}** was rejected.
 - For **H_{02.3}**, the one-way ANOVA results indicated that perceived musculoskeletal discomfort and duration of maintaining the adopted posture differed significantly with respect to the type of posture adopted. The *F*-ratio for type of posture was found to be significant for both musculoskeletal discomfort and duration of posture maintenance. The Tukey HSD post hoc test further revealed statistically significant mean differences between squatting posture and the other postures ($p < 0.05$), while no significant differences were observed among the remaining postural combinations. Thus, **H_{02.3}** was rejected.
 - For **H_{02.4}**, the one-way ANOVA results indicated that perceived musculoskeletal discomfort and duration of maintaining the adopted posture did not differ

significantly with respect to the type of tools used during craft activities, as the F-value was not significant at the 0.05 level. Thus, $H_{02.4}$ was accepted.

- For $H_{02.5}$, the chi-square test results indicated that perceived musculoskeletal discomfort and duration of maintaining the adopted posture differed significantly with respect to the workspace sitting arrangement. The post-hoc analysis using adjusted residuals (Z-score) revealed that craftsmen working on the floor showed a significant positive deviation from the expected frequency for both musculoskeletal discomfort ($Z = 2.10$) and duration of maintaining posture ($Z = 1.97$), as the values exceeded the critical limit of ± 1.96 . The other categories, namely Pidha, Murha, and Bench, showed no significant deviations. Thus, $H_{02.5}$ was rejected.
- For H_{03} , the chi-square test results indicated that the duration of maintaining the adopted posture did not differ significantly with respect to the personal variables age, gender, and work experience, as the Chi-square value was not significant at the 0.05 level. Thus, H_{03} was accepted.
- For H_{04} , the chi-square test results indicated that the extent of physical injuries did not differ significantly with respect to the type of tools used, whereas a significant association was observed with the workspace sitting arrangement. The post-hoc analysis using adjusted residuals (Z-score) revealed that floor sitting showed a significant positive deviation ($Z = 2.11$), while bench sitting exhibited a significant negative deviation ($Z = -2.37$). The categories Pidha and Murha showed no significant deviations. Thus, H_{04} was partially rejected.

4.6. Designing and Development of a Need-based Ergonomic Workstation for the Respondents

The present section focuses on the development of a need-based ergonomic workstation for bamboo and cane weaving craftsmen, based on assessment of anthropometric measurements, work posture analysis, and task requirements. The design process was carried out in three systematic phases as follows: **Phase I:** Assessment of Anthropometric Measurements of the Respondents, which involved evaluating the physical dimensions of the craftsmen to understand their ergonomic needs; **Phase II:** Designing of Need-Based Ergonomic Workstation, which focused

on conceptualizing the workstation based on anthropometric data, work tasks, and artisans' feedback; and **Phase III:** Development of Prototype of Need-Based Ergonomic Workstation and Cost Estimation, which included the fabrication, implementation, and evaluation of the workstation prototype to ensure it met the functional and ergonomic requirements of the craftsmen while also estimating the associated costs.



Figure 17: 3-D Side Elevation of the Workstation at Standard Sitting Height (Height-1)



Figure 18: 3-D Side Elevation Of The Workstation at Medium Sitting Height (Height-2)



Figure 19: 3-D Side Elevation of the Workstation at Low Sitting Height (Height-3)

A user manual was also developed for the need-based ergonomic workstation designed for Bamboo and Cane weaving craftsmen. The manual was prepared in both English and Assamese languages to ensure better comprehension and practical applicability among the respondents. It provided a detailed description of the features of the workstation, including the ergonomically designed table and chair. The specifications related to dimensions, height, structural components, material used, and functional aspects were systematically presented. The manual clearly explained the ergonomic features of the table, such as appropriate working height, adequate work space, provision for tool placement, and stability.

