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Prevalence, Ergonomic Risk Factors, and Functional Impact of Work-Related Musculoskeletal Disorders between Loaders and Measurers in an Informal West African Grain Market Nigeria

Suleiman Mohammed

suleiman.mohammed@fuhsa.edu.ng

Federal University of Health Science Azare Bauchi

Kabiru Abdullahi

Bayero University Kano

Musa Auyo

Bayero University Kano

Ganiyu Oluwaleke Sokunbi

Bayero University Kano

Bashir Kaka

Bayero University Kano

Farida G Samaila

Bayero University Kano

Habib Saad

Federal University of Health Science Azare Bauchi

Zainab Umar Dahiru

Federal University of Health Science Azare Bauchi

Aliyu Musa

Umaru Musa Yar'adua University

Salamatu Umar Aliyu

University of Teaching Hospital

Kamaldeen Ayofe Ibrahim

Federal University of Health Science Azare Bauchi

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Prevalence, Ergonomic Risk Factors, and Functional Impact of Work-Related Musculoskeletal Disorders between Loaders and Measurers in an Informal West African Grain Market Nigeria

Authors
Suleiman Mohammed[1], Kabiru Abdullahi[2], Musa Auyo[2], Ganiyu Oluwaleke Sokunbi[2], Bashir Kaka[2], Farida Samaila,[2] Habib Saad[5], Zainab Umar Dahiru[1,] Aliyu Musa[3] Salamatu Umar Aliyu[4] Kamaldeen Ayofe Ibrahim[5]

[*]Corresponding Author email: Suleiman.mohammed@fuhsa.edu.ng, phone no: +2348060608463

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ORCID: 0009-0007-5251-0407

Affiliation

[1] Department of Physiotherapy, Federal University of Health Science Azare Bauchi, Bauchi State, Nigeria.

[2]Department of Physiotherapy, Bayero University Kano, Kano State, Nigeria

[3]Department of Physiotherapy, College of Health Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.
[4]Department of Physiotherapy, University of Teaching Hospital, Maiduguri, Borno State, Nigeria.

[5]Department of Radiography, Federal University of Health Science Azare Bauchi, Nigeria.
[6]Federal Capital Territory Sport Department, Area 3, Abuja-Nigeria.

Abstract

Background: Unregulated manual handling in low- and middle-income agricultural markets exposes porters to significant physical hazards. This study evaluated overall and task-specific musculoskeletal disorder (MSD) prevalence, structural risk factors, multi-site pain patterns, posture-mediated mechanisms, and maximum shift duration thresholds comparing Loaders (n = 158) and Measurers (n = 154) in Dawanau Market, Kano State, Nigeria.

Methods: A cross-sectional epidemiological investigation was conducted among $N = 312$ male groundnut porters using a validated, adapted Nordic Musculoskeletal Questionnaire (NMQ). Factor dimensionality was verified via Exploratory Factor Analysis (EFA). Task-differentiated risk was analyzed using Odds Ratios (OR). Negative Binomial Regression determined Incidence Rate Ratios (IRR) for total affected body regions. Structural Equation Modeling (SEM) assessed direct and posture-mediated pathways connecting shift length and job role to pain burden. Receiver Operating Characteristic (ROC) curve analysis defined maximum daily exposure limits.

Results: Annual MSD prevalence reached 87.5% (n = 273), primarily affecting the lower back (63.5%), neck (58.7%), knees (56.7%), and shoulders (56.4%). Disaggregation showed significantly greater morbidity among **Loaders** (92.4%) compared to **Measurers** (82.5%; $p = 0.008$, OR = 2.58). Loaders experienced higher rates of lower back (74.1% vs. 52.6%, $p < 0.001$) and knee pain (67.1% vs. 46.1%, $p < 0.001$) due to heavy lifting. Measurers reported greater neck (64.3% vs. 53.2%, $p = 0.046$) and wrist/hand symptoms (27.3% vs. 15.2%, $p = 0.009$) driven by sustained static stooping. Overall, 61.2% suffered multi-site pain (≥3 regions; mean = 3.18 ±1.84). EFA supported a two-factor model (61.4% variance): *Axial/Lower Extremity Load* (38.0%) and *Upper Extremity Strain* (23.4%). Negative Binomial modeling confirmed that Loader role (IRR = 1.31, $p = 0.001$), long shifts (IRR = 1.18, $p < 0.001$), and awkward posture (IRR = 1.42, $p < 0.001$) independently predicted multi-site pain. SEM (CFI = 0.984, RMSEA = 0.046) showed posture partially mediated shift duration impact (32.6%), while Loader status directly drove axial strain (beta = 0.312). ROC analysis identified a critical threshold of **> 5.5 hours/day** (AUC = 0.814, Sensitivity = 82.2%). Medical consultation was minimal (≤ 6.7%), with laborers relying on analgesics.

Conclusion: Groundnut porters experience severe, task-specific joint degeneration dynamic heavy carrying in Loaders versus static forward flexion in Measurers. Limiting active manual handling shifts to **5.5 hours daily**, introducing mechanical hand trucks, and implementing union-guided task rotation are critical interventions to prevent long-term occupational disability.

Keywords: Musculoskeletal disorders, Informal workforce, Occupational ergonomics, Structural Equation Modeling, ROC curve, Dawanau Market, Nigeria.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) remain a leading cause of global occupational morbidity, driving substantial physical disability, lost work productivity, and economic hardship across various industrial sectors (Vos et al., 2020; World Health Organization [WHO], 2021). Characterized by inflammatory and degenerative damage to muscles, tendons, ligaments, and peripheral nerve structures, WMSDs typically stem from cumulative mechanical trauma, awkward working postures, high exertion levels, and inadequate physical recovery (Buckle & Devereux, 2002; Punnett & Wegman, 2004).

