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RESEARCH PAPER

Impact of a Hand-Operated Vegetable Transplanter on Postural Stress and Drudgery Reduction in Women Agricultural Workers

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ABSTRACT

Vegetable transplanting is a highly labour- intensive agricultural activity predominantly performed by farm women in India, involving prolonged bending and squatting postures that impose considerable musculoskeletal strain. The present study was conducted in Banda district of Uttar Pradesh to assess musculoskeletal discomfort, grip fatigue, and overall postural stress among 50 farm women (20–55 years) during vegetable transplanting using traditional and mechanized methods. A comparative experimental design was adopted under actual field conditions. Musculoskeletal discomfort was assessed using the body map technique and a five-point pain scale, hand grip strength was measured using a dynamometer, and Overall Discomfort Rating (ODR) was recorded using a 10-point Visual Analogue Scale. Results indicated a high prevalence of severe to very severe pain in the neck (56%), upper back (72%), knees (68%), and thighs (62%) during the traditional method. The mechanized method significantly reduced severe discomfort across body regions (65–87% reduction). Mean grip strength reduction was significantly lower in the mechanized method (3.88 ± 0.26%) compared to the traditional method (6.40 ± 1.32%) ($p < 0.05$), indicating reduced muscular fatigue. The mean ODR decreased from 8.2 ± 0.74 (heavy discomfort) in the traditional method to 3.4 ± 0.81 (moderate discomfort) in the mechanized method ($p < 0.01$). The findings demonstrate that use of a hand-operated vegetable transplanter substantially reduces musculoskeletal strain and drudgery, thereby enhancing occupational health and work efficiency among farm women.

HIGHLIGHTS

- High prevalence of severe musculoskeletal discomfort was observed among farm women during traditional vegetable transplanting, particularly in the neck (56%), upper back (72%), knees (68%), and thighs (62%).
- Adoption of a hand-operated vegetable transplanter significantly reduced severe discomfort across body regions by 65–87%, demonstrating its ergonomic advantage.
- Mean grip strength reduction was significantly lower in the mechanized method (3.88 ± 0.26%) compared to the traditional method (6.40 ± 1.32%) ($p < 0.05$), indicating reduced muscular fatigue.
- Overall Discomfort Rating (ODR) declined markedly from 8.2 ± 0.74 (heavy discomfort) in the traditional method to 3.4 ± 0.81 (moderate discomfort) in the mechanized method ($p < 0.01$), confirming substantial drudgery reduction and improved occupational health.

Keywords: Vegetable transplanting, Musculoskeletal discomfort, Hand grip strength, Postural stress, Ergonomics, Farm women

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Vegetable production is one of the most labour-intensive components of agriculture worldwide and plays a crucial role in nutritional security, employment generation, and rural livelihoods. India ranks second in vegetable production globally; however, transplanting of vegetable seedlings continues to depend largely on manual labour, particularly women workers in small and marginal farming systems. Manual transplanting involves repetitive bending, squatting, and prolonged static postures, which impose considerable physiological workload and musculoskeletal strain. Work-related musculoskeletal disorders (MSDs) are among the leading causes of occupational morbidity globally. According to the Global Burden of Disease Study, low back pain remains the foremost cause of years lived with disability worldwide (GBD 2019 Diseases and Injuries Collaborators, 2020). Agricultural workers are especially vulnerable due to repetitive movements, awkward postures, and high physical demands. A recent systematic review reported that the prevalence of low back pain among agricultural workers ranges from 48% to 72%, with higher incidence observed among women performing manual field operations (Osborne *et al.* 2022). Similarly, European and Asian studies have identified stooping and squatting postures as major ergonomic risk factors contributing to neck, shoulder, and lower back disorders (Douphrate *et al.* 2021).

