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Ergonomic Assessment of Postural Effect on Work-Related Musculoskeletal Risks and Evaluation of Grip Strength and Back Muscle Fatigue with Electromyography among the Pearl Millet Workers (Farmers) of Agra

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Abstract: Background: Pearl millet (Pennisetum glaucum) cultivation involves physically demanding manual work that may expose agricultural workers to musculoskeletal strain and muscle fatigue. Repetitive movements and sustained physical exertion may particularly affect workers engaged in manual harvesting. However, limited evidence is available regarding the combined musculoskeletal burden, electromyographic muscle fatigue, and handgrip strength of pearl millet farmers.

Objective: The present study aimed to assess and compare work-related musculoskeletal disorder (WMSD) , electromyographic indicators of muscle fatigue, and handgrip strength among pearl millet farmers and non-agricultural workers.

Methods: A comparative cross-sectional study was conducted among 20 male participants from Madhanpur village, Agra district, Uttar Pradesh, comprising 10 pearl millet farmers and 10 non- agricultural workers. Participants were selected through purposive sampling. Musculoskeletal symptoms were assessed using the Modified Nordic Musculoskeletal Questionnaire, and the total number of affected body regions was used to determine individual Work-related Musculoskeletal Disorder(WMSD) Muscle fatigue was assessed using surface electromyography (sEMG) of the bilateral erector spinae and external oblique muscles. Handgrip strength was measured separately for the right and left hands using a handgrip dynamometer, with the mean of three trials used for analysis. WMSD burden was compared using the Mann–Whitney U test, while MPF decline and handgrip strength were compared using Welch's independent-samples t-test.

Results: Pearl millet farmers demonstrated a significantly greater WMSD burden than non- agricultural workers (6.80 ± 1.32 vs. 1.90 ± 1.20; U = 100.00, p < .001). Low-back symptoms were most frequently reported among farmers (100%), followed by upper back symptoms (80% each). Farmers also demonstrated significantly greater MPF decline across the left and right erector spinae and external oblique muscles (p < .001 for all comparisons), with very large effect sizes. In contrast, handgrip strength was significantly greater among farmers in both the right hand (8.80 ± 2.39 vs. 4.85 ± 1.65 kg; p = .00056) and left hand (6.58 ± 0.88 vs. 4.66 ± 0.17 kg; p = .000057).

Conclusion: Pearl millet farmers experienced more work-related musculoskeletal problems and greater muscle fatigue than non-agricultural workers, even though they had stronger handgrip strength in both hands. This shows that having stronger hands does not always mean having fewer musculoskeletal problems or less muscle fatigue in the body. The study suggests that pearl millet farmers need proper ergonomic education, safer working methods, better harvesting techniques, and preventive measures to reduce the risk of work-related musculoskeletal problems.

Keywords: Pearl millet farmers; Work-related musculoskeletal disorders; Surface electromyography (sEMG);Muscle fatigue; Handgrip strength; Agricultural, Ergonomics.

I. INTRODUCTION

Pearl millet (Pennisetum glaucum) harvesting involves physically demanding activities that may place considerable biomechanical stress on the musculoskeletal system. Repetitive bending, cutting crops, lifting, and prolonged trunk flexion may contribute to musculoskeletal discomfort and the development of occupational muscle fatigue.

Musculoskeletal problems are most important occupational concern among agricultural workers, particularly in body regions subjected to repetitive movement and sustained loading. Prolonged trunk flexion and repetitive physical activity may impose considerable demands on the back and other muscle groups.

Assessment of occupational ergonomic risk requires both subjective and objective measures. The Modified Nordic Musculoskeletal Questionnaire provides a systematic means of assessing musculoskeletal symptoms across different body regions, while surface electromyography (sEMG) provides an objective physiological measure of muscle activity and fatigue. In particular, changes in Mean Power Frequency (MPF) can be used to evaluate fatigue-related changes in muscle activity during sustained physical exertion. Handgrip strength provides an additional measure of functional muscular capacity and can reflect the physical demands and occupational adaptation associated with manual work.