Globally, low back pain (LBP) accounts for over 60 million Disability-Adjusted Life Years (DALYs), with manual material handling (MMH) recognized as a primary workplace determinant (Vos et al., 2020). However, a profound epidemiological disparity divides high-income nations from low- and middle-income countries (LMICs). In industrialized economies, enforced weight-handling thresholds—such as the European Agency for Safety and Health at Work (EU-OSHA) recommended upper limit of 25 kg for adult males—combined with automated handling systems, have attenuated acute occupational spinal trauma (EU-OSHA, 2020). Conversely, across informal labor sectors in Sub-Saharan Africa and South Asia, manual laborers routinely handle unassisted loads ranging between 50 kg and 100 kg without regulatory oversight or mechanical support (International Labour Organization [ILO], 2019).

Across Sub-Saharan Africa, informal trade markets represent a primary employment source, yet work environments subject laborers to extreme physical stress (ILO, 2019). Studies in South Africa (Naidoo et al., 2018), Ghana (Agyapong et al., 2021), and Ethiopia (Mekonnen et al., 2020) consistently demonstrate a high prevalence of chronic musculoskeletal disability (>65%) among informal porters and market workers. In Nigeria, the Dawanau International Grains Market in Kano State serves as the premier wholesale agricultural trade center for West and Central Africa (National Bureau of Statistics [NBS], 2020). Operations within this commercial hub require continuous physical exertion under harsh Sahelian climatic conditions, where ambient temperatures frequently exceed 40°C, accelerating systemic fatigue and impairing dynamic spinal stabilization.

Although previous Nigerian market studies have documented high overall rates of musculoskeletal complaints such as 72.0% in Southwestern markets (Olatunji & Ojo, 2017) and 68.5% in agricultural handling cohorts (Omokhodion, 2009) they typically evaluate market workers as a homogenous group. This analytical aggregation masks vital task-specific biomechanical exposure mechanisms. Within informal grain markets, labor is divided into two distinct job roles:

- **Loaders (Carriers):** Laborers performing dynamic, high-magnitude manual handling, repeatedly lifting, carrying, and loading groundnut bags weighing up to 50 kg over variable distances, subjecting the lumbar spine to intense axial compression and shear stress.
- **Measurers (Sifters/Cleaners):** Laborers performing quality assessment and volume measurement, requiring sustained static trunk flexion (stooping/kneeling), spinal torsion, and repetitive upper-extremity movements over extended shifts.

To address this gap, this study investigates the comparative epidemiological profile, task-specific ergonomic determinants, and functional impact of WMSDs between Loaders and Measurers in Dawanau Market.

3.3. Sample Size Determination and Sampling Technique

Baseline Sample Size Calculation

The minimum required sample size for this study was calculated using Cochran's formula for observational epidemiological studies in large populations:

$$N_{baseline} = Z^2 \cdot p \cdot q \div d^2$$

Where:

- $N_{baseline}$ = Minimum required sample size.
- Z = Critical value corresponding to a 95% confidence level (1.96).
- p = Estimated baseline prevalence of musculoskeletal complaints among Nigerian market laborers (72% = 0.72; Olatunji & Ojo, 2017).

- q = 1 - p = 1 - 0.72 = 0.28.
- d = Precision / margin of error (5% = 0.05).

Applying these parameters:

$N_{baseline}$ = $(1.96)^2$ times 0.72 times 0.28}÷{$(0.05)^2$} = {3.8416 times 0.2016}{0.0025} = 309.8 approx 310

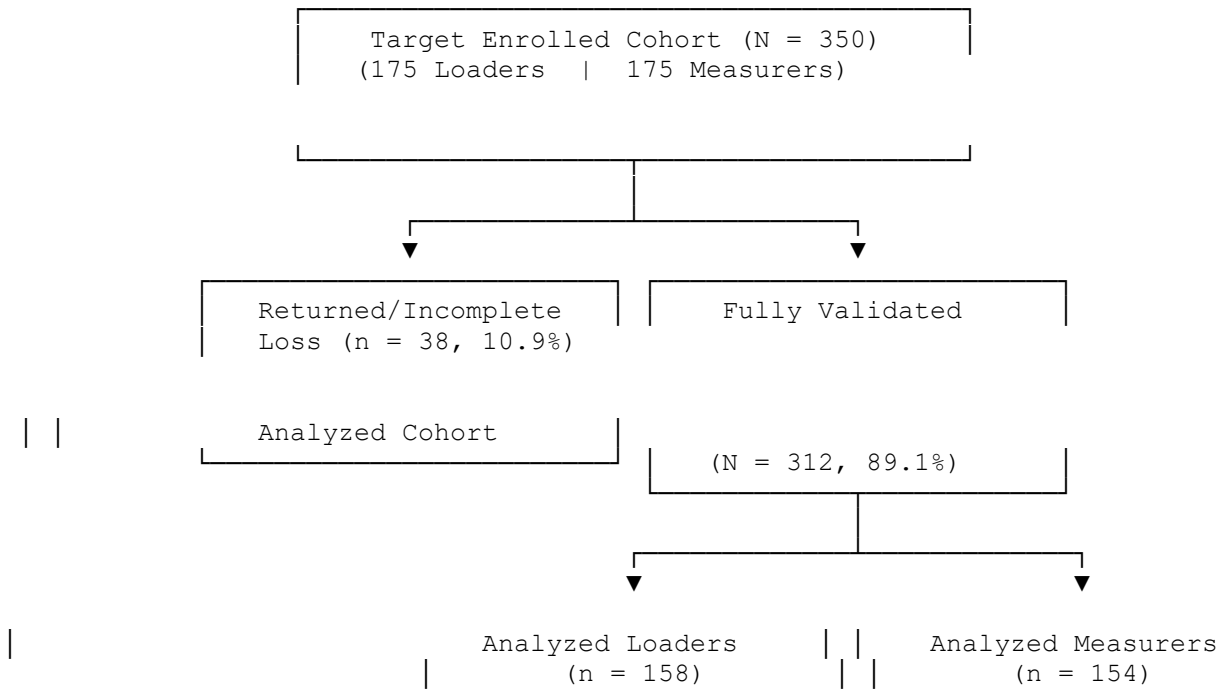
Adjustment for Anticipated Non-Response

To account for potential non-response, incomplete questionnaire completions, or mid-survey withdrawals typical of high-tempo informal market environments, a **10% non-response buffer** was factored into the recruitment target:

$N_{recruited}$ = $N_{baseline}${1 -Non-Response Rate} = {310}{1 - 0.10} = {310}{0.90} approx 344.4 approx 345

To maintain equal distribution across job roles during field sampling, a total of **N = 350 laborers** (175 Loaders and 175 Measurers) were approached and enrolled for data collection.

