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Ergonomic Workload, Musculoskeletal Symptoms, and Physiological Strain Among Juvenile Female Brickfield Workers: A Field-Based Analytical Cross-Sectional Study

Arijit Chatterjee and Rituja Bain*

Academic Institute for Education and Research, Kolkata, West Bengal, India

arijit.chatterjee2010@gmail.com

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ABSTRACT

Background: Juvenile (adolescent) girls from socio-economically disadvantaged households continue to perform heavy manual material-handling (MMH) tasks in India's unorganized brick-manufacturing sector, despite legal protections against child labour. Evidence on their ergonomic exposures, physiological strain, and musculoskeletal health remains scarce.

Objective: To evaluate the physical workload, postural stress, thermal exposure, musculoskeletal symptom prevalence, and acute physiological responses of juvenile girls employed in manual brick manufacturing units in West Bengal, India.

Methods: A cross-sectional study design was adopted involving 100 young females within the age group of 13 to 18 years who worked at brick manufacturing plants in Nadia and Howrah districts of West Bengal. Data collection included interviews using modified Nordic questionnaires, anthropometry, activity observations both direct and video recorded, postural analysis through the Ovako Working Posture Analysis System (OWAS), thermal environment assessment, and physiological parameters both pre and post tasks of brick carrying. A paired t-test was performed to assess the physiological parameters before and after brick carrying, while the chi-square test was used to determine any relationship between musculoskeletal symptoms and BMI or the number of bricks handled per day.

Results: The mean age was 15.5±2.33 years, BMI was 18.90±1.52 kg/m² and the occupational experience was 1.3±0.6 years. In general, 91% of participants complained of job-related pain, including the head (72%), neck (72%), and leg (78%). Neck pain was statistically correlated with chronic energy deficiencies (BMI < 18.5 kg/m², $\chi^2 = 9.675$, $p = 0.0019$). Lifting more than 2,000 bricks per day was statistically correlated with head pain ($\chi^2 = 6.722$, $p = 0.0095$), neck pain ($\chi^2 = 4.228$, $p = 0.0397$), shoulder pain ($\chi^2 = 4.396$, $p = 0.0360$), and back pain ($\chi^2 = 10.306$, $p = 0.0013$). Bricks lifting led to a significant increase in heart rate (from 80.33±3.67 to 112.45±2.13 beats/min, $p < 0.05$), systolic blood pressure (from 119.7±3.5 to 134.9±5.15 mmHg, $p < 0.05$), and perceived exertion level (from 13.2±1.5 to 18.6±0.45). Participants performed 45% of the tasks moderately and 25% heavily; unloading bricks from the kiln top was the most dangerous according to the OWAS scale.

Conclusion: Manual brick production entails heavy postural, thermal, and cardiovascular stress along with extremely high levels of musculoskeletal symptoms in female juveniles. There is an urgent need for intervention measures regarding ergonomics, nutrition, regulation, and education, including the abolition of hazardous juvenile labor, mechanization of load carrying, load restriction, rest breaks, hydration, safe postures, and schooling.

Keywords: *juvenile workers, ergonomics, manual material handling, musculoskeletal disorders, brick kiln, occupational health.*

1. Introduction

Nevertheless, child labour remains an important global public health and human rights issue. According to recent ILO-UNICEF estimates, there were approximately 138 million child labourers aged between 5 and 17 years old in 2024 [1]. It has been estimated that out of these numbers, nearly 54 million worked in conditions hazardous to their health, safety, and development. While significant progress has resumed globally resulting in the reduction of child labour by more than 22 million between 2020 and 2024, hazardous juvenile labour has continued in informal and rural economies.

In India, children and juveniles from poor families have resorted to participating in seasonal informal labour to earn money for their families. Brick manufacturing is an informal labour-intensive industry where workers are exposed to excessive physical activities, such as heavy manual handling, repetitive bending and lifting, dust exposure, heat from the sun, and radiant heat from the kilns. MMH tasks in such industries are typically performed by female workers [2, 3].

Juvenile girls are especially vulnerable because musculoskeletal tissues, thermoregulation, and the cardiovascular system are not fully developed in them. Additionally, juvenile girls also bear the brunt of domestic responsibilities that have no monetary value prior to or even after paid work, leading to insufficient recovery and increased fatigue. Juvenile girls working in brick kilns are undersampled in occupational health surveillance due to the unavailability of informal and underage labour in national labour statistics [4, 5, 6].