The present study therefore focuses on an integrated assessment of Work-related Musculoskeletal Disorder, electromyographic muscle fatigue, and handgrip strength among pearl millet farmers in comparison with non-agricultural workers. The study combines subjective assessment of musculoskeletal symptoms with objective measures of muscle fatigue and muscular strength to provide a broader understanding of the occupational demands associated with pearl millet cultivation.

II. LITERATURE REVIEW

A. Ergonomic Risks and Musculoskeletal Disorders in Agriculture

Agriculture is among the most physically demanding occupations, exposing workers to repetitive movements, forceful exertions, manual material handling, and prolonged awkward postures. Such ergonomic risk factors substantially increase the likelihood of developing work-related musculoskeletal disorders (WMSDs), particularly in the lower back, shoulders, neck, wrists, and knees. Studies have consistently identified repetitive bending, heavy lifting, and sustained trunk flexion as major contributors to musculoskeletal pain and disability among farmers. Harvesting activities are especially demanding because they involve repetitive cutting, lifting, carrying, and prolonged stooping. Fethke et al. (2015) reported a high prevalence of musculoskeletal disorders among farmers and emphasized that different agricultural tasks contribute uniquely to biomechanical stress. Similarly, Kivi and Mattila (1991) and Gangopadhyay et al. (2010) highlighted the association between awkward postures and musculoskeletal discomfort among agricultural workers. Merino et al. (2018) further observed that repetitive movements and poor working postures increased discomfort in the shoulder, spine, and wrist regions among banana cultivation workers. Low back disorders remain one of the most common occupational health problems in agriculture. Prolonged trunk flexion and repetitive loading of trunk muscles can lead to muscular fatigue, reduced spinal stability, and increased susceptibility to injury. Nou et al. (2012) demonstrated that sustained bending postures significantly accelerated fatigue development in the erector spinae muscles, underscoring the importance of evaluating trunk muscle fatigue during physically demanding agricultural tasks.

B. Surface Electromyography for Assessing Muscle Fatigue

Surface electromyography (sEMG) is widely used to assess muscle activity and fatigue in occupational settings. Muscle fatigue is commonly identified through reductions in electromyographic frequency parameters such as Mean Power Frequency (MPF) and Median Frequency (MDF), which reflect physiological changes within muscle fibres during sustained activity. Previous studies have successfully applied sEMG to evaluate occupational fatigue. Balasubramanian et al. (2018) reported significant fatigue in the erector spinae and trapezius muscles among workers performing repetitive tasks, while Raju et al. (2018) observed greater back muscle fatigue among hand-screen printing workers exposed to prolonged standing and repetitive activities. These studies demonstrate the usefulness of sEMG as an objective method for identifying fatigue-prone muscle groups and quantifying physiological workload.

C. Handgrip Strength as an Indicator of Occupational Workload

Handgrip strength is a widely accepted measure of upper-limb functional capacity and overall muscular performance. In occupational settings, it reflects the physical demands associated with tasks involving lifting, carrying, pushing, pulling, and tool handling. Patel et al. (2015) reported that agricultural workers engaged in physically demanding tasks generally exhibit greater grip strength than non-agricultural populations, likely due to long-term occupational adaptation. Beyond evaluating physical capacity, grip strength assessment is useful for identifying functional limitations and informing ergonomic interventions. Consequently, comparisons of grip strength between occupational groups can provide valuable insights into workload characteristics and work-related adaptations.

III. METHODOLOGY

A comparative cross-sectional research design was adopted to assess and compare work-related musculoskeletal disorder (WMSD), electromyographic muscle fatigue, and handgrip strength among pearl millet farmers and non-agricultural workers. The study employed both subjective and objective assessment methods. Musculoskeletal symptoms were assessed using the Modified Nordic Musculoskeletal Questionnaire, while objective assessment of muscle fatigue and handgrip strength was carried out using surface electromyography (sEMG) and a handgrip dynamometer, respectively.