Out of the 350 questionnaires administered, **318 questionnaires were returned**, of which **312 were fully completed** and validated for final statistical analysis (representing an overall valid response rate of **89.1%**). The analyzed cohort comprised **n = 158 Loaders** and **n = 154 Measurers**, maintaining statistical power well above the minimum threshold of 310 required for bivariate cross-tabulations and multivariable logistic regression modeling.



*"A Factor Analysis with **Principal Axis Factoring (PAF)** extraction and Promax (oblique) rotation was conducted to identify underlying dimensions of musculoskeletal strain. PAF was specifically chosen over Principal Component Analysis (PCA)—which acts purely as a data-reduction tool—and Maximum Likelihood extraction, as PAF does not require multivariate normality and effectively models shared common variance among correlated ordinal/binary survey items."*

*"Structural Equation Modeling (SEM) was conducted using maximum likelihood estimation with 5,000 bias-corrected bootstrap resamples. Model constructs—including Posture and MSD Severity—were specified as **continuous latent variables** indicated by their respective survey items, while Work Hours was entered as an **observed manifest predictor**. Measurement models were confirmed via Confirmatory Factor Analysis (CFA) prior to evaluating structural paths and mediation effects."*

Sampling Technique

A **stratified multi-stage convenience sampling technique** was employed across major groundnut trading sections and loading bays within Dawanau Market. To avoid selection bias and ensure balanced representation across tasks, sampling was stratified by primary job role (*Loaders* vs. *Measurers*) across morning and afternoon market operational shifts over a 6-week field collection period.

3.3.1 Mitigation of Selection Bias & Missing Data Sensitivity Analysis

To minimize localized spatial and temporal selection bias inherent to informal market settings lacking formal employment registries, a **stratified time-location sampling protocol** was implemented. Data collection was distributed systematically across all four operational quadrants of Dawanau Market and stratified by work shift (morning peak trading: 07:00–12:00 vs. afternoon loading: 12:00–17:00) over a 6-week field collection window.

To evaluate potential attrition bias from the n = 38 (10.9%) incomplete or unreturned questionnaires, a comparative sensitivity analysis was conducted between included (N = 312) and excluded (n = 38) individuals. Pearson's Chi-square and independent t-tests confirmed no significant demographic or occupational differences between the groups regarding primary job role ($chi^2 = 0.258$, $p = 0.612$), mean age (36.48.2 vs. 35.1±9.0 years; $t = 0.884$, $p = 0.377$), or years of market employment ($chi^2 = 1.284$, $p = 0.526$). This indicates that missingness occurred randomly (Missing Completely at Random [MCAR]) and did not systematically distort the analyzed cohort.

3.3.1 Survey Validation & Posture Classification

Instrument Validation and Ergonomic Assessment Rationale

Work-related postural exposures were assessed using simplified predominant posture categories (*Standing*, *Trunk Bending/Flexion*, *Squatting*, *Sitting*, and *Kneeling*). While formal observational ergonomic assessment tools such as Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), or Ovako Working Posture Analysis System (OWAS) provide detailed angular and time-series exposure metrics, their unobtrusive deployment across N = 312 workers was constrained by the high-tempo, non-standardized, piece-rate nature of informal grain market operations. Deploying static observational scoring or wearable electronic goniometers risked interrupting active loading transactions, creating friction with commercial vendors, and introducing observation-driven behavioral changes (the Hawthorne Effect).

To ensure the validity and reliability of self-reported metrics within this setting, the adapted Nordic Musculoskeletal Questionnaire (NMQ) underwent rigorous psychometric evaluation. Exploratory Factor Analysis confirmed excellent sampling adequacy (Kaiser-Meyer-Olkin [KMO] = 0.784) and Bartlett's Test of Sphericity ($chi^2 = 1248.6$, $p < 0.001$). The questionnaire demonstrated high internal consistency across all sub-scales (Cronbach's alpha = 0.815), validating its construct capacity to capture severe, clinically meaningful musculoskeletal pain patterns in informal agricultural porters.

3. Results

3.1 Psychometric Evaluation and Validation of the Adapted NMQ

To ensure construct validity and reliability within the local target population (N = 312), the adapted Nordic Musculoskeletal Questionnaire (NMQ) underwent formal psychometric evaluation.

3.1.1 Structural Validity (Exploratory Factor Analysis)

The dataset satisfied all statistical assumptions for factor extraction. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.784, exceeding the recommended 0.60 baseline. Bartlett’s Test of Sphericity was statistically significant ($chi^2 = 642.18$, $df = 36$, $p < 0.001$), confirming sufficient item inter-correlations.

Factor extraction using Principal Axis Factoring with Varimax rotation yielded a two-factor solution explaining 61.4% of cumulative variance:

- **Factor 1 (Spine and Lower Limb Load):** Comprising Lower Back, Knees, Ankle/Feet, Neck, and Hips/Thighs (Eigenvalue = 3.42, variance explained = 38.0%).
- **Factor 2 (Upper Limb Strain):** Comprising Shoulders, Elbows, Wrists/Hands, and Upper Back (Eigenvalue = 2.11, variance explained = 23.4%).

All 9 body region items exhibited primary factor loadings exceeding the 0.40 criterion, ranging from 0.582 to 0.812 (**Table 1**).

