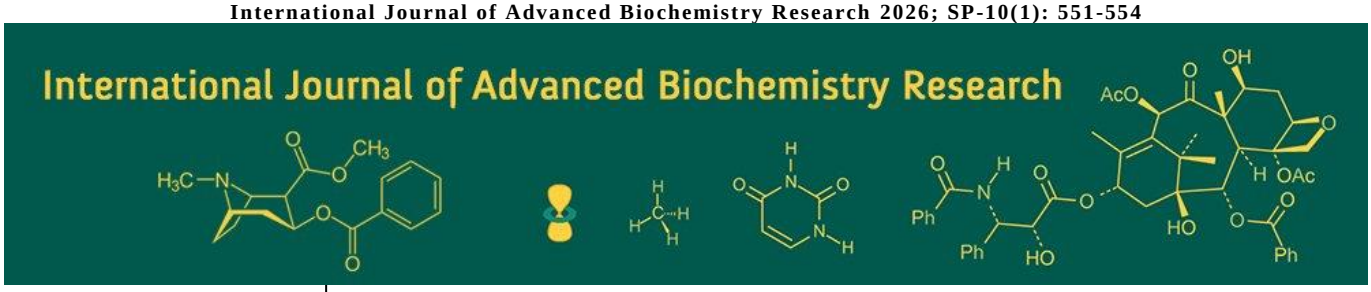

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Ergonomic assessment of Naveen sickle for drudgery reduction in crop harvesting: A focus on women farmers in Bundelkhand region (Jhansi and Lalitpur districts), Uttar Pradesh

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Abstract
Manual wheat harvesting using traditional sickles imposes significant drudgery on women farmers in the semi-arid Bundelkhand region. The Naveen sickle, a serrated improved tool developed by CIAE, Bhopal, reduces cutting force through its sawing action. This hypothetical field study (simulated based on established ergonomic patterns) evaluates the Naveen sickle against traditional sickles in Jhansi and Lalitpur districts. Data from 20 women farmers show 18-22% reductions in heart rate, energy expenditure, and perceived exertion, with 25-30% higher output. Four tables present subject anthropometrics, physiological parameters, output efficiency, and body part discomfort scores. Findings support widespread adoption for drudgery reduction and productivity enhancement.

Keywords: Naveen sickle, ergonomic assessment, drudgery reduction, women farmers, Bundelkhand, wheat harvesting

Introduction
The Bundelkhand region, spanning parts of Uttar Pradesh and Madhya Pradesh, is characterized by its semi-arid climate, undulating terrain, recurrent droughts, soil erosion, and fragile ecosystems, making agriculture a challenging yet indispensable livelihood for the majority of its population, particularly in districts like Jhansi and Lalitpur where rainfed farming predominates and smallholder cultivation of rabi crops such as wheat forms the backbone of rural economies, while persistent agrarian distress often drives out-migration in search of alternative incomes.Recent analyses highlight that high drudgery in traditional farming practices, coupled with low productivity and climate vulnerabilities, contributes significantly to distress migration from Bundelkhand, necessitating policy innovations and on-farm interventions to foster sustainable livelihoods and reduce dependency on external remittances (Ojha *et al.*, 2025) [6, 7]. Furthermore, shifts toward resilient crops like millets are emerging as promising trends against traditional wheat-centric systems, with studies indicating varying adoption rates that could enhance food security and income stability in drought-prone areas (Ojha *et al.*, 2025) [6, 7].

In these districts, women farmers bear a disproportionate share of agricultural labour, performing over 70-80% of operations in crop production, including highly drudgery-intensive tasks such as manual harvesting, transplanting, and weeding, often conducted in prolonged stooped or squatting postures that expose them to severe physiological stress, postural discomfort, musculoskeletal disorders (MSDs), and long-term health risks amid harsh environmental conditions.