Similarly, the features of the chair, including proper seat height, supportive backrest, and posture-alignment design, were described to facilitate correct sitting posture. Illustrations and labelled diagrams were incorporated to enhance clarity and ensure proper utilization of the workstation. The manual aimed to promote correct usage, improve comfort, reduce musculoskeletal strain, and enhance productivity among the craftsmen during weaving activities

4.7. Feedback of the Respondents on Comfort Level of the Developed Need-based Ergonomic Workstation

The developed need-based ergonomic workstation was evaluated to assess its effectiveness in improving comfort, posture, and work efficiency among bamboo and cane weaving craftsmen. The workstation was designed based on anthropometric and ergonomic principles and incorporated adjustable height options suitable for both normal sitting and traditional low-sitting postures. Integrated features included a fitted cutter machine for splitting, tool-storage provisions within the table and chair, bending log support, a dedicated space for fire gun use during finishing, and a back-supported chair. The entire workstation was constructed using bamboo and cane, ensuring sustainability, cultural acceptability, and ease of local replication.

A trial implementation was conducted among a sub-sample of craftsmen, who used the workstation for one week while performing all major weaving activities, namely splitting, stripping, bending, weaving, and finishing. Feedback was collected using a structured schedule focusing on improvement in comfort and reduction of fatigue, ease of use and posture maintenance, and improvement in efficiency across work activities. The feedback analysis revealed a high level of user satisfaction across all parameters. With respect to comfort and fatigue reduction, the highest weighted mean score was recorded for “helped reduce fatigue and discomfort” (W.M.S. = 4.52), followed closely by “made work more comfortable” (W.M.S. = 4.48). These findings indicate that ergonomic features such as adjustable height, supportive seating, and optimized work surface design effectively minimized postural strain and muscular fatigue during prolonged and repetitive work. In terms of ease of use and posture maintenance, the parameter “helped maintain better posture” achieved a high weighted mean score (W.M.S. = 4.46), reflecting improved spinal alignment and reduced forward bending during weaving tasks. The parameter “easy to use and fit in workspace” recorded a W.M.S. of 4.21, indicating that the workstation was well accepted within the existing work environment despite minor spatial adjustments. Regarding efficiency across work activities, respondents reported notable improvements in bending (W.M.S. = 4.44), weaving (W.M.S. = 4.39), stripping (W.M.S. = 4.35), splitting (W.M.S. = 4.32), and finishing (W.M.S. = 4.28). The bending log support facilitated controlled bending and reduced strain on the lower back and upper limbs, while integrated tool storage and fixed placement of the cutter

machine and fire gun improved workflow continuity and reduced unnecessary movements. Overall, all feedback parameters recorded weighted mean scores above 4.20, demonstrating a high degree of comfort, usability, and effectiveness of the developed workstation. The findings validate that the integration of ergonomic design principles with indigenous materials significantly enhances comfort, posture, and work efficiency among bamboo and cane weaving craftsmen. The positive user response confirms the suitability of the developed workstation as a sustainable ergonomic intervention for improving occupational health and productivity in traditional craft practices.

4.8. Development of Informative Pamphlet on Coping Strategies for prevention of Musculoskeletal discomfort and Physical Injuries experienced by the respondents at workplace

4.8.1. Coping Strategies for prevention of Musculoskeletal discomfort and Physical Injuries experienced by the respondents at workplace

The occupational activities involved in bamboo and cane weaving require craftsmen to adopt static and often awkward postures for extended durations. Activities such as splitting, stripping, bending, weaving, and finishing demand repetitive hand movements, prolonged squatting or cross-legged sitting, and frequent bending of the trunk. As per the suggestions from ergonomic expert, physiotherapists and architectural designer, the following coping strategies were suggested to the Bamboo and Cane Weaving Craftsmen to improve posture, minimize mechanical injuries, and enhance musculoskeletal health:

- i. Ergonomic Seating with Popliteal Support:** An adjustable cushion seat (30–40 cm height) with lumbar backrest (95°–105° inclination) and 5–8 cm popliteal support was recommended to maintain neutral spine alignment and improve lower limb circulation. This design reduces lumbar strain, nerve compression, and discomfort during prolonged sitting or squatting.
- ii. Anti-Fatigue Mats and Floor Support:** Non-slip thermoplastic or rubber mats (1–3 cm thickness; minimum 120 × 60 cm) were suggested for floor-based tasks. These mats reduce localized pressure on knees and heels, thereby minimizing fatigue and micro-trauma.

