Impact of Illumination, Noise and Thermal Environment on Occupational Health of Handloom Weavers in Assam: An Ergonomics Perspective

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Impact of Illumination, Noise and Thermal Environment on Occupational Health of Handloom Weavers in Assam: An Ergonomics Perspective

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Abstract: The impact of physical environment (illumination, noise, and thermal environment) on handloom weavers' health and performance is under-reported. Current research aims to assess environmental variables and provide mitigation strategies to improve working conditions. Prevailing levels of environmental variables were measured, and questionnaires were administered to determine their impact on weavers' occupational health and performance involving weavers (30 females and 6 males) residing in Sualkuchi, Assam, India. It was observed that inadequate illumination (101.13 $\pm$ 60.95 Lux) inside handlooms led to visual discomfort, while high noise level (90.87 $\pm$ 2.53 dBA) negatively impacted their occupational health, particularly the shifting of the hearing threshold. The installation of LED bulbs provided recommended illumination in the looms. Survey revealed that the majority (90%) of the weavers were dissatisfied with the existing thermal environment in summer. Mitigation strategies have been proposed to ameliorate the negative impact of the predominant indoor handloom environments.

Keywords: audiometry, Environmental ergonomics, Illumination, noise, occupational health, thermal comfort

1. Introduction

In most developing countries, economic transformation from agricultural to industrial plays a strategic role in overall development. The handloom industry possesses significant importance in generating local employment. In India, the handloom sector is the largest source of employment after agriculture, with 85% (3.9 million of 4.6 million) of the world's installed handloom capacity [1,2]. Handloom products are not only textiles; they hold a significant cultural artefact, reflecting the heritage and identity of their regions. Most of the weavers in India are based in small towns and villages, and their skills are transferred from one generation to the next, like handicrafts [3,4]. Around 23.77 lakh looms and more than 3 million people are employed in direct or allied activities of handloom [5].

Today's consumers are becoming more and more mindful of their choices, opting for handloom products to reduce their carbon footprint. The global handloom industry is increasing continuously, with its market value estimated at USD 7.29 billion in 2022. The market is projected to grow significantly, reaching $13.68 billion by 2030, exhibiting a CAGR (Compound Annual Growth Rate) of 8.41%. More importantly, the Asia Pacific region dominates the global handloom market, accounting for 55.97% global market share in 2022[6]. In India, the handloom sector constitutes 4% of Gross Domestic Product (GDP), and makes up 13% of India's export earnings. In 2022-23, it has accounted for Rs. 106.06 crore (US$ 13.2 million)[7].

Ergonomics study in the Indian textile industry is not very common [8]. Literature reviews in handloom industries in different states (Assam, Odisha, West Bengal, etc.) indicate the prevalence of occupational health problems among weavers. Due to the repetitive nature of the job, weavers were found to suffer from repetitive strain injuries of the upper limbs in West Bengal [9]. Another study conducted in Ahmedabad revealed that handloom weavers often experience knee and back pain because of poor workstation design, intensifying the risk of musculoskeletal disorders [8]. Due to improper seat design and static posture, it has been found that handloom weavers of Uttarakhand were suffering from lower back

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pain [8]. Some health hazards associated with handloom workers also include poor eyesight, early cataract, loss of vision, and heart and lung problems[10]. Women weavers of Assam were found to have a high prevalence of developing musculoskeletal disorders (MSDs) due to weaving [8]. Studies have explored different perspectives and causes of occupational health-related issues in the textile industry, particularly in the handloom sector. Still, there remains a significant gap in the quantification of specific challenges faced by Indian weavers, such as the effects of illumination on occupational health and productivity, hearing loss due to continuous exposure to noise, and thermal comfort of the weavers during weaving. Existing research mainly addresses large-scale textile industries and power looms, so those may not adequately fill the gap in the handloom sector. As per the handloom census 2019-20, this industry employs about 3,522,512 workers across the country, and women workers are contributing a significant share with 72.29% of the total workforce[11]. A study on handloom weavers of Manipur identified that inadequate illumination, improper ventilation, and noise are predominant environmental factors affecting the weavers' occupational health [12].

This study aims to address and quantify the critical issues of occupational health and well-being among handloom weavers in Assam. More precisely, it seeks to investigate the impact of environmental factors, such as illumination, noise levels, and weather conditions, on weavers' physical and physiological health.

2. Methodology

2.1. Study Area

This study was conducted in the Sualkuchi region of rural Kamrup district in Assam, one of the biggest handloom clusters in the north-east region [13]. Approximately 92% of the population in Sualkuchi is involved in handloom activities, making it a significant economic and cultural hub for the state.