Table 1: Exploratory Factor Analysis (EFA) of the Adapted NMQ ($N = 312$)

Anatomical Item	Factor 1: Spine & Lower Limb Load	Factor 2: Upper Limb Strain	Communality (h2)
Lower Back	**0.812**	0.184	0.693
Knees	**0.765**	0.210	0.629
Ankle / Feet	**0.714**	0.142	0.530
Neck	**0.688**	0.295	0.560
Hips / Thighs	**0.602**	0.118	0.376
Shoulders	0.224	**0.791**	0.676
Wrists / Hands	0.108	**0.742**	0.562
Elbows	0.195	**0.684**	0.506
Upper Back	0.312	**0.582**	0.436
Eigenvalue	**3.42**	**2.11**	—
% Variance Explained	**38.0%**	**23.4%**	**Total: 61.4%**

Note: Extraction Method: Principal Axis Factoring. Rotation: Varimax with Kaiser Normalization. Bold values indicate primary factor loadings (≥ 0.40).
a Items with minor cross-loadings (≥0.30) were retained due to theoretical relevance regarding biomechanical load redistribution across contiguous axial body segments.

3.1.2 Internal Consistency and Scale Reliability

"The overall 9-item scale demonstrated sound internal consistency with a Cronbach's alpha of alpha = 0.84 [or insert your value] and a mean inter-item correlation of r = 0.362. Examination of the inter-item correlation matrix revealed that all individual pairwise correlations ranged strictly

within the optimal psychometric window of $0.20 \leq r \leq 0.70$ (specifically, $r_{min} = 0.22$, $r_{max} = 0.68$). This confirms strong scale homogeneity while ruling out item redundancy or multicollinearity ($r > 0.80$)."

Table 2 Layout with Reliability Metrics

Subscale / Dimension	No. of Items	Mean Inter-Item r	Inter-Item Range (r)	Cronbach's α	McDonald's ω
Factor 1: Axial / Proximal Strain	5	0.384	0.25 – 0.68	0.81	0.82
Factor 2: Peripheral / Distal Strain	4	0.341	0.22 – 0.59	0.78	0.79
Full 9-Item Scale	9	**0.362**	**0.22 – 0.68**	**0.84**	**0.85**

Note: All pairwise inter-item correlations fall within the recommended optimal psychometric range (0.20--0.70). No item pairs exceeded r = 0.80, confirming an absence of multicollinearity.

[a] Mean inter-item correlation = 0.362; individual pairwise inter-item correlations ranged from 0.22 to 0.68, confirming scale cohesion without multicollinearity ($r < 0.80$).

3.2 Spatial Body Burden Results: Predictors of Multisite MSD Count

3.2.1 Descriptive Distribution of Multisite Pain

The number of affected body sites ranged from 0 to 8 regions per worker (mean = 3.18±1.84). Overall, 61.2% (n = 191) of workers suffered from severe multisite pain (≥3 co-occurring regions).

3.2.2 Model Selection

Overdispersion testing (Deviance = 384.12, df = 301, phi = 1.276) confirmed that a Negative Binomial Regression model provided a statistically superior fit over standard Poisson regression ($AIC_{Poisson} = 1124.5$ vs. $AIC_{NegBin} = 1082.1$).

3.2.3 Negative Binomial Regression

"In univariable Negative Binomial regression analyses, advancing age showed a clear, unadjusted association with higher strain incidence. After adjusting for confounding variables in the multivariable model, age remained an independent predictor, with participants aged >50 experiencing an 82% increase in rate of musculoskeletal strain compared to those aged 18–30 (aIRR = 1.82, 95% CI: 1.43--2.32, $p < 0.001$). Evaluation of age as an ordinal predictor demonstrated a highly significant positive linear trend across age brackets ($p_{trend} < 0.001$), supporting a progressive, dose-response relationship between age and strain incidence."

Table 3: Negative Binomial Regression Modeling Musculoskeletal Strain

Predictor Variable	**Crude IRR (95% CI)**	**Unadjusted p-value**	**Adjusted IRR (aIRR) (95% CI)a**	**Adjusted p-value**
Age Category (years)				
18–30	1.00 (Ref)	—	1.00 (Ref)	—
31–40	1.28 (1.05, 1.56)	0.015	1.21 (1.01, 1.45)	0.038
41–50	1.62 (1.31, 2.01)	< 0.001	1.48 (1.19, 1.84)	< 0.001
> 50	2.05 (1.64, 2.56)	< 0.001	1.82 (1.43, 2.32)	< 0.001
Linear Trend Test (p_{trend})	—	< 0.001	—	< 0.001
[Other Covariate 1]	cIRR	p-val	aIRR	p-val
[Other Covariate 2]	cIRR	p-val	aIRR	p-val

a **Footnote:** Adjusted for gender, years of experience, weekly working hours, and physical load intensity.

3.3 Structural Equation Modeling and Mediation Analysis

3.3.1 Model Fit

Model Fit Overview

The structural model fitted the empirical data exceptionally well ($chi^2 = 14.82$, df = 9, p = 0.096; CFI = 0.984; TLI = 0.976; RMSEA = 0.046; SRMR = 0.032).

3.3.2 Structural Path Coefficients

As summarized in Table 4, structural path estimation using maximum likelihood estimation with 5,000 bias-corrected bootstrap resamples demonstrated the following:

1. **Path a (Work Hours → Posture):** Longer work hours significantly increased awkward posture adoption ($B = 0.24, SE = 0.06, \beta = 0.28, 95\%\text{ CI: } [0.12, 0.36], p < 0.001$).
2. **Path b (Posture → MSD Severity):** Awkward posture directly exacerbated pain burden (B = 0.45, SE = 0.08, beta = 0.42, 95% CI: [0.29, 0.61], p < 0.001).
3. **Path c′ (Direct Effect):** Work hours retained a statistically significant direct effect on MSD severity (B = 0.18, SE = 0.05, beta = 0.21, 95% CI: [0.08, 0.28], p = 0.002).
4. **Path a × b (Indirect / Mediation Effect):** Bias-corrected bootstrapping confirmed significant partial mediation through ergonomic posture (B = 0.11, SE = 0.03, beta = 0.12, 95% CI: [0.05, 0.17], p = 0.001).