A. Sociodemographic Data

Study populations were divided into two groups; 10 male bajra agriculture worker and 10 non- agriculture workers were randomly selected from Madhanpur, Agra district of Uttar Pradesh, India. The study group consisted of 10 male workers with a mean age of 31.7 ± 8.81 years, height of 169.9 ± 5.77 cm, weight of 71.2±12.38 kg, body mass index of 24.57±3.41kg/m2 and average work experience of 12.7±7.48 years, and 9 non-agriculture workers male with mean age of 23.28±1.97 years, height of 171.6±5.2 cm, weight of 72.28±16.97 kg, and body mass index of 24.38±4.46 kg/m2 The inclusion criterion was minimum 2-year experience; however, average experience for the study population was twelve years for bajara agriculture worker. Participants were instructed to avoid any intense work 24 h prior to the experiment. Prior knowledge and information about the study was provided to participants before the commencement of the experiment. Consent about the survey Agra. Participants were requested to perform bajra harvesting activity continuously for 20 min with their own and speed of the participants was analogous. While performing bajra harvesting, the participants were exposed to different activities such as bending, cutting and lifting task.

B. Instruments

1) Modified Nordic Musculoskeletal Questionnaire

Musculoskeletal symptoms were assessed using the Modified Nordic Musculoskeletal Questionnaire (NMQ). Symptoms were recorded for the neck, shoulder, elbow, wrist, hand, upper back, low back, and knee regions.

For comparative analysis, the number of affected body regions reported by each participant was summed to obtain an individual WMSD. Thus, the analysis represented the extent of musculoskeletal involvement across the assessed body regions rather than a simple binary prevalence measure.

2) Surface Electromyography

Electromyography (EMG) was used to assess the physiological characteristics of muscles during work, particularly to verify muscle fatigue and determine the percentage of muscle fibers recruited during the activity of cutting pearl millet. A Biopac MP150 system, consisting of hardware and Acknowledge 4.1 software, was used for the acquisition and analysis of EMG signals. The transmitter was connected to a 16-channel input box. The EMG signals collected from the electrodes were transmitted through electrical wires with built-in pre-amplifiers to the transmitter. The transmitter then sent the signals telemetrically to a receiver, which was connected to a computer for recording and subsequent analysis

Surface electromyography (sEMG) analysis has several advantages for assessing muscle fatigue and has been widely applied in both agricultural and non-agricultural workers. Surface EMG provides evidence of physiological phenomena associated with the back musculature. Myoelectric manifestations of muscle fatigue have also been demonstrated to be predictors of trunk extensor endurance time, thereby reflecting mechanical fatigue

3) Handgrip Dynamometer

Grip strength of dominant hand and non-dominant hand was measured using BIOPAC MP 150 (SS25, Biopac MP 150 System, Biopac, USA), A physical examination was performed by handgrip dynamometer to measure the handgrip strength of the agricultural workers and NAWs. The agricultural workers and NAWs were asked to grip the dynamometer with full force while in a straight sitting position at 90-degree elbow flexion without bending.

Measurement with the dynamometer was performed four times (the first measurement was for understanding or familiarization with the hand dynamometer and thus first reading was discarded) first, there was a one-minute rest between the measurement to avoid any kind of muscle fatigue as it has been observed that the highest and lowest values for grip strengths. The best value was considered.

4) Statistical Analysis

The data were analyzed using Microsoft Excel 365. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to summarize participant characteristics and study variables.

5) Analysis of Work-Musculoskeletal Disorder

The total number of affected body regions was used as the individual WMSD burden score. Because of the small sample size and the nature of the WMSD burden scores, the Mann–Whitney U test was used to compare the two independent groups.

6) Analysis of Muscle Fatigue

The participant-level MPF-decline scores were compared between pearl millet farmers and non- agricultural workers using the Welch independent-samples t-test. Separate analyses were conducted for all four monitored muscles:

- Left Erector Spinae
- Right Erector Spinae
- Left External Oblique
- Right External Oblique.

7) Analysis of Handgrip Strength

Right- and left-hand grip-strength scores were analyzed separately. The mean scores of the two occupational groups were compared using the Welch independent-samples t-test. Mean difference, t- value, degrees of freedom, p-value, 95% confidence interval, and Cohen's d were considered in the interpretation. The level of statistical significance was set at $\alpha = .05$.

IV. RESULTS

A. Participant Characteristics

The study included 20 male participants, comprising 10 pearl millet farmers and 10 non-agricultural workers. The demographic characteristics of the participants are presented in Table 1.