2.2. Study Subjects

The Consortium of Sualkuchi Cluster is comprised of 20 Self-Help Groups (SHGs), providing primary livelihood for around 340 weavers [14]. Given that the number of weavers within each SHG is not fixed, a random sampling was followed to cover at least 34 weavers (10% of the total weaver population) from the Sualkuchi cluster. Male and female weavers with at least 5 years of weaving experience were selected for the study. The weavers' education levels were generally low, with only a few possessing matriculation degrees. A total of 36 weavers were chosen for the study (30 female and 6 male). To compare the hearing threshold, 20 workers (15 Male, 5 female) from different occupations in the same location were included.

After preliminary observations of the conditions in handloom weaving, we have conducted measurements of illumination and noise levels along with a subjective questionnaire. A comparison of hearing thresholds between weavers and non-weavers using pure tone audiometry has been done to check the impact of noise. Part-time weavers and persons with presbycusis or pre-existing hearing issues were excluded from the study.

2.3. Preparation and standardization of questionnaires

Three questionnaires were developed for the study. The first and second questionnaires assessed the weavers' subjective responses to the illumination and noise levels in the handloom environment, respectively. The third questionnaire evaluated their thermal comfort sensations during work. The reliability and validity of questionnaires were found as per the Cronbach alpha coefficient, 0.97, 0.75 and 0.70, respectively, indicating high reliability[15]. Additionally, the content validity index (CVI) was 1 for all the questionnaires, suggesting that the items effectively measure the intended constructs as per the experts' [16].

2.4. Assessment of illumination

A total of 36 handloom weavers were randomly selected to participate in the study. Initially, their responses regarding the existing conditions were collected by questionnaire and illumination levels were recorded with a digital Lux meter (Peak Meter- PM6612). Subsequently, 40W LED bulbs were installed in the looms, and after a few weeks, the weavers' responses were reassessed under the new lighting conditions. This approach allowed for comparing their perceptions and experiences before and after the intervention.

To analyze the weavers' responses against pre- and post-intervention circumstances, the data were subjected to a Shapiro-Wilk test and found to be non-normally distributed. Consequently, a non-parametric test, the Independent Samples Mann-Whitney U test, was employed to assess significant differences in weavers' responses between pre- and post-intervention situations.

2.5. Assessment of Noise

In the study area (Sualkuchi), handlooms are located in the weavers' own houses and are considered a cottage industry (informal sector). As the handlooms are not housed under one or more common sheds, the number of looms under each unit (house) is not fixed. Generally, one to four looms are present in each household. Digital Sound Level Meter (Kusum Meco-KM 929 MK-1) measured noise levels during weaving in two locations: near the weavers' ears and in the centre of the weaving shed for 36 looms.

2.6. Audiometry

To check the impact of existing noise levels in handlooms, audiometry has been performed with a Maico Ma-39

Audiometer to identify if there is any shift in hearing threshold in weavers. The audiometric data were further compared with non-weavers of the same areas (Sualkuchi) to better understand the impact of other noise sources.

For the weavers: Handloom weaving is their primary source of income, and they are doing it daily, at least >5hours/day and having experience of more than 5 years.

For the non-weavers: They were residents of the same area (Sualkuchi) but involved in any profession other than handloom weaving.

Pure Tone Average (PTA), calculated as the average hearing threshold at 500 Hz, 1000 Hz, and 2000 Hz, was compared between weavers and non-weavers to determine if any significant difference exists.

2.7. Assessment of thermal comfort

It has been found that April-June has the highest average daytime temperature (Equipment used: Kestral 4500 pocket weather tracker) in the Sualkuchi (Table 3) region. In April-June, 36 weavers were randomly selected to participate in the "Thermal Comfort feedback" survey.

3. Result

Subjective perception of the weavers on pre- and post-intervention illumination levels on their occupational health and performance:

In the existing situation, weavers reported high levels of impairment in work performance (90%), headaches (80%), fatigue (65%), eye irritation (75%), and difficulty in differentiating thread colours (75%) and identifying defects due to inadequate illumination (80%). Illumination levels were measured at four positions (L1-L4) (Figure1) of the handloom in pre- and post-intervention scenarios, and it was found that after the intervention of LED bulbs, illumination levels at all positions (L1-L4) were significantly enhanced (Table 1).

After implementing lighting interventions, the study found significant improvements in weavers' occupational health and well-being. Post-intervention, the issues above were significantly reduced or eliminated, with weavers reporting high levels of job satisfaction (100%) and a significant reduction in physical fatigue due to awkward posture while weaving.