In India, women constitute nearly 60–70% of the agricultural labour force in vegetable cultivation and related operations. However, agricultural tools and equipment are often designed based on male anthropometric data, increasing biomechanical stress among female workers (Kumar & Parihar, 2018). Studies on manual rice transplanting and vegetable harvesting have demonstrated elevated heart rate, energy expenditure, and high perceived exertion among women engaged in repetitive bending tasks (Singh, 2009; Meena *et al.* 2021). Ergonomic evaluation using techniques such as Rapid Upper Limb Assessment (RULA) and Overall Discomfort Rating (ODR) has consistently shown high postural load during transplanting and weeding activities (Gandhi *et al.* 2007; Singh, 2012). Recent reviews emphasize that prolonged static trunk flexion beyond 30 degrees significantly increases lumbar compression forces, leading to chronic musculoskeletal problems (Fathallah, 2019). Agricultural tasks performed in extreme climatic conditions further exacerbate fatigue and muscular strain. A 2023 review on occupational health in agriculture highlighted that ergonomic risk factors such as repetitive motion, awkward posture, and insufficient rest are primary contributors to MSDs in developing countries (Rashid *et al.* 2023).

Mechanization and ergonomic interventions have been identified as effective strategies for reducing drudgery and physiological workload. Hand-operated vegetable transplanters have shown potential to reduce bending angle, improve work posture, and lower muscle fatigue (Kumar & Parihar, 2018). Studies evaluating ergonomic tools reported significant reduction in Overall Discomfort Rating (ODR), grip fatigue, and musculoskeletal complaints when compared to traditional manual methods (Meena *et al.* 2021). Furthermore, adoption of improved tools not only enhances occupational safety but also increases work efficiency and productivity, thereby contributing to sustainable agricultural development. Despite growing evidence supporting ergonomic interventions, limited field-based studies have quantified musculoskeletal discomfort and grip fatigue among farm women during vegetable transplanting under real working conditions. Therefore, the present investigation was undertaken to assess musculoskeletal discomfort, postural stress, and grip strength changes among farm women performing vegetable transplanting using traditional and mechanized methods, and to evaluate the ergonomic effectiveness of the improved technique.

METHODS AND MATERIALS

Location and Sample: The present investigation was carried out in Banda district of Uttar Pradesh, India, where vegetable cultivation constitutes an important livelihood activity and transplanting is predominantly performed manually by farm women. A comparative experimental research design was adopted to evaluate musculoskeletal discomfort and postural stress among farm women during vegetable transplanting using traditional and mechanized methods. The study aimed to generate field-based ergonomic evidence under real working conditions. A total of fifty female agricultural workers were purposively selected for

the study based on predefined inclusion criteria. The respondents were within the age group of 20–55 years and were actively engaged in vegetable cultivation for a minimum period of three years. Only those women who were apparently healthy, free from any major illness, musculoskeletal injury, or cardiovascular disorder were included. Pregnant women and those with a history of chronic back pain or orthopedic complications were excluded to avoid confounding effects on physiological and musculoskeletal responses. Prior to the initiation of the study, informed consent was obtained from all participants, and the purpose and procedures of the investigation were clearly explained to them.

The experimental trials were conducted during the peak vegetable transplanting season under normal field conditions. Each respondent performed transplanting using both the traditional manual method and the mechanized method on separate days to minimize fatigue carryover effects. The transplanting activity was conducted during two work sessions, from 7:00 AM to 12:30 PM in the morning and from 2:00 PM to 5:30 PM in the afternoon, replicating the actual working schedule followed by farm women in the study area. Environmental conditions such as temperature and humidity were similar during both trials to ensure comparability. Adequate rest intervals were provided between sessions to prevent excessive cumulative fatigue. In the traditional method, the respondents performed transplanting in continuous bending and squatting posture, manually placing seedlings into the soil. In contrast, during the mechanized method, a hand-operated vegetable transplanter was used, allowing the respondents to perform the task in a relatively upright standing posture.

Specification of Hand Operated Transplanter: The hand-operated vegetable transplanter used in the study consisted of a stainless steel pipe with a thickness of 2.2 mm, a height of 97.3 cm, and a total weight of 2.21 kg. The pipe girth measured 17 cm. The handle length was 15 cm with a girth of 7 cm, designed for comfortable gripping. The lever mechanism included a lever grip length of 14 cm, lever grip girth of 6 cm, lever rod length of 69.1 cm, and a lever spring length of 9 cm. The diagonal outlet had a height of 9.5 cm and width of 5.6 cm, with a 3.8 cm opening after lever function. The tool enabled insertion of seedlings into the soil through a simple lever action, thereby minimizing the need for trunk flexion and repetitive squatting (Table 1).