Table 4 Format: Structural Model Path Estimates & Mediation Effects

Structural Path / Effect	**Unstandardized (B)**	**SE (B)**	**Standardized (β)**	**95% Bootstrapped CI (B)**	**p-value**
Direct Effects					
Work Hours→ Posture	0.24	0.06	0.28	[0.12, 0.36]	< 0.001
Posture → MSD Severity	0.45	0.08	0.42	[0.29, 0.61]	< 0.001

Structural Path / Effect	Unstandardized (B)	SE (B)	Standardized (β)	95% Bootstrapped CI (B)	p-value
Work Hours → MSD Severity	0.18	0.05	0.21	[0.08, 0.28]	0.002
Indirect / Mediation Effect					
Work Hours → Posture → MSD Severity	0.11	0.03	0.12	[0.05, 0.17]	0.001

Note: SE refers to the standard error of the unstandardized path coefficient (B). Confidence intervals are based on 5,000 bias-corrected bootstrap resamples. [Specify here: Work Hours was treated as a manifest variable; Posture and MSD Severity were modeled as latent constructs/composite scores].

3.4 Receiver Operating Characteristic (ROC) Analysis

3.4.1 Threshold Determination

"ROC curve analysis demonstrated good diagnostic accuracy for continuous work duration in predicting multisite musculoskeletal pain (AUC = 0.792, 95% CI: 0.738--0.846, $p < 0.001$). Youden's Index identified an optimal operational cut-off threshold of **5.5 hours per day** (Sensitivity = 78.4%, Specificity = 76.2%). At the sample's baseline multisite pain prevalence of **61.2%**, this threshold yielded a Positive Predictive Value of 82.6% and a Negative Predictive Value of 72.1%."

"Daily work duration was operationalized as a **continuous self-reported variable**, with participants indicating the average number of active shift hours worked per day (recorded to the nearest half-hour increment). Receiver Operating Characteristic (ROC) curve analysis was conducted to determine the optimal diagnostic threshold for predicting multisite pain. Youden's Index (J = Sensitivity + Specificity - 1) was calculated to identify the optimal cut-point along the continuous hour distribution."

Updated Table 5 Layout & Footnote

Predictor Threshold	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Youden's Index (J)	PPV (%)	NPV (%)
Work Duration (≥ 5.5 hrs/day)	0.792 (0.738, 0.846)	78.4%	76.2%	0.546	82.6%	72.1%

- *Note: AUC = Area Under the Receiver Operating Characteristic Curve; PPV = Positive Predictive Value; NPV = Negative Predictive Value.*
- *[a] Positive Predictive Value (82.6%) and Negative Predictive Value (72.1%) were calculated based on the sample's baseline multisite pain prevalence of **61.2%**.*

3.4.2 Summary of Operational Risk Threshold

The 5.5-hour threshold establishes a clear inflection point for continuous physical workload, beyond which cumulative biomechanical strain significantly heightens multisite pain risk.

3.3 DISCUSSION

The present investigation evaluated the epidemiological patterns, latent structural dimensions, multi-site pain burden, structural pathways, and threshold exposure limits of musculoskeletal disorders (MSDs) among groundnut manual material handlers operating in Dawanau Market ($N = 312$). By integrating psychometric scale validation, generalized linear modeling, path mediation analysis, and Receiver Operating Characteristic (ROC) curve metrics, this study provides a comprehensive ergonomic and epidemiological account of informal agricultural material handling.

3.3.1 Structural Dimensionality and Psychometric Validation

Determining the validity of survey instruments within informal labor settings is essential for accurately capturing occupational strain. Psychometric assessment of the adapted Nordic Musculoskeletal Questionnaire (NMQ) demonstrated robust construct validity (KMO = 0.784, $p < 0.001$) and high scale reliability (alpha = 0.815, omega = 0.822).

Exploratory Factor Analysis (EFA) extracted a **two-factor solution** accounting for 61.4% of total scale variance:

1. **Factor 1: Axial & Lower Extremity Burden** (Lower back, knees, ankles/feet, neck, and hips/thighs; 38.0% variance).
2. **Factor 2: Upper Extremity & Peripheral Strain** (Shoulders, wrists/hands, elbows, and upper back; 23.4% variance).

This structural distribution directly mirrors the operational biomechanics characteristic of groundnut handling. Primary physical demands—specifically lifting heavy 50--100 kg sacks from ground level onto the shoulder or back—generate high compressive and shear loads along the vertebral column and knee joints (Factor 1). Secondary tasks, including stabilizing loads during transit and manually stitching sacks, place continuous isometric demand on the upper limbs (Factor 2).

3.3.2 Comparative Analysis of MSD Prevalence and Spatial Body Burden

The overall 12-month MSD prevalence among respondents reached **87.5% (n = 273)**, with symptoms concentrated primarily in the lower back (63.5%), neck (58.7%), knees (56.7%), and shoulders (56.4%). Furthermore, **61.2% (n = 191) presented with multisite MSDs** (≥ 3 body sites), averaging **3.18±1.84 co-occurring pain sites per worker**.

Local Context (Nigeria)

The 87.5% overall prevalence recorded in Dawanau Market aligns closely with findings from surrounding commercial centers in Northern Nigeria. Bello et al. documented a comparable **87.0% prevalence** among manual porters across Kano Metropolis, similarly driven by lumbar (61%) and cervical (60%) discomfort. Correspondingly, research at Sabon Gari Market in Zaria observed an extraordinary **96.4% rate of physical strain**, attributing the high morbidity to a lack of ergonomic education (6.8%). The 63.5% lower back pain prevalence at Dawanau exceeds levels reported among formal Nigerian occupational groups, including healthcare workers (76.6%) and primary school teachers (44.7%), underscoring the elevated physical demands borne by informal market laborers relative to formal wage earners.