In the post-intervention scenario, issues regarding the differentiation and identification of different coloured threads and minute defects in the cloth get resolved.

Subjective perception against prevailing noise level and objective evaluation of hearing loss:

The results indicated that the decibel levels in both areas increased with the number of looms operating simultaneously. Notably, the sound levels near the weavers' ears consistently exceeded 85 decibels, regardless of the number of looms in operation. The average noise levels near the ears and in the centre of the shed were 90.87 dBA and 83.82 dBA, respectively (Table 2). It has been

Fig. 1: Positions where Lux levels were measured

Table 1: Comparison of illumination level (in Lux) under pre- and post-intervention scenarios

Position	Pre-intervention illumination (Mean $\pm$ SD) (in lux)	Post-intervention illumination (Mean $\pm$ SD) (in lux)	Average percentage difference
L1	106.06$\pm$68.61	497.77$\pm$310.17	576%*
L2	101.13$\pm$60.95	483.61$\pm$176.66	779%*
L3	121.25$\pm$108.28	424.72$\pm$147.75	692%*
L4	89.71$\pm$51.98	297.72$\pm$104.25	420%*
*Significant at p<0.001 (Wilcoxon Signed-Rank Test)			

observed that noise generated from each loom operation varies greatly (78-85 dBA). On the other hand, simultaneously operational 3-4 looms generate a noise level of (85-90 dBA). 42% of the weavers have reported high noise levels while running the loom and experiencing headache (59%) and irritation (56%) because of this. The majority of the weavers (56%) were dissatisfied with the present noise environment in the handloom, and they also felt that it had a significant impact on their working performance. Weavers (56%) have reported that noise due to running looms also causes speech interference (56%) and difficulty in hearing (62%) with fellow weavers.

As illustrated in Figure 2, weavers exhibited a higher prevalence of moderate and moderately severe hearing loss (41-55 dB) compared to non-weavers. Air conduction testing in pure tone audiometry revealed that weavers consistently required higher decibel levels than non-weavers to hear sounds in all frequencies (Figure 3).

Due to the non-normal distribution of the dataset, a Mann-Whitney U test was conducted to compare the Pure Tone Average (PTA) between weavers (38.62 $\pm$ 10.25) and non-weavers (28.28 $\pm$ 8.67). The Mann-Whitney U test revealed that the hearing threshold for weavers was significantly

Table 2: Sound level (in dBA) inside the looms

Location	Noise level Mean $\pm$ SD (in dBA)
Near the weaver's right ear	90.87 $\pm$ 2.53
Middle of the Shed	83.82 $\pm$ 4.21

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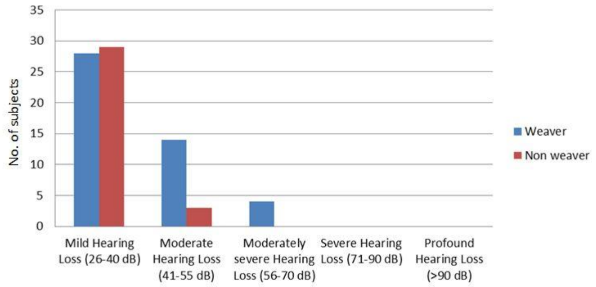

Fig. 2: Comparison of hearing loss between weavers and non-weavers

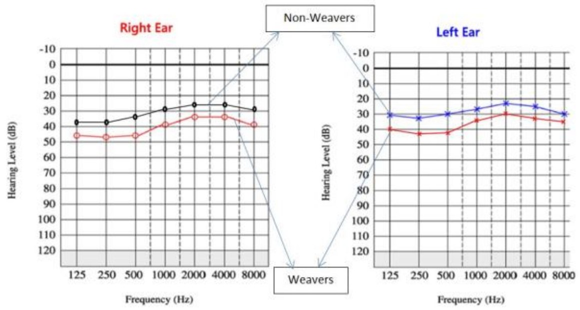

Fig. 3: Comparison of hearing threshold between weavers and non-weavers

Table 3: Month-wise thermal environment in looms during summer

Month	Dry bulb Temp. (°C)	Wet bulb Temp. (°C)	Relative Humidity (%)	Wind Speed (m/sec)
Apr	32	27	73	0.1
May	33	26	75	0.2
June	32	27	73	0.4
July	30	28	83	0.3

higher in comparison to non-weavers.

Assessing the thermal environment and weaver's perception of prevailing environmental conditions during summer:

It has been found that the humidity in the looms is moderately high, but the poor wind speed has worsened the situation. The majority of the weavers were dissatisfied with the existing thermal environment in the handloom workspace (Table 3). A significant majority (90%) of respondents strongly disagreed with the statement that the temperature is comfortable for work during this period. Similarly, most weavers expressed dissatisfaction with air movement and ventilation and agreed that sweating is prevalent during work, affecting their overall comfort. Humidity levels were also perceived as moderately affecting comfort during weaving.

