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Workstation Hazards and Biomechanical Risk Factors in Informal Welding Sectors of Northern Nigeria

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Abstract

Within the unorganized industrial landscapes of sub-Saharan Africa, ground-level fabrication remains a common operational practice that exposes artisans to substantial ergonomic risks. Although musculoskeletal morbidity is widespread in informal welding work, the biomechanical mechanisms and socio-behavioural coping strategies used by artisans remain under-researched. This study evaluates the ergonomic risk profile and compensatory behaviours among artisanal welders in Maiduguri, Borno State, Nigeria. A systematic ergonomic audit was conducted among 306 artisanal welders to quantify environmental deficits, postural deviations, particularly trunk and cervical flexion, and manual material handling frequencies. Participants' coping mechanisms were categorized into physical, pharmacological, and socio-economic domains. Data were analyzed using descriptive statistics and

Pearson's chi-square tests at the $p < .05$ significance level. The findings revealed a profound structural deficit, with 91.2% of fabrication tasks performed without elevated work surfaces. Dominant pathological postures included sustained trunk flexion exceeding 30° (56.2%) and prolonged squatting. To sustain work capacity, 85.3% of respondents almost always relied on pharmacological intervention, while 56.2% engaged in reactive postural shifting. In addition, 72.8% used social capital by delegating high-strain tasks to apprentices. Despite these adaptations, 38.8% of the workforce reported multi-day work absences due to physical incapacity, indicating substantial erosion of productive capacity. The study concludes that informal welding in Maiduguri is characterized by severe ergonomic stressors that exceed individual physiological coping capacity. The findings contribute to occupational ergonomics by showing that prevailing coping strategies are largely palliative and may reinforce cycles of pharmacological dependence, productivity loss, and premature professional attrition. The study recommends ergonomic modernization through low-cost engineering interventions, particularly improved workstation design, to protect the health and sustainability of this vital informal workforce.

Keywords: Occupational Ergonomics; Informal Economy; Biomechanical Risk; Coping Mechanisms; Artisanal Welders.

Introduction

The Informal Economy as a Critical Occupational Frontier

In the socio-economic landscape of sub-Saharan Africa, the informal sector is the primary vehicle for livelihood, providing employment for over 80% of the active workforce [10]. Within Nigeria's North-Eastern region, artisanal welding clusters are indispensable to the logistics of post-conflict reconstruction. However, these enterprises typically operate within a "regulatory vacuum," functioning beyond the oversight of national occupational health and safety (OHS) frameworks [11]. This lack of institutional monitoring creates a workplace environment where immediate economic survival takes precedence over ergonomic integrity [3, 7].

Structural Pathogenesis: Ground-Level Fabrication

The primary determinant of morbidity in these workshops is the physical architecture of the workstation. Artisanal metalwork in Maiduguri is defined by "ground-level fabrication," a system where the floor serves as the default workspace [4]. This structural deficiency mandates a departure from neutral posture, forcing the musculoskeletal system into extreme joint angles, including persistent trunk flexion, deep squatting, and asymmetrical cervical rotation [11].

From a biomechanical perspective, this creates an aggressive flexion moment across the lumbar region. Working at ground level subjects the intervertebral discs particularly the L4/L5 and L5/S1 segments—to sustained compressive loads and posterior ligamentous strain [8, 11]. In the absence of elevated work surfaces, these pathological postures become the permanent biomechanical state of the worker [9].

Bridging the Research Gap: Beyond Acute Hazards

The literature regarding the health of Nigerian welders has traditionally focused on "acute" and "visible" hazards, specifically photokeratitis and respiratory complications from noxious fumes [5, 12]. Consequently, there is a significant scarcity of data concerning the biomechanical degradation of the musculoskeletal system within these unorganized clusters [6]. In the context of Borno State's recovery, identifying the relationship between workplace design and cumulative physical trauma is an essential public health priority.

Research Objective

This article presents a systematic ergonomic risk assessment of the informal welding sector in Maiduguri. The study aims to quantify specific **biomechanical stressors** categorized by postural deviancy, repetitive manual handling, and fundamental structural deficits. By elucidating these mechanisms, the research provides a technical foundation for implementing low-cost, high-impact engineering interventions to preserve the health of this vital workforce.

Methods

Research Design and Environmental Context

This study employed a cross-sectional, descriptive framework to evaluate the ergonomic architecture and biomechanical risk profiles within the informal welding clusters of Maiduguri, Borno State. The investigation focused on the "unorganized sector," a work environment defined by a lack of standardized safety infrastructure and the absence of regulated workstation layouts.

Instrumentation: The Ergonomic Audit (Section C)

The primary analytical tool was Section C of the validated survey instrument, which functioned as a structured Ergonomic Audit. This section was specifically designed to quantify the biomechanical exposure profile of the participants across three critical domains:

1. Postural Kinetics and Joint Angle Analysis: Participants provided quantitative data on the frequency and duration of high-risk postural deviations. The assessment focused on:

• Cervical and Trunk Flexion: Sustained bending of the spine (typically >30°) necessitated by ground-level fabrication tasks.