- iii. **Adjustable Work Surfaces:** A raised platform of at least 10 inches with 10°–15° tilt and a surface area of 3 × 2 feet was recommended. Proper work height and reach distance help prevent trunk bending, overreaching, and cumulative musculoskeletal strain.
- iv. **Anti-Slip Grip Tools:** Tools with textured rubber handles (2.5–4 cm diameter) and contoured grips were advised to enhance grip efficiency. These features reduce excessive hand force, forearm fatigue, and slippage-related injuries.
- v. **Cut-Resistant Gloves:** Gloves made of HPPE or Kevlar (0.5–0.8 mm thickness) extending 2–3 cm beyond the wrist were recommended. They protect lacerations while maintaining tactile sensitivity and dexterity.
- vi. **Repetitive Motion Management:** Alternating use of dominant and non-dominant hands was suggested to balance muscular load. This practice reduces the risk of repetitive strain injuries such as tendonitis and carpal tunnel syndrome.
- vii. **Scheduled Micro-Breaks:** Short breaks of 2–5 minutes after every 30–45 minutes of work were advised. These intervals allow muscle relaxation, improve circulation, and reduce cumulative fatigue.
- viii. **Targeted Stretching and Mobility Exercises:** Exercises including wrist flexion-extension (10–15 repetitions), shoulder rolls, and knee–ankle rotations were recommended. These movements enhance flexibility, reduce stiffness, and promote musculoskeletal recovery.
- ix. **Task Rotation:** Alternating high-intensity tasks with low-intensity activities every 45–60 minutes was recommended. Task rotation distributes physical load across muscle groups and prevents localized fatigue.
- x. **Hand and Foot Exercises:** Regular stretching of hands and ankles was encouraged to maintain flexibility and circulation. These exercises help in minimizing discomfort and long-term musculoskeletal risk.
- xi. **Elevation of Foot During Work:** Use of a small footrest or stool was advised to elevate the lower limb during seated work. This reduces lower body discomfort and enhances blood circulation.
- xii. **Neutral Spine and Trunk Alignment:** Maintaining trunk flexion below 30° and hip–knee flexion between 90°–110° was emphasized. Lumbar rolls (10–12 cm thickness) were recommended to support spinal alignment.

- xiii.** Ergonomic Education Workshops: Periodic training sessions by ergonomists and physiotherapists were suggested. These workshops focus on posture correction, safe tool handling, and early identification of MSD symptoms.
- xiv.** Environmental and Safety Measures: Optimal lighting (300–500 lux) and tool placement within 50–60 cm reach was recommended to reduce trunk flexion and overreaching. Supportive footwear or anti-fatigue mats further enhance safety and stability.

An informative pamphlet proposing coping strategies for Bamboo and Cane weaving craftsmen was developed as part of the present investigation. The pamphlet was prepared in both English and Assamese languages to ensure clarity, accessibility, and better comprehension among the respondents. It incorporated practical ergonomic recommendations, safe work practices, posture modification techniques, the importance of periodic rest breaks, appropriate workspace arrangements, and preventive measures to reduce musculoskeletal discomfort and physical injuries. The content was designed in a simple, illustrated, and user-friendly format to facilitate effective communication of health and safety measures. The developed pamphlet was subsequently distributed among the selected respondents to enhance awareness and promote healthier and safer work practices in their craft activities.

4.8.2. Recommendations for the North Eastern Handicrafts and Handlooms Development Corporation Ltd. (NEHHDC)

- i.** Institutional Support for Ergonomic Workstations: NEHHDC may facilitate subsidized provision of ergonomic seating, raised platforms, and adjustable work surfaces. Such support would directly reduce postural strain and musculoskeletal disorders.
- ii.** Provision of Low-Cost Ergonomic Aids: Distribution of anti-fatigue mats, lumbar cushions, footrests, and grip attachments is recommended. These low-cost aids can significantly improve comfort and reduce lower limb and spinal fatigue.
- iii.** Strengthening Occupational Safety Measures: Regular access to cut-resistant gloves and non-slip supports should be ensured. Inclusion of protective

equipment in craft schemes would enhance safety without affecting productivity.