4. Discussion

Assam comprises the major handloom employment state in India with around 40.37% of total weavers and 53.89% of total Indian women weavers (Fourth Handloom Census India 2019-20 [11]). Handloom weaving consists of multiple tasks which require repetitive movement of upper limb and lower limb muscles and thereby can affect occupational health significantly[17]. Work-related stress and musculoskeletal disorders (MSDs) not only affect the physical outcomes of the workers but also affect psychosocial aspects [18,19]. Weaving consists of repetitive movement of the upper and lower limb muscles to operate pedals and shuttles with abduction of the upper arm. In case of occupational diseases or injuries, more than 50% of the weavers do not have any insurance to compensate [17]. The study's findings revealed that illumination levels in most of the handlooms for weaving are not up to the BIS recommended level (handloom weaving: 200-750 lux) [20]. After the provision of a 40W LED bulb at a height of 1.3-1.5m from the working height, in different loom, illumination levels at all positions (L1 - L4), have increased and also significantly impacted weavers' productivity and occupational wellbeing. In weaving, identification of small and fine details, such as light coloured cotton or wool, requires a light intensity of at least 300 lux [21]. Illumination in the workplace significantly affects work efficiency. To observe fine details during work, adequate lighting has a vital effect on maintaining the quality of work and occupational well-being [22]. The main symptoms in poor lighting are irritation and inflammation of the eyes, blurring or double vision, redness and watery eyes, which thereby cause headache, irritation, indigestion, giddiness, etc. [23]. Due to a low level of illumination, weavers frequently adopt an awkward posture during their delicate or precise weaving activities, like designing motifs. Awkward postures like forward bending are common in unorganised sectors where precision activities are predominant [39]. Lighting makes it easier to see details without producing discomforts[24]. Lighting affects the aspect of a task, which can be comprised of the visual, cognitive, and motor components. Poor lighting conditions harm workers' visual comfort, thereby influencing human behaviour and ultimately hampering work efficiency [25]. Poor illumination at the workplace not only compromises human health adversely but also impacts the overall productivity and quality of work, thereby increasing accidents and safety concerns [23) 26]. The introduction of adequate lighting addressed these issues effectively. The brighter working environment significantly reduced eye strain and headache during continuous weaving, enhancing their overall comfort by preventing them from forward bending to observe and identify thread colour and weaving pattern. With better visibility, weavers could identify minute defects more easily and thereby increase their overall productivity.

The noise level in the handloom also impacts the handloom workers' overall productivity and health status. Worldwide, about 16% of the disabling hearing loss in adults is due to

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occupational noise; the percentage varies from 7% to 21% based on the various sub-regions [27]. Due to differences in occupational categories, economic employment sectors, and working lifetimes in developing countries, males are more prone to hearing issues. Most handloom weavers were overexposed to noise levels ranging from 86 to 95 dBA throughout the year, significantly increasing their risk of potential hearing loss [28]. Exposure to high-intensity noise from power looms causes mental and physical problems among weavers[29]. The handloom's Noise level was higher than the BIS recommended standards (within 75 dBA) [30]. Daily exposure to high noise may damage hearing or, in the worst-case scenario, cause hearing loss. High noise might be caused by friction between the moving parts (Treadles and shuttles) during weaving. Weavers often weave in a rhythmic pattern and ignore the power of the sound level delivered and thereby accidentally influence their auditory framework [17]. Audiometry found that weavers require a comparatively higher sound level at each frequency in both ears than non-weavers of the same area. Our study also found a significant difference in hearing threshold, as quantified by PTA, between weavers and non-weavers. This outcome provides evidence supporting the notion that this occupational group may experience distinct auditory health challenges compared to the general population. Though this result does not fulfil all the criteria of noise-induced hearing loss, there is a shift in hearing threshold in weavers. According to World Health Organization this shift can be categorized as mild to moderate hearing loss[31]. Due to high noise levels in the textile industry, more than three-fourths of the workers in this sector have issues such as nervousness and hearing problems[17]. A similar study in Banahatti and Vadagaon weaving units has found noise levels in handlooms at an average of 96.01 dBA, significantly impacting workers' health. Over 40% of weavers experienced severe hearing loss [33].