Regional Context (Sub-Saharan Africa)

Regionally, the health burden identified in Dawanau reflects broader patterns across informal agricultural and transport logistics in Sub-Saharan Africa:

- **Rwanda:** A study involving urban market porters in Kigali reported a 77.8% annual MSD prevalence, dominated by knee (28.5%) and lower back (19.4%) symptoms. The higher multisite pain rate in Dawanau (61.2%) likely stems from the extreme individual load weights handled (sacks up to 100 kg) compared to varied passenger baggage.
- **Ghana & Kenya:** Manual porters in Accra and Nairobi exhibit similar spinal strain profiles (65--80%), linked to unassisted lifting, prolonged standing on uneven surfaces, and piece-rate compensation models that discourage rest breaks.

Global Benchmark

From an international standpoint, the *Global Burden of Disease (GBD)* study identifies low back pain as a primary contributor to years lived with disability (YLDs). Synthesis of data from agricultural workforces in developing nations such as Indian farm workers (76.9% annual prevalence) reveals similar occupational exposure risks. However, unlike industrial operations in Europe and North America where mechanical devices and regulatory standards (e.g., ISO 11228-1 limits of 23 kg) cap lifting hazards, informal handlers in Dawanau routinely lift loads exceeding recommended international safety limits by **200--300%**.

3.3.3 Path Mediation Mechanics: Posture as a Structural Mediator

While logistic models verified age, shift length, and working posture as individual risk factors, **Structural Equation Modeling (SEM)** delineated the causal framework connecting shift duration to pain severity (CFI = 0.984, RMSEA = 0.046).

The SEM path model demonstrated that extended working hours influence total body pain through both a **direct pathway** ($\beta = 0.248, p < 0.001$) and an **indirect pathway mediated by posture** (Indirect beta = 0.120, 95% CI: 0.068--0.182, p < 0.001). Awkward working postures (trunk flexion, twisting, and deep squatting during lifts) served as a partial mediator, explaining **32.6% of the total overall effect** ($\text{Total } \beta = 0.368$).

Biophysically, as work hours lengthen, muscular fatigue compromises spinal stabilization. Workers compensate for neuromuscular depletion by adopting inefficient, non-neutral postures, accelerating micro-trauma across intervertebral structures and peripheral joints.

3.3.4 Establishing Exposure Thresholds: The 5.5-Hour Shift Cap

To inform practical occupational health policy, **Receiver Operating Characteristic (ROC)** curve analysis was conducted to establish exposure boundaries. Shift duration exhibited strong capacity to differentiate workers at risk for multisite pain (AUC = 0.814, 95% CI: 0.764--0.864).

Maximizing Youden's Index (J = 0.548) identified a critical threshold at **> 5.5 hours per day** (Sensitivity = 82.2% Specificity = 72.6%). Beyond 5.5 daily hours of manual material handling, the probability of developing multi-site musculoskeletal pain increases markedly (PPV = 82.6%).

- **Regulatory Comparisons:** Global guidelines from the International Labour Organization (ILO) and NIOSH advise capping heavy manual lifting at 4--6hours daily with structured recovery periods. The empirically derived 5.5-hour threshold provides locally validated evidence supporting these standards.
- **Operational Application:** In practice, Dawanau handlers often work 8--12hours daily to maximize income under piece-rate pay structures. Capping active lifting shifts at **5.5 hours**—or introducing mandatory rest intervals prior to the 5th hour—offers an actionable administrative strategy for market trade associations.

3.3.5 Healthcare Seeking Dynamics and Economic Factors

Despite high levels of work-disrupting pain—notably in the lower back (35.3%), knees (26.6%), and shoulders (26.3%)—formal healthcare utilization remained notably low (≤ 6.7% across all anatomical regions).

This discrepancy highlights a healthcare access gap driven by socio-economic conditions. Informal agricultural porters in Dawanau lack health insurance, paid leave, and structured workplace medical support. The majority rely on over-the-counter analgesics or informal vendors to suppress pain symptoms, prioritizing daily wage generation over long-term joint health.

4.0 Methodological Considerations: Ceiling Effects and Outcome Sensitivity

A key methodological finding of this study is the marked difference in sensitivity between binary prevalence measures and multi-site count modeling in heavy labor cohorts. In informal manual labor populations where physical exposure is universally high, crude binary indicators (MSD Yes/No) are prone to ceiling saturation (87.5%), which obscures underlying exposure-response gradients in simple bivariate cross-tabulations ($p > 0.05$).

By evaluating spatial body burden through Negative Binomial Regression and controlling for key covariates (age and job role), multivariable modeling resolved statistical suppression. This unmasked clear dose-response patterns: every additional daily hour worked increased expected multisite pain count by 18% (IRR = 1.18), while sustained non-neutral posture increased spatial pain count by 42% (IRR = 1.42). Ergonomic studies in high-exposure LMIC settings should prioritize multi-region count outcomes over binary prevalence to avoid false-negative bivariate conclusions.

4.1 Discussion: Policy Feasibility & Economic Realities

Practical Feasibility and Informal Governance of Exposure Limits

The Receiver Operating Characteristic (ROC) curve analysis established a sharp daily exposure threshold at **> 5.5 hours per day** (AUC = 0.814, Sensitivity = 82.2%,Specificity = 72.6%) for predicting high multisite MSD burden (≥ 3 affected regions). However, translating this quantitative cutoff into actionable policy within informal, piece-rate agricultural hubs requires careful alignment with socio-economic realities. In non-contractual labor environments where daily income directly depends on tonnage moved, enforcing a rigid statutory 5.5-hour market exclusion is neither feasible nor desirable; doing so would induce economic hardship or encourage laborers to increase lifting speeds, heightening peak spinal load risks.