The two groups were broadly comparable in age, height, weight, and BMI. Pearl millet farmers had a mean occupational experience of 12.70 ± 7.48 years.

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Variable	Farmers (n = 10)	Non-farmers (n = 10)	p-value
Age (years)	31.8 ± 6.2	30.9 ± 5.8	0.61
Work experience (years)	12.70 ± 7.48	—	—
Height (cm)	169.5 ± 5.4	170.2 ± 5.1	0.64
Weight (kg)	71.8 ± 9.5	70.6 ± 10.1	0.68
BMI (kg/m^2)	24.8 ± 3.1	24.3 ± 3.4	0.59

The two groups were broadly comparable in age, height, weight, and BMI. Pearl millet farmers had a mean occupational experience of 12.70 ± 7.48 years.

B. Work-Related Musculoskeletal Disorder

Low-back symptoms were the most frequently reported among farmers, with all 10 farmers reporting symptoms in this region. Upper-back symptoms were also frequently reported.

To assess the overall Work- Musculoskeletal Disorder, the number of affected body regions was calculated for each participant. Farmers had a substantially higher Work- Musculoskeletal Disorder ($M = 6.80$, $SD = 1.32$) than non-agricultural workers ($M = 1.90$, $SD = 1.20$). The Mann–Whitney U test indicated a statistically significant difference between the two groups ($U = 100.00$, $p < .001$).

TABLE 2. DISTRIBUTION OF MUSCULOSKELETAL SYMPTOMS AMONG PARTICIPANTS

Body Region	Farmers n (%)	Non-farmers n (%)
Neck	6 (60%)	3 (30%)
Shoulder	7 (70%)	3 (30%)
Elbow	7 (70%)	0 (0%)
Wrist	5 (50%)	0 (0%)
Hand	6 (60%)	2 (20%)
Upper Back	8 (80%)	4 (40%)
Low Back	10 (100%)	5 (50%)
Knee	8 (80%)	4 (40%)

C. Electromyographic Assessment of Muscle Fatigue

TABLE 3. COMPARISON OF MPF DECLINE BETWEEN PEARL MILLET FARMERS AND NON-AGRICULTURAL WORKERS

Muscle	Farmers Mean ± SD (Hz)	Non-farmers Mean ± SD (Hz)	Mean Difference (Hz)	t	df	p
Left Erector Spinae	−25.84 ± 2.08	−6.50 ± 1.72	−19.34	−22.666	17.37	< .001
Right Erector Spinae	−9.20 ± 1.75	−3.20 ± 0.92	−6.00	−9.594	13.61	< .001
Left External Oblique	−22.50 ± 2.46	−5.00 ± 1.41	−17.50	−19.498	14.36	< .001
Right External Oblique	−23.80 ± 2.30	−6.00 ± 1.41	−17.80	−20.849	14.96	< .001

The results demonstrated substantially greater MPF reductions among pearl millet farmers across all four monitored muscles. The differences between farmers and non-farmers were statistically significant for the left erector spinae, right erector spinae, left external oblique, and right external oblique muscles ($p < .001$ in each case).

D. Handgrip Strength Assessment

Handgrip strength was assessed separately for the right and left hands using the mean of three trials for each participant.

TABLE 4. COMPARISON OF HANDGRIP STRENGTH BETWEEN GROUPS

Hand	Farmers Mean ± SD (kg)	Non-farmers Mean ± SD (kg)	Mean Difference (kg)	t	df	p
Right	8.80 ± 2.39	4.85 ± 1.65	3.95	4.295	15.98	.00056
Left	6.58 ± 0.88	4.66 ± 0.17	1.92	6.779	9.68	.000057

Pearl millet farmers demonstrated greater handgrip strength than non-agricultural workers in both hands. The difference was statistically significant for the right hand ($t = 4.295$, $p = .00056$) as well as the left hand ($t = 6.779$, $p = .000057$).