Handloom is a physically demanding occupation which involves repetitive movement of hands and legs and requires maintaining static posture of the lower back during weaving; there is a high chance of repetitive strain injuries and work-related musculoskeletal disorders (WRMSDs) [9]. Due to repetitive body movements in a constrained posture, poor ventilation, and malnutrition, handloom weavers often appear much older than their actual age [10]. This repetitive movement of arms for a long duration mainly causes health risks in the neck and shoulder region [32].

Productivity and quality of the product are also enhanced by a safe and healthy working environment[34], workers' health is also harmfully impacted by improper ventilation and poor indoor environment [35,36], thereby resulting in a high prevalence of illness [37]. The majority of the workers are having issues of headache, respiratory illness, vomiting and fatigue[38].

The situation is better in modern large industrial units where the workers have a better work-life balance, but in the small-scale and handloom sector, the situation is in veil [17]. Our study has found that during hot summer days, the thermal situation inside the handloom is uncomfortable for the weavers, affecting their daily job. There are a few probable causes of this discomfort, such as poor ventilation in the room and high humidity. Most of the rooms have one or multiple running looms at a time, but in case of multiple looms, there are not enough windows to provide cross ventilation. Due to high temperatures and infrequent rain during April-July, the humidity is high, causing sweating and discomfort during continuous weaving. In most handlooms, either a ceiling fan is not present or is moving at a slow speed due to low voltage, potentially causing discomfort for the weavers. Most handloom workers work in a piecework method, so their wages depend primarily on the quantity of product items. Therefore, their income fluctuates based on demand throughout the year. This condition led the workers to put more effort into increasing the product volume despite occupational risk factors, resulting in health-related issues [11].

The COVID-19 pandemic drives a shift in societal behavior and forced organizations to redesign their overall operational strategies. This disruption had a significant impact on traditional and contemporary markets for artisans worldwide. The Indian government (Ministry of Textiles) has taken different initiatives, such as the implementation of the Government e-marketplace (GeM), to enable the artisans in direct selling of their products to various organisations to mitigate the impact 6. The National Handloom Development Program (NHDP) has been launched to develop various stages of the handloom business across the country. The Market Access Initiative (MAI) program has started to promote overall exports on a sustained basis [5]. The Raw Material Supply Scheme (RMSS) has been introduced to provide quality yarn at a subsidized rate [11].

To optimize the visual environment in the handloom several strategies can be adopted. This study has identified that providing an LED bulb with an optimum lux level can significantly mitigate visual discomfort. Other strategies, such as a transparent sheet in the ceiling[40], roof monitor and saw tooth system (vertical or sloping openings in the roof used to capture light), and light pipe system to enhance illumination at the farthest depth of an interior space can also be considered to improve the overall visual environment in the handloom[41].

To reduce the risk of noise, personal protective devices such as earplugs, earmuffs, and cotton plugs can be used to protect the ears from noise exposure during running loom. Indigenous items such as mufflers, gamocha, and cloth can cover the auditory part of the weavers and reduce noise exposure while weaving. Engineering interventions such as partitioning and enclosing machinery parts, developing

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accessories with low noise-emitting materials such as rubber and redesigning the looms with noise-dampening materials could also be adopted[23].
Thermal comfort can be improved for indoor working environments by combining active and passive cooling methods. Active cooling may involve fans and evaporative coolers, directly reducing air temperature. Passive cooling strategies minimize heat gain and maximize heat loss, such as utilizing shading techniques (green roofs, using PVC material in the rooftop, and tree planting), forming conductive insulation, and optimizing natural ventilation. Innovative approaches include incorporating phase change materials (microcapsules of paraffin), heat sinks, and passive cooling shelters to create a thermally comfortable working environment[42]. It is advised that a combination of active and passive cooling would facilitate achieving better thermal comfort.

5. Limitations and future scope

This study's limited sample size suggests a need for future research with larger and more diverse samples. Expanding the scope to include other handloom clusters would allow for a more comprehensive understanding of drudgery and the development of more targeted intervention strategies.
In the current study, LED bulbs are installed to improve the illumination level, and thereafter, subjective feedback is collected. Future studies can be planned by implementing proposed intervention strategies for other environmental variables to improve the working environment inside the loom. Further effectiveness of the remedial measures can be quantified, and their impact can be studied objectively.

6. Conclusion

This study aimed to measure environmental variables such as light, noise, and temperature within handloom workspaces and quantify the drudgery experienced by weavers. The results of this study have provided a better understanding of the challenges faced within this industry. After the identification of specific environmental stressors, targeted remedial strategies were proposed. These strategies offer a pathway towards improved working conditions and enhanced occupational well-being for handloom weavers. Future research can focus on implementing and evaluating these strategies, ensuring their effectiveness and sustainability in fostering a healthier and more productive handloom sector.

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