There is already existing scientific literature on musculoskeletal problems, injuries, heat stress, respiratory symptoms, and nutritional deficiencies in informal workers in Indian industries [7]. However, ergonomic research on juvenile girls carrying bricks in West Bengal is scarce. Therefore, the current research aims to: (1) characterize the anthropometric, occupational, and socio-work situation of juvenile female brick carriers; (2) determine the prevalence and distribution of work-related musculoskeletal symptoms; (3) investigate the relationship between symptoms, body mass index, and amount of bricks carried per day; (4) assess the acute physiological response to brick carrying; and (5) identify high-risk postures and thermal exposures through OWAS and workplace environment assessment [8, 9].

2. Materials and Methods

2.1 Study design and setting

A cross-sectional field study was conducted on six brick manufacturing plants using manual techniques of brick manufacturing from a larger population of such enterprises present in Nadia and Howrah districts of West Bengal, India. Observations were made during the peak season for manufacturing bricks from October 2025 to April 2026, as the process is carried out in an open area during this season.

The environmental factors observed were temporary employment, piece-rate system, partial mechanization, transients working near the production area, dust, sunlight, and radiant heat from the kilns.

2.2 Study population and sampling

Out of the 320 female workers found in the four units, 119 were juvenile girls within the age group of 13-18 years. From among the eligible participants, 100 juvenile girls were randomly recruited for the study. The participants who refused consent or failed the assessment were excluded. Thus, the total analytical population consisted of 100 juvenile female brick carriers.

Inclusion criteria: Female workers aged 13-18 years; currently engaged in brick carrying/related MMH work; agreeable to participation after giving verbal informed consent from the participant and guardian; and available during the production period.

Exclusion criteria: Acute febrile disease or inability to perform the assessment; refusal of consent or assent; and incomplete physiological/questionnaire data.

2.3 Ethical considerations

This investigation adhered to the ethical codes for research involving human subjects established by the Indian Council of Medical Research (ICMR), Government of India [10]. As the participants were children, this research employed the principle of informed consent from parents/guardians and assent from the subject. The interviews were conducted through oral questioning in either Bengali or Hindi, as most of the respondents were illiterate. No invasive procedures were involved.

2.4 Questionnaire and musculoskeletal assessment

Ergonomic questionnaires were designed using information gathered from direct observation at the workplace and included information on demographics, work duration, experience, daily brick carrying, wage system, work hours, domestic chores, food and health-related problems, work environment, and discomfort perception.

Symptoms of musculoskeletal disorders were analyzed based on the modified Nordic Questionnaire. The Nordic Questionnaire is one of the most popular instruments for describing symptoms in the neck, shoulders, upper and lower back, and arms. It was translated into Bengali and Hindi [11, 12].

2.5 Anthropometry and nutritional status

Body mass was measured using a calibrated weighing machine. Stature was determined using an anthropometric rod. Body mass index (BMI) was calculated as the ratio of body mass in kilograms to stature in square meters. A BMI of <18.5 kg/m² was considered to be a chronic energy deficiency (CED) based on the WHO classification applied in the original study [13, 14].

2.6 Physiological and psychophysical measurements

Heart rate and blood pressure were recorded before performing physical activity. Heart rate and blood pressure were also measured immediately after

completing the brick lifting task. Heart rate was recorded using a calibrated stopwatch pulse count, while blood pressure was measured using a calibrated sphygmomanometer. The Borg Rating of Perceived Exertion (RPE) was used to measure perceived exertion [15].

2.7 Postural and activity analysis

Postures for brick carrying were analyzed using the OWAS technique [16]. The OWAS technique analyzes the posture of the back, arms, and legs, along with load lifting, to determine the presence of harmful postures for work. Direct observations along with video assisted indirect observations were performed to measure the task cycle sequence, load lifted per task cycle, time taken for each task cycle, number of task cycles per hour, and time spent in different levels of workload. Christensen's physiological workload levels were used to classify the workload.

2.8 Thermal environment

Dry Bulb Temperature (DBT), Wet Bulb Temperature (WBT), and Globe Temperature (GT) were recorded using a sling psychrometer and globe thermometer. The effective temperature (ET) was calculated based on the temperatures mentioned above [17].