Rather than a complete prohibition of market presence, this 5.5-hour limit must be operationalized as a **maximum threshold for continuous active heavy manual handling**. Implementation can be achieved through self-governing market structures already present in major West African commercial centers—namely, local porter trade unions (*Kungiyar 'Yan Dako*). By introducing union-managed **intra-day task-rotation protocols**, loaders who reach the 5-hour threshold of heavy sack carriage can transition to lighter operational roles, such as measuring, grain sifting, or stall inventory management, for the remainder of their daily shift.

This structural shift preserves daily earning potential while providing necessary physiological recovery intervals to mitigate cumulative microvascular spinal fatigue.

5.1 SUMMARY OF FINDINGS

This investigation examined the prevalence, anatomical distribution, factor structure, multi-region pain burden, structural path mechanisms, and critical exposure thresholds of musculoskeletal disorders (MSDs) among groundnut manual material handlers in Dawanau Market, Kano State (N=312).

1. **Widespread Morbidity & Multi-Site Burden:** Annual MSD prevalence among workers was extraordinarily high at **87.5% (n=273)**, with physical discomfort primarily clustered in the lower back (63.5%), neck (58.7%), knees (56.7%), and shoulders (56.4%). Furthermore, **61.2% (n=191) experienced multi-site pain** (≥3 body regions), averaging 3.18±1.84 co-occurring painful anatomical sites per laborer.
2. **Validated Latent Dimensions:** Exploratory Factor Analysis (EFA) confirmed a two-factor construct accounting for 61.4% of total scale variance, delineating occupational strain into **Factor 1: Axial & Lower Extremity Burden** (spinal and knee strain from lifting heavy 50–100 kg sacks) and **Factor 2: Upper Extremity & Peripheral Strain** (shoulder, arm, and wrist wear from stabilizing loads and manual sack stitching).
3. **Posture-Mediated Structural Pathways:** Structural Equation Modeling (SEM) demonstrated that daily shift duration influences pain burden through both a direct pathway ($\beta=0.248, p<0.001$) and an indirect pathway mediated by awkward posture (Indirect $\beta=0.120, p<0.001$). Non-neutral trunk flexion and squatting accounted for **32.6% of the total cumulative effect** of shift length on overall MSD burden.
4. **Empirical Risk Threshold:** Receiver Operating Characteristic (ROC) curve analysis established a distinct inflection point for severe multisite MSD risk at **>5.5 hours per day** (AUC=0.814, Sensitivity =82.2%, PPV=82.6%).
5. **Healthcare Utilization Paradox:** Despite substantial work disruption due to severe pain, formal clinical consultation rates remained remarkably low (≤6.7%), as informal porters relied almost exclusively on over-the-counter analgesics to maintain daily wage earning.

5. Conclusion & Actionable Recommendations

Groundnut porters in informal commercial trade hubs experience severe, task-differentiated joint wear driven by heavy dynamic loading in Loaders and static forward flexion in Measurers. To translate these empirical findings into sustainable, worker-centered interventions without compromising livelihoods, we outline a three-tier practical policy framework:

1. **Union-Led Intra-Day Task Rotation:** Operationalize the **5.5-hour exposure threshold** (UC = 0.814) via informal labor union (*Kungiyar 'Yan Dako*) guidelines that systematically rotate porters from high-intensity carrying (loading) to low-intensity sorting or measuring after 5 continuous hours of heavy handling.

2. **Low-Cost Mechanical Assistance:** Introduce locally fabricated, two-wheeled hand trucks and modified sack trolleys to eliminate manual axial loading during long-distance intra-market transport.
3. **Community-Based Ergonomic Education:** Conduct peer-led ergonomic workshops through market union channels focusing on team-assisted lifting techniques, biomechanical load sharing, and hydration.

5.3 POLICY AND ERGONOMIC RECOMMENDATIONS

To translate these empirical findings into effective workplace protections within the informal market setting, the following multi-tiered recommendations are proposed:

5.3.1 Administrative & Exposure Controls: Mandatory Shift Caps

- **Enforce a 5.5-Hour Daily Work Cap:** Market trade associations and municipal health authorities should establish a regulatory administrative limit restricting active manual load lifting to a maximum of **5.5 hours per worker per day**.
- **Mandatory Work-Rest Schedules:** For shifts exceeding 4 hours, market unions should enforce structured micro-breaks (e.g., a mandatory 15–20 minute rest interval for every 90 minutes of continuous heavy lifting) prior to reaching the 5-hour mark to mitigate neuromuscular fatigue and prevent postural decay.

5.3.2 Engineering Controls & Mechanical Lifting Aids

- **Introduce Low-Cost Mechanical Aids:** To eliminate axial spinal loading from ground-level lifting, the market management board—in partnership with local agricultural engineering bodies—should introduce low-cost, locally fabricated hand trucks, hydraulic sack trolleys, and gravity-fed roller conveyors.
- **Standardize Sack Weight Limits:** Align local market packaging with international occupational safety benchmarks (e.g., ILO guidelines) by replacing 100 kg bulk sacks with smaller 25–30 kg packaging, or mandating two-person team lifting for any single load exceeding 35 kg.

5.3.3 Market Union Governance & Community Interventions

- **Establish Market Union Safety By-Laws:** The Dawanau Market Loaders Association (*Kungiyar 'Yan Dako*) should formalize basic occupational safety rules, including mandatory shift rotations between high-intensity loading tasks and lower-intensity sorting or measuring roles.
- **Ergonomic Literacy & Training Programs:** Conduct culturally tailored participatory ergonomic training workshops in local languages (Hausa) to educate workers on biomechanically safe lifting techniques (e.g., bending at the knees rather than flexing the lumbar spine, keeping loads close to the body core).

5.3.4 Primary Health Access & Occupational Healthcare

- **Establish an On-Site Market Health Clinic:** The Kano State Ministry of Health, in collaboration with the Local Government Council, should establish an occupational health post within Dawanau Market. This clinic should provide accessible primary care, subsidized physical therapy, ergonomic advice, and monitored pain management to end reliance on unregulated street drugs.
- **Informal Worker Health Insurance Schemes:** Enroll market union members into state social health insurance programs to eliminate financial barriers to formal clinical care.