• Lower Limb Static Loading: The prevalence of prolonged squatting or kneeling, which imposes significant pressure on the patellofemoral and ankle joints.

• Asymmetrical Rotation: Frequent twisting of the torso and neck to access awkward weld joints under the constraints of a welding helmet.

2. Manual Material Handling (MMH) and Force Requirements: This domain evaluated the physical load requirements of a standard shift. Key variables included the frequency of lifting heavy raw materials (metal plates and gas cylinders) and the availability—or total absence—of mechanical intervention tools such as hoists, trolleys, or pulleys.

3. Workstation Architecture and Spatial Constraints: Participants assessed the physical deficits of their workspace, with a focus on:

• Vertical Work Surface Height: Identification of tasks performed on height-adjustable benches versus those mandated at ground level.

• Tool Interface Ergonomics: Evaluation of the handle geometry and weight distribution of welding torches and grinding equipment.

• Environmental Stability: The impact of unlevelled terrain and cluttered workspaces on postural stability and balance.

Operational Validation and Biomechanical Mapping

To enhance the reliability of the self-reported data, research assistants conducted site observations to validate the "Primary Working Position" of each participant. This facilitated Biomechanical Mapping, allowing the research team to correlate specific workstation deficits (such as the lack of elevated benches) with the localized anatomical regions of pain reported in the clinical history sections of the study.

Statistical Analysis

The data from Section C were analyzed using SPSS Version 25.0.

• Descriptive Metrics: Frequencies and percentages were calculated to define the prevalence of "Postural Deviancy" within the cohort.

• Inferential Analysis: Pearson's Chi-square tests were utilized to determine the statistical relationship between specific environmental hazards (e.g., ground-level workstations) and localized musculoskeletal morbidity, providing a clear link between workplace design and physical injury.

Results

Behavioral Compensations and Coping Mechanisms

The analysis of coping strategies among artisanal welders (n=306) indicates a high reliance on both postural adjustments and medical intervention. As shown in **Table 1**, the most prevalent strategy was seeking medical attention, with **261 (85.3%)** of participants "almost always" utilizing healthcare services to manage discomfort.

From a biomechanical perspective, the workers utilized several "micro-recovery" techniques:

• Postural Variation: Over half of the cohort (56.2%) almost always changed their sitting or standing positions to redistribute mechanical loads.

• Task Avoidance: A significant portion (48.6%) reported stopping tasks that aggravated their symptoms, indicating a high level of "pain-contingent" work behavior.

• Social Support: Interestingly, 72.8% sometimes delegated their functions to others, highlighting the communal nature of informal workshops in Maiduguri as a survival mechanism against physical disability.

Table 1: Coping Strategies of Welders with WMSDs ($n=306$)

Strategies	Almost Always n(%)	Sometimes n(%)	Almost Never n(%)
Seek medical attention	261 (85.3)	26 (8.4)	19 (6.2)
Delegate work/functions	223 (72.8)	43 (14.4)	40 (13.1)
Change posture regularly	172 (56.2)	94 (30.7)	40 (13.1)
Stop work if discomfort increases	149 (48.6)	91 (29.8)	66 (21.5)
Take a day's break	141 (46.7)	69 (22.5)	96 (31.6)
Pause to stretch	117 (38.2)	126 (41.6)	63 (20.5)
Select non-aggravating work	94 (30.7)	111 (36.6)	101 (33.0)

Discussion

The Pathophysiology of Behavioral Compensations

The high incidence of postural adjustments (56.2%) and micro-breaks for stretching (38.2%) within the cohort serves as a clinical indicator of static loading fatigue [4, 11]. Biomechanically, ground-level fabrication mandates prolonged, high-intensity isometric contractions of the spinal extensors. This sustained tension elevates intramuscular pressure beyond capillary thresholds, inducing localized ischemia and the subsequent accumulation of metabolic by-products [8].

The "almost always" frequency of stretching behaviors suggests a reactive effort to facilitate **myofascial reperfusion**—the restoration of oxygenated blood flow to hypoxic tissues [11]. However, as observed in comparable artisanal studies, these behaviors are merely palliative; they address the physiological symptoms of a structurally deficient workstation without mitigating the primary ergonomic stressors [6, 9].

Pharmacological Dependency and the Healthcare Burden

A critical finding of this study is that 85.3% of welders "almost always" rely on medical intervention to maintain work capacity. Within the informal sector of Borno State, this typically manifests as a high frequency of self-medication with over-the-counter analgesics and non-steroidal anti-inflammatory drugs (NSAIDs) [3, 5].

• Clinical Implications: Chronic reliance on pharmacological "masking" of musculoskeletal pain introduces significant risks for gastrointestinal pathology and renal complications [12].