2.9 Statistical analysis

Continuous variables were described by mean ± SD with range as obligatory. Categorical variables were presented as frequency and percentage [18, 19]. Paired t-test analysis was used to compare heart rate, systolic blood pressure, and diastolic blood pressure before and after work [20, 21]. The chi-square test of independence was performed to test the relationship between musculoskeletal symptoms and BMI categories (<18.5 kg/m² and ≥18.5 kg/m²) and between musculoskeletal symptoms and brick carrying volume (<2000 bricks per day and >2000 bricks per day). A p value < 0.05 for two tailed p value was considered statistically significant. Fisher's exact test would be a better choice when cell size is small; however, the contingency table was not provided in the original dataset to reanalyze the exact probability. All analyses were performed using a two-sided hypothesis testing approach. Due to the lack of individual-level raw data, effect sizes and multivariable adjustments were not available in this case [22, 23, 24, 25].

3. Results

3.1 Participant characteristics

Table 1. Anthropometric and occupational characteristics of juvenile female brick workers (n = 100).

Variable	Mean ± SD	Range
Age (years)	15.5 ± 2.33	14–17
Height (cm)	151.6 ± 2.86	148–155
Body weight (kg)	46.91 ± 3.16	39–54
BMI (kg/m²)	18.90 ± 1.52	17.8–20.11
Work experience (years)	1.3 ± 0.6	0.6–2.0

3.2 Work organization and exposure

The labourers were hired for the months of October to April. Their normal working timings were from 06:00 am to 11:00 am and from 02:00 pm to 06:00 pm, six days a week. Labourers were paid according to the number of bricks carried and not the number of hours spent in work.

The labourers carried approximately 8-10 unbaked or baked bricks on their heads in one round. The overall load that the labourers had to carry was estimated to be 50.06±2.23 kg, although the load differed depending on the task being performed.

3.3 Self-reported health problems

Table 2. Self-reported health problems among female juvenile brick workers (n = 100 participants).

Health problem	Workers reporting condition (n)	Prevalence (%)
Pain	91	91.0
Respiratory symptoms	39	39.0
Gastrointestinal symptoms	18	18.0
Skin diseases	18	18.0
Gynaecological symptoms	5	5.0
Cardiovascular symptoms	3	3.0

3.4 Musculoskeletal pain by body region

Table 3. Prevalence of musculoskeletal pain by body region (n = 100 participants).

Body region	Workers reporting pain (n)	Prevalence (%)
Head	72	72
Neck	72	72
Shoulder	62	62
Arm	42	42
Wrist	54	54
Back	58	58
Waist	59	59
Leg	78	78

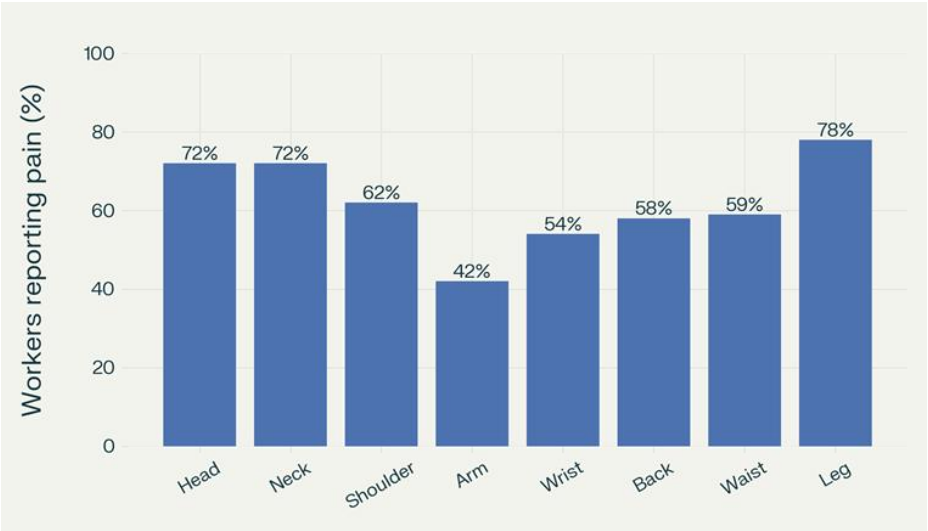


Figure 1. Self-reported musculoskeletal pain by body region (n = 100 participants).