- iv. **Ergonomic Awareness and Training Programmes:** Periodic capacity-building programmes in collaboration with experts are recommended. Training should emphasize posture correction, work–rest cycles, and fatigue management.
- v. **Dissemination of Informative Materials:** Adoption and distribution of evidence-based pamphlets and visual manuals in local languages is suggested. Field demonstrations would improve understanding and practical implementation.
- vi. **Integration of Ergonomics in Skill Development:** Ergonomic principles should be embedded within skill training modules. Early integration ensures sustained adoption of health-conscious work practices.
- vii. **Periodic Health Screening:** Organization of musculoskeletal health camps in collaboration with healthcare professionals is recommended. Early detection and timely intervention would reduce disability and productivity loss.
- viii. **Promotion of Work Organization Strategies:** Guidelines encouraging task rotation and micro-breaks should be circulated. These strategies help distribute workload and minimize cumulative trauma.
- ix. **Support for Prototype Development:** NEHHDC may encourage development and field validation of low-cost ergonomic workstation prototypes. Participatory design involving craftsmen would enhance acceptability and sustainability.
- x. **Inclusion of Occupational Health in Welfare Schemes:** Ergonomic aids and safety equipment may be integrated into existing welfare initiatives. This would ensure comprehensive occupational health support for registered craftsmen.
- xi. **Monitoring and Evaluation Mechanisms:** A structured framework to periodically assess health outcomes and workstation effectiveness is recommended. Continuous evaluation would support policy refinement and scaling up.
- xii. **Collaboration with Academic Institutions:** Partnerships with research and academic bodies are encouraged for updating ergonomic standards. Such collaboration would promote evidence-based, context-specific interventions in the craft sector.

5. CONCLUSION

The present study was undertaken with the dual objectives of assessing the extent of perceived musculoskeletal discomfort among craftsmen engaged in bamboo and cane weaving in Assam and developing a scientifically informed, need-based ergonomic workstation to alleviate work-related discomfort and occupational injuries. Bamboo and cane weaving, as traditional craft activities, require prolonged static postures, repetitive hand movements, and sustained physical effort, exposing craftsmen to significant ergonomic risks and physical strain.

The research comprehensively examined personal, situational, and occupational factors influencing work practices, postural load, fatigue, musculoskeletal discomfort, and injury prevalence. The demographic analysis revealed that bamboo and cane weaving is predominantly practiced by middle-aged craftsmen, with a balanced representation of both males and females, reflecting inclusivity within these traditional occupations. Respondents exhibited diverse educational backgrounds, ranging from secondary to graduate-level education, while work experience varied from 2 to 41 years, averaging 15.42 years. On average, craftsmen worked 7.5 hours daily, producing between 20 and 68 items per month. Most craftsmen operated in informal, non-standardized workspaces within homes or small community workshops, relying primarily on manual tools such as knives, Dao, chisels, hand saws, and measuring tapes, indicating limited mechanization and heavy dependence on manual dexterity. Workspace arrangements varied, including floor sitting, low wooden stools (Pidha), bamboo stools (Murha), and benches, with seating type directly influencing postural load and overall ergonomic risk.

Detailed postural analysis revealed that craftsmen frequently adopted static and constrained postures, including squatting, crossed-leg sitting, one-leg-folded, and upright positions, often maintained for 70–80% of the task duration. Task repetition, particularly during weaving and finishing operations, was high, while rest breaks were brief or irregular, contributing to sustained physical load and elevated ergonomic risk. Perceived musculoskeletal discomfort was widespread, affecting both upper and lower body regions, with wrists, forearms, neck, and lower back most commonly affected. Hand discomfort was particularly pronounced in the dominant right hand, especially in the hypothenar eminence and distal interphalangeal joints, highlighting the strain associated with repetitive manual movements. Tasks such as splitting, stripping, and bending were

perceived as highly demanding, while weaving and finishing required moderate yet sustained effort. Fatigue assessment revealed high physical fatigue, accompanied by moderate mental fatigue, reduced activity levels, and diminished motivation, further underscoring the occupational challenges faced by craftsmen. Physical injuries were frequent, including splinters, cuts, lacerations, punctures, and pinch injuries, illustrating the hazardous nature of traditional weaving practices.