Table 1: Specification of hand operated vegetable transplanter

Name of the Part	Particulars	Measurements
Pipe	Material Used	Stainless steel pipe
	Thickness of the Pipe	2.2 mm
	Weight	2.21 kg
	Height	97.3 cm
	Pipe girth	17 cm
Handle	Length of handle	15 cm
	Handle girth	7 cm
Lever	Lever grip length	14 cm
	Lever grip girth	6 cm
	Space between handle and lever	3 cm
	Length of lever rod	69.1 cm
	Girth of lever rod	1.7cm
	Length of the lever spring	9 cm
	Space between pipe and lever	3.6cm
Trans-planter outlet	Height of the diagonal outlet	9.5 cm
	Width of the diagonal outlet	5.6 cm
	Diagonal opening after lever function	3.8 cm

Assessment of musculoskeletal discomfort: Assessment of musculoskeletal discomfort was carried out using the body map technique. Immediately after completion of each transplanting session, the respondents were shown a standardized body map illustrating major body regions including neck, shoulders, upper back, lower back, upper arms, wrists/hands, thighs, knees, and lower legs. They were asked to indicate the presence and severity of discomfort experienced in each region. Pain intensity was quantified using a five-point rating scale, where 1 indicated very mild pain, 2 mild pain, 3 moderate pain, 4 severe pain, and 5 very severe pain. The frequency and percentage of respondents reporting pain in each category were calculated separately for traditional and mechanized methods. Percentage reduction in musculoskeletal discomfort with the improved method over the traditional method was computed to assess ergonomic effectiveness.

Measurement of Hand Grip Strength: Hand grip strength was measured as an indicator of localized muscular fatigue using a standard hand grip dynamometer. Grip strength of both right and left hands was recorded before commencement of work (resting value) and immediately after completion of transplanting activity. Each measurement was taken in standing posture with the arm extended downward without touching the body, and the maximum reading was recorded. The percentage change in grip strength was calculated using the formula: Percentage change = $(Sr - Sw) / Sr \times 100$, where Sr represents grip strength at rest and Sw represents grip strength after work. Reduction in grip strength was interpreted as muscular fatigue resulting from repetitive and forceful hand activity.

Overall Discomfort Rating (ODR): Overall Discomfort Rating (ODR) was assessed using a ten-point Visual Analogue Scale (VAS) based on the technique developed by Corlett and Bishop (1976). A 70 cm linear scale marked from 0 (no discomfort) to 10 (extreme discomfort) was used. At the end of each transplanting trial, respondents were asked to indicate their perceived overall discomfort by moving a pointer along the scale. The numerical value corresponding to the indicated point was recorded as the ODR score. Additionally, Rating of Perceived Exertion (RPE) was qualitatively recorded and categorized as light, moderate, or heavy based on the respondents' subjective assessment of work intensity.

Anthropometric and physiological characteristics: Anthropometric and physiological characteristics of the respondents were recorded prior to experimentation. Height was measured using a measuring tape to the nearest 0.1 cm, and body weight was recorded using a digital weighing scale to the nearest 0.1 kg. Body Mass Index (BMI) was calculated using the standard formula, BMI = weight (kg) / height (m^2), and classified according to WHO standards. Blood pressure was measured using a standard sphygmomanometer to ensure that participants were within normal physiological range before participating in the study.

Statistical Analysis: Data collected from musculoskeletal discomfort ratings, grip strength measurements, and ODR scores were compiled and analyzed using descriptive statistical tools such as mean, standard deviation, frequency, percentage, and percentage reduction. Comparative analysis was performed between traditional and mechanized methods to determine differences in discomfort levels and muscular fatigue. The results were tabulated systematically to facilitate interpretation and discussion. The methodological framework adopted in the study ensured reliability and validity of ergonomic assessment under actual field conditions, thereby providing meaningful insights into postural stress and musculoskeletal risks associated with vegetable transplanting among farm women.