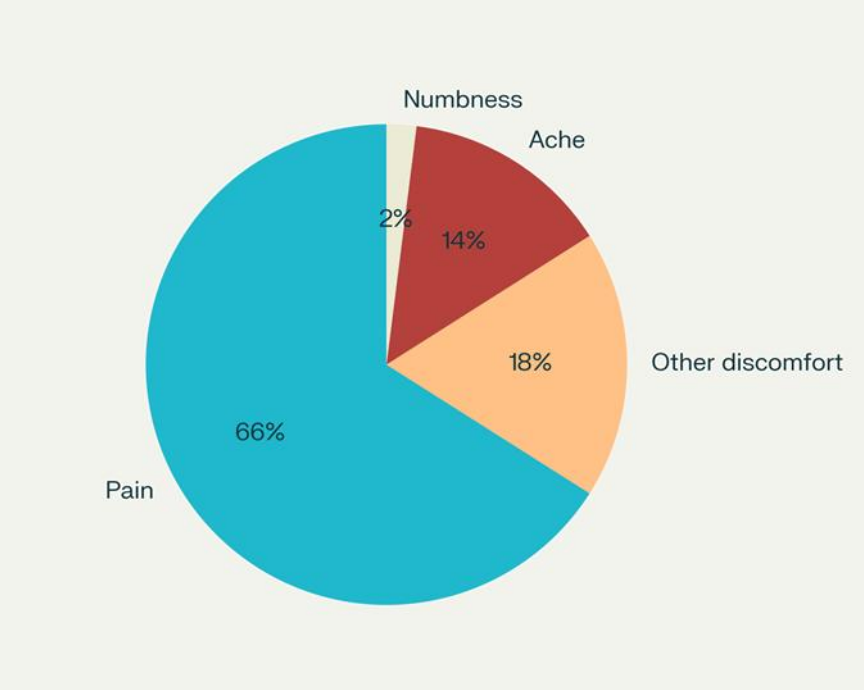


Figure 2. Type of work-related discomfort reported.

3.5 Type of discomfort

Among participants who reported discomfort, pain was the most common sensation (66%), followed by other discomfort (18%), ache (14%), and numbness (2%).

3.6 Association between musculoskeletal symptoms and BMI

Table 4. Association between musculoskeletal complaints and BMI category.

Body region	BMI <18.5		BMI ≥18.5		χ^2	p value	Interpretation
	Yes	No	Yes	No			
Head	48	22	24	6	1.360	0.243	Not significant
Neck	44	26	28	2	9.675	0.0019	Significant
Shoulder	40	30	22	8	2.336	0.126	Not significant
Arm	32	38	10	20	1.321	0.250	Not significant
Wrist	36	34	18	12	1.098	0.295	Not significant
Back	40	30	18	12	0.070	0.791	Not significant
Waist	39	31	20	10	1.041	0.308	Not significant
Leg	54	16	24	6	0.099	0.752	Not significant

Significance threshold: $p < 0.05$.

3.7 Association between symptoms and daily brick-carrying volume

Table 5. Association between musculoskeletal complaints and daily brick-carrying volume.

Body region	<2,000 bricks/day		>2,000 bricks/day		χ^2	p value	Interpretation
	Yes	No	Yes	No			
Head	17	29	34	20	6.722	0.0095	Significant
Neck	27	19	42	12	4.228	0.0397	Significant
Shoulder	22	24	37	17	4.396	0.0360	Significant
Arm	18	28	18	38	0.540	0.463	Not significant
Wrist	14	32	14	40	0.251	0.617	Not significant
Back	15	31	35	19	10.306	0.0013	Significant
Waist	20	26	34	20	3.797	0.0514	Not significant
Leg	26	20	36	18	1.085	0.298	Not significant

3.8 Physiological and psychophysical responses

Table 6. Physiological and psychophysical responses before and after brick carrying.

Parameter	Before work	After brick carrying	Change	Statistical interpretation
Heart rate (beats/min)	80.33 ± 3.67	112.45 ± 2.13	+32.12 (+40.0%)	Significant $p < 0.05$
Systolic blood pressure (mmHg)	119.7 ± 3.5	134.9 ± 5.15	+15.2 (+12.7%)	Significant $p < 0.05$
Diastolic blood pressure (mmHg)	80.4 ± 1.45	83.4 ± 4.67	+3.0 (+3.7%)	Marginal $p < 0.10$
Rate of perceived exertion	13.2 ± 1.5	18.6 ± 0.45	+5.4	High perceived strain

Values are mean ± SD. "After" measurements were taken immediately after cessation of the brick-carrying task.