To systematically examine the influence of personal, situational, and occupational variables on work practices, musculoskeletal discomfort, and injury prevalence, four key hypotheses were tested. Hypothesis testing indicated that the time spent on weaving varied significantly with work experience, while posture type was influenced by age, with younger craftsmen predominantly adopting squatting postures, leading to partial acceptance of H01. Musculoskeletal discomfort and duration of posture were significantly associated with time spent, task repetition, posture type, and workspace arrangement, although no significant relationship was found with the tools used, resulting in partial support for H02. H03 was accepted, indicating that duration of maintaining posture did not vary significantly with personal factors. H04 was partially accepted, with workspace arrangement influencing injury prevalence, while tools had no significant effect. These findings emphasize that ergonomic risk and occupational health are multifactorially determined by task demands, posture, and work environment, rather than tools alone. In response to these findings, a need-based ergonomic workstation was designed and developed using locally available bamboo and cane materials. The design process was executed in three sequential phases. Phase I involved recording anthropometric measurements of 260 craftsmen to determine critical dimensions such as seating height, limb clearance, reach, and overall workspace requirements. Phase II focused on conceptualizing and designing a workstation with multiple height configurations, adjustable work surfaces with 10°–15° tilt, tool storage compartments, cutter machine slots, bending support, task-specific lighting, and height-adjustable chairs to accommodate traditional postures while improving comfort and efficiency. Phase III involved fabrication of a functional prototype, evaluated by 20% of respondents, with a total cost of ₹30,000, demonstrating practical feasibility, cost-efficiency, and sustainability. The prototype successfully integrated ergonomic principles while preserving the cultural and functional aspects of traditional weaving practices.

A one-week trial with 12 craftsmen demonstrated high satisfaction, with weighted mean scores exceeding 4.20 across comfort, posture maintenance, and task efficiency parameters. Respondents reported significant reduction in fatigue, improved posture, and enhanced efficiency in bending, weaving, stripping, splitting, and finishing tasks. In addition, an informative pamphlet was developed in English and Assamese to promote coping strategies for reducing musculoskeletal discomfort and preventing physical injuries. The strategies included ergonomic seating with lumbar and popliteal support, anti-fatigue mats, adjustable work surfaces, anti-slip tools, cut-resistant gloves, scheduled micro-breaks, stretching exercises, task rotation, and environmental safety measures such as proper lighting. Recommendations for the North Eastern Handicrafts and Handlooms Development Corporation Ltd. were also proposed, including support for ergonomic workstation implementation, provision of personal protective equipment, integration of ergonomic principles into skill development programs, periodic health screening, and ongoing monitoring and evaluation of interventions.

6. IMPLICATIONS AND RECOMMENDATIONS

6.1. Implications of the Study

The findings of the present research have significant academic, practical, and policy-oriented implications, particularly in the domains of ergonomics, occupational health, interior design, and traditional craft sustainability as follows-

a. For Bamboo and Cane Weaving Craftsmen (Unorganized Sector)

The study highlights the high prevalence of work-related musculoskeletal discomfort, fatigue, and physical injuries among bamboo and cane weaving craftsmen, primarily arising from prolonged static postures, repetitive movements, and inadequately designed workspaces. The findings imply that the adoption of ergonomically improved workstations, appropriate tools, and posture-corrective practices can significantly enhance physical comfort, reduce occupational health risks, and promote long-term work sustainability. Increased ergonomic awareness among craftsmen may also contribute to improved productivity and reduced work-related absenteeism.

b. For Product Designers and Workstation Designers

The research offers empirically grounded guidelines for the design of need-based, ergonomically appropriate workstations suited to traditional bamboo and cane

weaving activities. It emphasizes the importance of user-centered design approaches that integrate anthropometric considerations, cultural work practices, and the use of locally available materials. The study demonstrates that ergonomically informed design interventions can effectively address postural constraints while maintaining cultural relevance and economic feasibility, thereby improving occupational well-being without disrupting traditional craft processes.