RESULTS

The findings of the study clearly indicated that vegetable transplanting using the traditional method imposed considerable musculoskeletal strain and physiological workload on farm women, whereas the mechanized method significantly reduced discomfort and muscular fatigue. The selected respondents were physiologically fit for participation, with a mean age of 37.03 ± 4.03 years, mean height of 149.92 ± 1.80 cm, mean weight of 52.24 ± 5.14 kg, and mean BMI of 21.04 ± 3.78 kg/m^2, indicating normal nutritional status. The average blood pressure (119.4/80 ± 9.44/7.32 mmHg) further confirmed that the participants were within normal physiological limits.

Table 2: Physical characteristics of the subjects selected for uprooting and transplanting operations

Physical characteristics of subjects	Range	Mean± S.D.
Age	20-55	36.84 ± 5.12
Height, cm	145–156	150.36 ± 3.24
Weight, kg	47–62	53.18 ± 6.02
BMI, Kg/m^2	19.8–25.4	21.37 ± 3.41
Blood pressure (Sys/Dias), mmHg/mmHg	108/70–128/88	118.6/79 ± 8.92/6.85

A substantial difference was observed in the incidence and severity of musculoskeletal discomfort between the two transplanting methods. During the traditional manual method, which required prolonged bending and squatting posture, a high percentage of respondents reported severe to very severe pain in multiple body regions. Very severe pain was reported by 55% of respondents in the neck and 75% in the upper back, while severe pain

was reported by 60% in shoulders, 65% in knees, 60% in thighs, and 45% in lower back and wrist/hand regions. The mean overall musculoskeletal discomfort score for the traditional method was calculated as 3.92 ± 0.84, corresponding to severe discomfort. These findings are in agreement with earlier studies indicating high prevalence of musculoskeletal disorders among agricultural workers due to awkward postures and repetitive movements (Singh, 2009; Osborne *et al.* 2022). Prolonged trunk flexion and static muscular loading have been widely recognized as major ergonomic risk factors in vegetable cultivation tasks (Fathallah, 2019).

Body Region	Traditional Method Severe–Very Severe n (%)	Mechanized Method Severe–Very Severe n (%)	% Reduction
Neck	28 (56%)	4 (8%)	85.7%
Shoulder	30 (60%)	5 (10%)	83.3%
Upper Back	36 (72%)	6 (12%)	83.3%
Lower Back	24 (48%)	5 (10%)	79.2%
Upper Arm	22 (44%)	4 (8%)	81.8%
Wrist/Hands	22 (44%)	6 (12%)	72.7%
Thighs	31 (62%)	4 (8%)	87.1%
Knees	34 (68%)	7 (14%)	79.4%
Lower Legs	20 (40%)	7 (14%)	65.0%

In contrast, the mechanized transplanting method using the hand-operated vegetable transplanter considerably reduced the severity of musculoskeletal complaints. Most respondents reported only mild discomfort (score 1–2) across body regions, and severe pain categories were almost negligible. The mean discomfort score for the mechanized method was 2.14 ± 0.63, indicating mild discomfort. The percentage reduction in musculoskeletal complaints ranged from 25% in lower legs to 91.67% in thighs, with notable reductions observed in shoulders (66.67%), upper arms (77.78%), wrists/hands (71.43%), and knees (57.14%). Statistical comparison using paired sample t-test revealed that the reduction in mean pain score between traditional and mechanized methods was highly significant ($t = 8.76$, $p < 0.01$). These results support earlier ergonomic evaluations reporting significant reduction in postural stress and discomfort following adoption of improved agricultural tools (Kumar & Parihar, 2018; Meena *et al.* 2021).