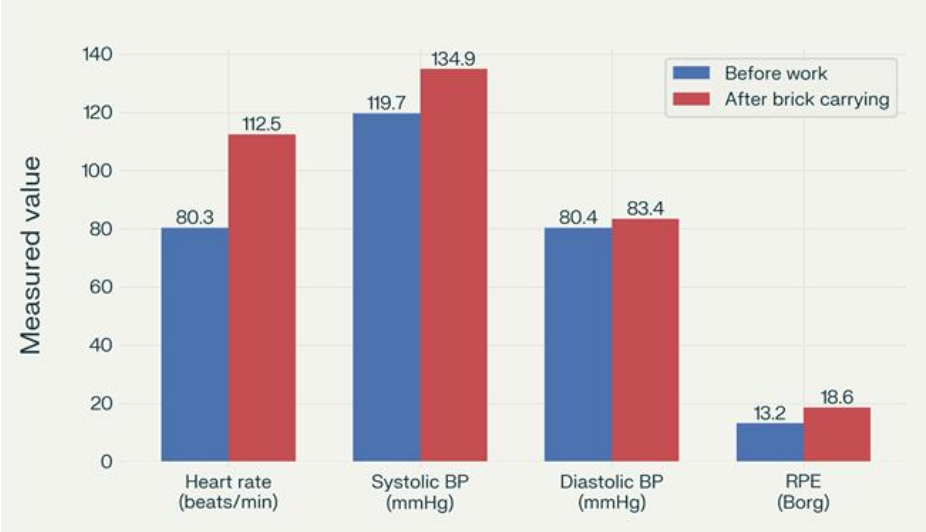


Figure 3. Physiological and psychophysical responses to brick carrying.

3.9 Postural risk analysis

Table 7. OWAS postural analysis of brick-carrying tasks.

Activity	OWAS posture code	Load carried (kg)	Time per cycle (s)	Cycles per hour
Stack bricks on head	1, 3, 3, 3	50.51 ± 0.42	10.58 ± 2.21	22
Stand with bricks on head	1, 3, 1, 3	51.05 ± 0.59	5.23 ± 3.12	49
Walk with bricks on head	1, 3, 6, 3	52.31 ± 1.02	47.23 ± 4.67	19
Unload bricks at kiln top	2, 2, 7, 3	30.27 ± 4.11	11.02 ± 1.13	23

The posture code for unloading at the kiln top indicates the highest risk observed in the task.

3.10 Workload distribution

Participants spent most of their working time performing moderate work (45%), followed by heavy work (25%), light work (15%), very light work (10%), and very heavy work (5%).

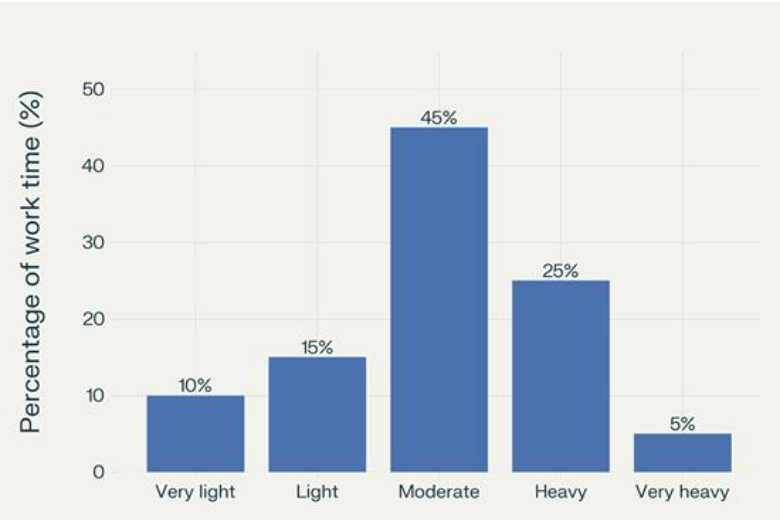


Figure 4. Distribution of daily work time by workload class.

3.11 Thermal environment

Table 8. Mean workplace thermal parameters by season.