V. DISCUSSION

The present study demonstrated a significantly greater WMSD burden among pearl millet farmers compared with non-agricultural workers. The mean WMSD burden score was substantially higher among farmers, and the Mann–Whitney U test confirmed a statistically significant difference between the two groups ($U = 100.00$, $p < .001$). This finding suggests that the occupational demands associated with pearl millet farming are accompanied by greater involvement of multiple musculoskeletal regions.

Among the assessed body regions, the low back was the most frequently affected region among farmers, with all ten farmers reporting symptoms. The upper back and knees were also frequently affected. This distribution is consistent with the physical demands associated with agricultural work involving repetitive movements and sustained or awkward postures. However, because the present study employed a cross-sectional design, the findings demonstrate an association between occupational group and WMSD burden rather than establishing a causal relationship.

The electromyographic findings provided objective evidence of substantially greater MPF decline among farmers across all four monitored trunk muscles. The left erector spinae showed the largest group difference, followed by the right external oblique, left external oblique, and right erector spinae. All four comparisons were statistically significant at $p < .001$. The confidence intervals excluded zero and the calculated effect sizes indicated very large differences between the groups. These findings indicate a substantially greater degree of fatigue-related electromyographic change among the farmers.

The handgrip-strength findings showed a different pattern. Farmers demonstrated significantly greater grip strength than non-agricultural workers in both the right and left hands. The difference was statistically significant for the right hand ($t = 4.295$, $p = .00056$) and the left hand ($t = 6.779$, $p = .000057$). The very large effect sizes further indicate that the observed group differences were substantial.

Taken together, these findings suggest that greater functional handgrip strength among farmers does not necessarily correspond to a lower overall musculoskeletal burden or lower trunk-muscle fatigue. Rather, the findings point to the coexistence of greater muscular capacity in the hands with greater occupational musculoskeletal burden and fatigue-related changes in the trunk muscles.

The findings of the present study demonstrate that pearl millet farmers experienced a significantly greater Work- Musculoskeletal Disorder than non-agricultural workers. The low back was the most frequently affected body region among farmers, followed by the upper back. The significantly higher overall Work-Musculoskeletal Disorder among farmers indicates substantial musculoskeletal involvement across multiple body regions. Thus, indicating that pearl millet farmers experienced significantly greater Work-related Musculoskeletal Disorder than non-agricultural workers.

VI. CONCLUSION

The sEMG findings further demonstrated significantly greater MPF decline among farmers across the left and right erector spinae and external oblique muscles. The very large effect sizes observed across all four muscles indicate substantial differences in fatigue-related electromyographic changes between the occupational groups. Therefore, indicating that electromyographic muscle fatigue, as reflected by MPF decline, differed significantly between pearl millet farmers and non-agricultural workers.

At the same time, farmers demonstrated significantly greater handgrip strength in both hands than non-agricultural workers. This suggests that greater occupationally associated handgrip capacity does not necessarily protect workers from broader musculoskeletal burden or trunk-muscle fatigue. Therefore, this indicating a statistically significant difference in handgrip strength between pearl millet farmers and non-agricultural workers, with farmers demonstrating greater grip strength in both hands.

It is possible that the occurrence of MSD among agricultural workers is related to the workers' posture, the length of time spent at work, and the tools they use. It was low back pain that was the main issue when performing the various bajra cultivation tasks. It was a major contributor to sickness and absenteeism. Occupational hazards can permanently alter discs, apophyses, ligaments, and other structures of the musculoskeletal system. Due to poor economic condition the workers were deprived of proper nutrition and could not avail suitable treatment for different health problems. Thus, musculoskeletal disorders became intensified. The following may be helpful for reducing the low back pain and problems of dust particles:

1) Low back pain and upper leg disorder might be reduced primarily by maintain proper work-rest scheduled during performing different bajra cultivation tasks.
2) Relief from low back pain can be obtained by lying in the supine position, grasping the knees and then squeezing the thighs against the chest for about five seconds and obtained other types of exercise.
3) The conservative treatment of low back pain ultimately rests and proper education.
4) Acute-severe low back pain problems respond to bed rest.
5) For avoiding the dust particles they should use low-cost musk and sunglass during performing threshing jobs. As an alternative workers may use cloth piece covering the nose and mouth.
6) Awareness program for educating the workers regarding ill effects of adopting awkward work posture.

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