c. For Policymakers, Government Agencies, and Welfare Organizations

The study provides evidence-based insights that can inform the formulation and implementation of policies aimed at improving occupational health conditions within the unorganized craft sector. The findings underscore the need to integrate ergonomic standards into existing artisan welfare schemes, skill development programs, and infrastructure support initiatives implemented by government bodies such as the North Eastern Handicrafts and Handloom Development Corporation (NEHHDC). Incorporating ergonomics into policy frameworks can enhance the effectiveness of craft development initiatives while safeguarding the health and well-being of craftsmen.

d. For Academic Institutions and Researchers

The research contributes meaningfully to the existing body of knowledge in ergonomics, occupational health, and interior design, with particular relevance to the discipline of Family and Community Resource Management. It establishes a methodological and conceptual foundation for future studies across other traditional handicraft sectors and encourages interdisciplinary research integrating ergonomics, design, and sustainability. The study also offers scope for comparative research and longitudinal evaluations of ergonomic interventions in craft-based occupations.

e. For the Department of Family and Community Resource Management

The findings of the study hold specific relevance for students and scholars of the Department of Family and Community Resource Management, where Interior Design and Ergonomics constitute key areas of specialization at both graduate and postgraduate levels. The research provides real-world insights into occupational health challenges faced by craftsmen, enabling students to develop a critical understanding of traditional work environments. By linking theoretical ergonomic principles with field-based evidence, the study supports experiential learning and

enhances students' capacity to apply ergonomics in sustainable workstation design and community-oriented interventions.

f. Implications for Sustainable Development and Craft-Based Industries

The study reinforces the role of ergonomics as a vital component in promoting sustainable livelihoods, preserving traditional craft practices, and improving the quality of work life of craftsmen. The findings support the integration of health-focused and ergonomically informed design strategies within craft-based production systems, thereby contributing to inclusive development and long-term sustainability. In this context, the research aligns with broader national and global development goals related to decent work, occupational health, and sustainable industrial practices.

6.2. Recommendations for Future Studies

- a. A study can be conducted to evaluate the long-term impact of ergonomic workstation designs on reducing musculoskeletal disorders among bamboo and cane weaving craftsmen.
- b. A comparative study can be undertaken to analyse traditional floor-based working postures versus ergonomically improved seating and table arrangements across different age groups of craftsmen.
- c. A similar study can be designed to redesign and test ergonomic hand tools (cutting knives, splitters, slicers) aimed at minimising repetitive strain and enhancing productivity.
- d. A cross-sectional study can be carried out to examine psychosocial variables such as stress, income insecurity, and workload pressure and their influence on craftsmen's health and performance.
- e. A study can be planned to assess the respiratory health impact of bamboo dust exposure and identify safer, dust-free processing alternatives.
- f. A similar study can investigate the effectiveness of sustainable and eco-friendly preservatives, dyes, and finishing materials in reducing chemical exposure among craftsmen.
- g. A comparative study can explore the ergonomic challenges faced by women artisans and ageing craftsmen engaged in bamboo and cane weaving.

- h.** A cross-state comparative study can be initiated to evaluate ergonomic issues, work patterns, and health outcomes among bamboo artisans from Tripura, Manipur, Karnataka, and Tamil Nadu.
- i.** A policy-focused study can be executed to assess the implementation and impact of initiatives such as the Assam Bamboo & Cane Policy (2019), the National Bamboo Mission, and NEHHDC programmes on craftsmen's welfare.
- j.** A longitudinal study can be carried out to track changes in musculoskeletal discomfort and productivity after the introduction of ergonomic interventions.
- k.** An experimental study can be designed to test workstation heights, tool angles, and seating styles to identify biomechanically efficient combinations for artisans.
- l.** A qualitative study can be undertaken to document the lived experiences of craftsmen regarding pain, fatigue, occupational challenges, and coping mechanisms.
- m.** A participatory design study can be implemented in which craftsmen collaborate in co-creating ergonomic workstation solutions suited to their cultural and work practices.
- n.** A technological adoption study can explore the feasibility, acceptance, and impact of integrating semi-mechanized tools, digital design aids, or assistive technologies into the craft process.
- o.** A market-oriented study can be conducted to examine how improved ergonomics and reduced fatigue influence product quality, market competitiveness, and income levels for artisans.

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