Thermal parameter	Winter (°C)	Summer (°C)
Dry-bulb temperature (DBT)	24	38
Wet-bulb temperature (WBT)	16	27
Globe temperature (GT)	28	45
Effective temperature (ET)	20	32

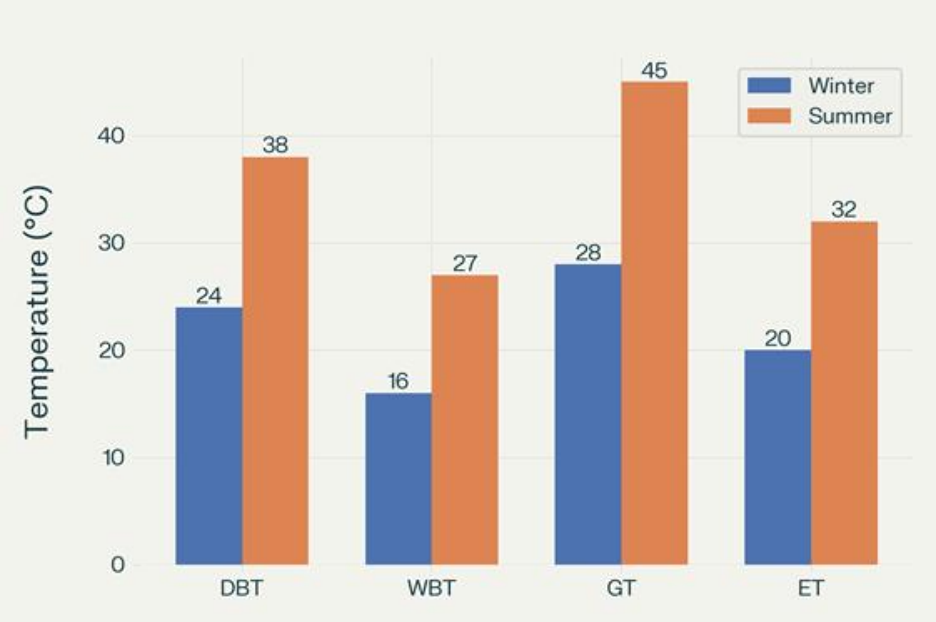


Figure 5. Mean workplace thermal parameters by season.

4. Discussion

In this study, it was found that girls performing manual brick carriage had high levels of musculoskeletal symptoms, cardiovascular stress, load lifting, and unfavorable thermal environment. It is plausible for girls to experience 91% work pain due to the high physical requirements of repetitive head loading, walking, bending, and lifting [3, 9, 26, 27].

It is biologically plausible that the high rate of head and neck pain seen in girls performing manual brick carriage. This is because they carry 50–52 kg of bricks on their heads, causing compressive and shear forces on the neck, upper back, and shoulders [27, 28].

The correlation between a high daily brick-carrying quantity and head and back pain indicates a dose–response relationship between mechanical exposure and symptoms. This is associated with ergonomic research, which shows that repetitive heavy MMH, awkward posture, and lack of recovery time are key factors for musculoskeletal problems among workers [26, 29, 30].

Significantly, neck pain was associated with CED. Low BMI may be related to low energy and protein intake, less muscle mass, and physiological reserve. Therefore, this may increase susceptibility to fatigue-induced postural strain [31, 32]. However, due to the cross-sectional design of this study, it is not possible to exclude reverse causality and confounding [33].

The rapid increase in heart rate and systolic blood pressure during brick carrying is an indication of high cardiovascular demand [34, 35, 36]. A significant increase in the rate of heartbeats by nearly 40% while engaging in work activities is a clear indication that the activity is highly strenuous for the age group [37].

Another problem associated with this activity is the level of heat exposure involved. Summer DBT, GT, and ET are significantly higher than their winter counterparts, with added heat exposure from kilns [38, 39]. Thermal stress can reduce work capacity and cause additional physiological burdens [40, 41].

The results reveal an occupational health problem associated with gender: girls were engaged in brick carrying for pay, as well as domestic activities such as cooking, cleaning, fetching water, and caring for children [42, 43]. This double burden might affect recovery periods and intensify fatigue [44, 45].

5. Conclusion

Young girls working in the manual brick manufacturing units of West Bengal have been subjected to excessive mechanical, postural, thermal, and psychophysical stresses. The high prevalence of musculoskeletal pain, strong associations with the weight of materials carried per day, and high cardiovascular stress and dangerous OWAS postures among young girls are collectively occupational hazards.

Key strategies include:

1. Abolishing hazardous occupations for children and young people.

2. Substituting head carriage with the use of wheelbarrows, hand-carts, conveyors, or other mechanical means of transporting materials.

3. Imposing age-specific weight limits and prohibiting heavy MMH among minors.

4. Job rotation, regular rest breaks, provision of shade, access to hydration, and heat stress prevention measures.

5. Safe lifting and carrying instructions for workers legally allowed.

6. Nutritional screening and supplementation for undernourished workers.

7. Return to schooling and financial assistance to the families of the affected population.

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