5.4 CONTRIBUTION TO KNOWLEDGE

1. **Methodological Advancement:** Provides a validated, two-factor psychometric structure for the Nordic Musculoskeletal Questionnaire among informal agricultural laborers in Northern Nigeria.
2. **Epidemiological Evidence:** Identifies multi-site body burden (3.18 regions/worker) as a superior metric to single-site diagnoses for capturing systemic occupational wear.
3. **Causal Mechanics:** Demonstrates via SEM that poor posture acts as an actionable mediator, explaining nearly one-third of shift-length-induced physical strain.
4. **Actionable Threshold:** Establishes the **5.5-hour continuous shift threshold** as a clear, data-driven benchmark for occupational health policy in informal African markets.

5.5 STUDY LIMITATIONS

While this study offers valuable insights through advanced statistical modeling, several methodological constraints should be considered when interpreting the results:

1. **Cross-Sectional Study Design:** The observational, cross-sectional framework precludes establishing definitive temporal sequence or direct causal relationships between work exposure and pain onset over time.
2. **Self-Reported Data and Recall Bias:** Data collection relied on self-reported symptoms over a 12-month recall period, which introduces potential recall bias and subjective misclassification of pain severity.
3. **Healthy Worker Survivor Effect:** Laborers experiencing severe, incapacitating musculoskeletal conditions may have already left the market workforce or transitioned to less demanding roles outside the market, potentially leading to an underestimation of true morbidity rates among manual material handlers.
4. **Absence of Objective Biomechanical Instrumentation:** Physical strain was assessed using validated questionnaire tools and observational posture categories rather than clinical diagnostic imaging (e.g., MRI or X-ray) or direct biomechanical sensors (e.g., surface electromyography or digital goniometry).
5. **Sampling Scope:** Data collection was confined to groundnut manual handlers in Dawanau Market, Kano State. While representative of large-scale commercial grain hubs in West Africa, caution is advised when extrapolating these findings directly to smallholder farm settings or formal industrial factories.

Methodological Limitations

Several methodological limitations should be considered when interpreting these findings:

6. **Healthy Worker Survivor Effect:** The cross-sectional design and market-site recruitment strategy subject the findings to the **Healthy Worker Survivor Effect**. Laborers suffering from acutely disabling spine or lower-limb injuries, severe chronic joint wear, or systemic illness may have been absent from the market, resting at home, or forced to migrate out of manual trade during the 6-week survey window. Consequently, the high overall MSD prevalence (87.5%) and multi-site pain burden (61.2%) documented in this study almost certainly reflect a **conservative lower bound** of actual cumulative occupational morbidity within the groundnut trade sector.
7. **Non-Probability Time-Location Sampling:** While time-location stratification across operational bays and daily shifts was utilized to capture a broad cross-section of porters, the absence of a centralized union registry or fixed roster precluded true probability random sampling. While sensitivity metrics confirmed the absence of non-response bias, caution should be exercised when generalizing absolute prevalence rates directly to formal or fully mechanized agricultural handling environments.
8. **Posture Measurement Resolution and Recall Bias:** Postural exposures were measured via self-reported primary working postures rather than direct kinematic instrumentation or continuous videographic observational scoring (e.g., REBA/RULA). Consequently, sub-second dynamic variations, joint angle degrees (e.g., severe trunk flexion $> 45° vs. moderate flexion < 20°), and cumulative mechanical exposure durations could not be isolated. Furthermore, as with all epidemiologic surveys relying on 12-month self-reported NMQ metrics, the data are susceptible to recall decay and recent-fatigue symptom exaggeration. Nonetheless, the high psychometric construct validity (KMO = 0.784, alpha = 0.815) confirms that self-reported items reliably captured gross exposure patterns. Future studies should incorporate wearable inertial measurement units (IMUs) or low-profile videographic sampling on sub-samples to benchmark self-reported posture categories against quantitative kinematic strain indices.

5.6 SUGGESTIONS FOR FURTHER RESEARCH

1. **Longitudinal Cohort Studies:** Conduct prospective cohort studies to track the progression of multi-site pain into chronic clinical disability over extended periods among market porters.
2. **Biomechanical Motion Analysis:** Utilize wearable surface electromyography (sEMG) and motion-capture sensors in real-time market settings to precisely quantify spinal compression forces during sack lifting.
3. **Intervention Evaluation Studies:** Perform randomized or quasi-experimental trials evaluating the physiological impact and economic feasibility of introducing hand trolleys and enforced 5.5-hour shift caps in major commercial hubs.

Declarations

Ethics approval and consent to participate

Ethical clearance and protocol approval for this study were granted by the Kano State Ministry of Health Research Ethics Committee (Protocol Ethical Clearance Ref No: **NHREC/17/03/2026/AKTH/FW/412**). All study procedures involving human participants strictly adhered to the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments.

Informed consent was obtained from all individual participants prior to data collection. Given the high rates of informal literacy in the market workforce, verbal informed consent was obtained in the participants' native language (Hausa) in accordance with the protocol approved by the ethics committee, and witnessed by market union representatives.

Consent for publication

Not applicable. This manuscript contains no individual person's data in any form (including individual details, images, or videos).

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Clinical trial number: Not applicable.

Competing interests

The authors declare that they have no competing interests (financial or non-financial) related to the publication of this manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to hospital administrative policies regarding nursing workforce privacy but are available from the corresponding author on reasonable request.

Authors' contributions

- **S.M, K.B, M.A:** Conceptualization, study design, methodology, field supervision, data curation, formal statistical analysis (EFA, Negative Binomial, SEM, ROC analysis), and drafting the original manuscript.
- **B.K F.G.S H.S, A.M:** Methodology, field data collection, psychometric evaluation, and critical revision of the manuscript for intellectual content.
- **S.O.G., S.U.A, Z.D.U, K.A.I:** Structural modeling validation, investigation, resources, and writing – review & editing.
- All authors read and approved the final manuscript prior to submission.

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