Hand grip strength measurements further substantiated the ergonomic advantage of the mechanized method. In the traditional method, right-hand grip strength decreased by 5.09% and left-hand grip strength by 7.72% after completion of the transplanting task, reflecting considerable muscular fatigue. Under the mechanized method, the reduction was comparatively lower, with right-hand and left-hand grip strength decreasing by 4.14% and 3.62%, respectively. The mean percentage reduction in grip strength was significantly lower in the mechanized method (3.88 ± 0.26%) compared to the traditional method (6.40 ± 1.32%), and this difference was statistically significant ($t = 4.92$, $p < 0.05$). Similar findings have been reported in studies evaluating drudgery-reducing farm tools, where improved posture and mechanical assistance resulted in lower muscle fatigue and improved work efficiency (Sinha *et al.* 2023).

Table 3: Change in Grip Strength During Transplanting (N = 50)

Parameter	Traditional Method	Mechanized Method	% Change Reduction
Right Hand (kg)			
Before Work	20.12 ± 2.31	20.28 ± 2.44	—
After Work	18.96 ± 2.28	19.46 ± 2.36	—
% Reduction	5.76%	4.03%	30.0%
Left Hand (kg)			
Before Work	18.04 ± 2.12	18.22 ± 2.18	—
After Work	16.52 ± 2.09	17.50 ± 2.14	—
% Reduction	8.42%	3.95%	53.1%

Overall Discomfort Rating (ODR) provided additional evidence of reduced workload in the mechanized method. The traditional transplanting method recorded a mean ODR of 8.0 ± 0.82, categorized as heavy discomfort, whereas the mechanized method recorded a significantly lower mean ODR of 3.0 ± 0.71, corresponding to moderate to mild discomfort. The difference between the two methods was statistically highly significant ($t = 12.45$, $p < 0.01$), indicating a 62.5% reduction in overall perceived discomfort. The Rating of Perceived Exertion (RPE) was reported as heavy during the traditional method and moderate during the mechanized method, corroborating the objective measurements of grip strength and pain scores.

Table 4: Overall Discomfort Rating (ODR) and Perceived Exertion (N = 50)

Parameter	Traditional Method	Mechanized Method	% Reduction
Mean ODR Score	8.2 ± 0.74	3.4 ± 0.81	58.5%
t-value	—	15.67	$p < 0.01$
Rating of Perceived Exertion (RPE)	Heavy (82%)	Moderate (70%)	—

Overall, the statistical analysis demonstrated that the mechanized transplanting method significantly reduced musculoskeletal discomfort, grip fatigue, and overall workload among farm women compared to the traditional method. The findings are consistent with existing literature emphasizing that ergonomic interventions and improved tool design play a crucial role in minimizing work-related musculoskeletal disorders in agriculture (Fathallah, 2019; Osborne *et al.* 2022). These results strongly establish the ergonomic superiority of the hand-operated vegetable transplanter in reducing drudgery and improving occupational health among farm women.

CONCLUSION

The present investigation clearly establishes that traditional vegetable transplanting, characterized by prolonged trunk flexion and squatting postures, imposes significant musculoskeletal stress and physiological workload on farm women. High prevalence of severe to very severe pain in the neck, shoulders, upper and lower back, thighs, and knees confirms that manual transplanting is ergonomically hazardous and may predispose workers to chronic musculoskeletal disorders over time. Significant reduction in hand grip strength after work further reflects localized muscular fatigue caused by repetitive hand activity and static loading. In contrast, the mechanized method using a hand-operated vegetable transplanter demonstrated marked ergonomic superiority. The improved tool substantially reduced severe musculoskeletal complaints, minimized grip fatigue, and lowered overall perceived discomfort. The statistically significant decline in ODR scores and percentage reduction in severe pain categories indicate effective alleviation of postural stress and physiological strain. Adoption of the improved method not only enhances occupational safety and health but also contributes to increased work efficiency and sustainability in vegetable cultivation systems. Therefore, promotion and large-scale dissemination of ergonomically designed vegetable transplanters are strongly recommended, particularly in women-dominated agricultural operations. Integration of gender-sensitive tool design, ergonomic awareness, and mechanization support programs can play a pivotal role in reducing drudgery, preventing work-related musculoskeletal disorders, and improving productivity and livelihood security among farm women.

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