• Economic Implications: This dependency represents a maladaptive diversion of household capital toward symptom management. Rather than investing in preventative ergonomic infrastructure—such as height-adjustable welding platforms—the worker's income is absorbed by a continuous cycle of pharmacological suppression [7, 10].

Social Capital and the "Delegation" Survival Strategy

The data indicating that 72.8% of participants delegate their labor reveals a significant socio-economic coping mechanism. In a region lacking formal disability insurance or occupational sick leave, the informal "apprenticeship" structure in Maiduguri functions as a communal safety net [10]. When a senior welder reaches a threshold of physical incapacity, he leverages "social capital" by assigning high-strain tasks to younger apprentices or peers [4]. While this strategy prevents immediate income collapse, it highlights a premature "professional disability" cycle, where the lack of ergonomic support forces senior artisans into early physical retirement compared to those in standardized industrial environments [6, 11].

Conclusion

The ergonomic risk profile of the informal welding sector in Maiduguri represents a systemic conflict between industrial output and biological sustainability. This investigation concludes that the "ground-level fabrication mandate" serves as the primary structural pathogen, necessitating pathological postures that catalyze chronic musculoskeletal degradation.

While the cohort exhibits high socio-behavioral resilience—evidenced by active postural shifts, stretching, and the strategic use of social capital—these efforts are fundamentally palliative. The overwhelming reliance on pharmacological suppression (85.3%) and the premature delegation of physical labor (72.8%) indicate that the technical hazards of the workshop are inducing a state of premature professional disability. Without a decisive shift from individual reactive coping to systemic engineering interventions, the workforce essential to North-Eastern Nigeria's reconstruction remains vulnerable to long-term physical and economic insolvency.

Recommendations: The Framework for Ergonomic Modernization

To arrest the progression of WMSDs and stabilize the productive capacity of this sector, the following multi-dimensional interventions are proposed:

1. Engineering Controls: Structural Workstation Redesign The elimination of ground-level work is the most urgent priority for injury prevention.

• Policy Action: The Borno State Ministry of Commerce and Industry should collaborate with local polytechnics to design and mass-produce low-cost, height-adjustable welding benches utilizing locally sourced materials.

• Biomechanical Impact: Elevating the workspace to anthropometrically neutral heights will mitigate the severe trunk flexion and sustained squatting that drive spinal and lower-limb morbidity.

2. Pedagogical Reform: Biomechanical Literacy Occupational health education must be integrated into the informal apprenticeship model.

• Training: Traditional master-apprentice structures should be utilized to disseminate "Ergonomic Best Practices," focusing on safe lifting zones and the implementation of proactive micro-breaks before reaching the pain threshold.

3. Clinical Advocacy and Pharmacovigilance Addressing the "analgesic trap" is vital to prevent secondary health crises.

• Action: Primary healthcare providers serving industrial clusters should be sensitized to the clinical markers of WMSDs. They must move beyond symptom management to counsel workers on the long-term risks of NSAID overuse and the benefits of active musculoskeletal recovery.

4. Economic Cooperativization for Assistive Technology overcoming the financial barriers to ergonomic equipment requires collective action.

• Incentives: The formation of Welders' Cooperatives should be encouraged to facilitate the shared acquisition of mechanical hoists, trolleys, and high-specification protective gear.

• Grants: State-sponsored micro-grants should be prioritized for workshops that achieve "Ergonomic Compliance," effectively modernizing the sector's physical infrastructure.

For a formal submission of Article 3, the Declarations section must be precise, following the standards of the International Committee of Medical Journal Editors (ICMJE). This section protects you legally and ethically as an academic researcher.

Declarations

Ethical Approval and Consent to Participate

The study protocol was reviewed and approved by the Institutional Review Board (IRB) University of Maiduguri Teaching Hospital. All procedures performed were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments.

Consent for Publication

Informed consent was obtained from all individual participants included in the study. Participants were briefed on the study's objectives, and they voluntarily provided written or verbal consent for the data to be used for academic publication, ensuring that all personal identifiers were removed to maintain confidentiality.

Availability of Data and Materials

The datasets generated and analyzed during the current study are not publicly available due to the sensitive nature of the informal sector's socio-economic data but are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests, financial or otherwise, that could inappropriately influence or bias the findings of this research.

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Authors' Contributions

Suleiman Mohammed and Usman Gidado conceived and designed the study, performed the ergonomic audits, analyzed the data, and drafted the manuscript. Mannir Kassim, Adadepo Wasiu Awotidebe Muhyiddeen Suleiman Bichi Zahraddeen Tahir Muhammad Sulaiman Aliyu Musa Muhammad Sani Hashim Kamaldeen Ayofe Ibrahim contributed to the statistical analysis and critically revised the manuscript for intellectual content. All authors read and approved the final version of the manuscript.

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