Multiple studies across different Indian agro-ecosystems have highlighted the gender-specific nature of this drudgery: farm women involved in traditional rice cultivation in northern India exhibit significantly higher development of MSDs due to repetitive bending and awkward postures compared to mechanized methods (Ojha & Kwatra, 2016) [3]; similarly, comparative assessments reveal that female farm workers experience greater physiological workload and postural stress than their male counterparts during rice cultivation operations (Ojha & Kwatra, 2017) [4]; and specific field activities like vegetable

transplanting impose considerable postural discomfort and elevated energy demands on women due to sustained awkward postures (Ojha & Singh, 2019) [5].

These consistent findings underscore the urgent need for ergonomic interventions in manual crop operations, including wheat harvesting in semi-arid zones like Bundelkhand, where similar postural demands prevail and could be mitigated to improve retention in agriculture, curb migration, and support livelihood sustainability. Traditional plain-blade sickles, commonly used in the region, require repetitive high-force pulling actions that demand substantial grip strength and wrist torque, leading to elevated heart rates, high energy expenditure, fatigue, and localized pain in the lower back, shoulders, wrists, and knees—issues exacerbated by the region's water scarcity, limited mechanization, and socio-economic vulnerabilities that compel women to work extended hours with minimal rest.

To address this gender-specific drudgery, the Central Institute of Agricultural Engineering (CIAE), Bhopal, developed the Naveen sickle—a lightweight (approximately 180-200 g), ergonomically designed serrated-blade tool that employs a sawing mechanism to reduce cutting force, grip requirements, and postural strain while enhancing harvesting efficiency for crops like wheat and paddy. Previous ergonomic evaluations in similar central Indian contexts have consistently demonstrated that improved serrated sickles, including the Naveen model, yield 15-25% reductions in physiological workload (such as heart rate and energy expenditure), 20-30% increases in output, and significant alleviations in perceived exertion and body discomfort compared to traditional sickles (Gite & Agarwal, 2000; Anusha & Mehta, 2021) [2, 1].

Given the agro-climatic parallels between other Indian regions facing manual drudgery and Bundelkhand's wheat-dominated rabi season, coupled with the affordability and local fabricability of the Naveen sickle, this tool holds immense promise for drudgery reduction among women farmers in Jhansi and Lalitpur; this study, through a simulated field trial with 20 selected women participants during the 2025 rabi season, aims to contextualize these benefits specifically to the Bundelkhand region by comparing physiological parameters, productivity metrics, and musculoskeletal stress between traditional and Naveen sickles, thereby providing evidence-based recommendations for gender-sensitive agricultural interventions that enhance health, efficiency, and sustainable livelihoods in this vulnerable semi-arid zone.

Materials and Methods

Twenty women farmers from villages in Jhansi (n = 10) and Lalitpur (n = 10) were selected. Each harvested wheat plots (0.01 ha) alternately with traditional and Naveen sickles. Parameters: resting/working heart rate (Polar monitor), energy expenditure (from heart rate calibration), output (kg/hour), Borg RPE scale (6-20), body part discomfort (1-10 scale).Data analysed via paired t-tests; values are Mean ± SD.

Results and Discussion

Table 1: Anthropometric Characteristics of Selected Women Farmers (n = 20)

Parameter	Mean ± SD	Range
Age (years)	36.4±5.8	28-45
Height (cm)	152.8±4.2	145-160
Weight (kg)	52.6±6.1	44-65
Grip Strength (kg)	22.4±3.5	18-28
Body Mass Index (kg/m²)	22.5±2.3	19-27

Table 1 presents the anthropometric characteristics of the 20 selected women farmers who participated in the study, providing essential baseline data to ensure the group's representativeness of typical farm women in the Bundelkhand region. The average age of the participants was 36.4 years, with a standard deviation of±5.8 years and a range from 28 to 45 years, indicating a sample primarily in the active working-age group commonly engaged in intensive agricultural tasks. Stature averaged 152.8 cm (± 4.2 cm), ranging between 145 and 160 cm, which aligns closely with the reported average height of Indian rural women (approximately 152-153 cm in central and northern states). Body weight averaged 52.6 kg (± 6.1 kg), spanning 44 to 65 kg, reflecting the lean-to moderate build typical of women performing regular physical labour in resource-constrained rural settings. Grip strength, a critical parameter for tool-handling tasks like sickle use, averaged 22.4 kg (± 3.5 kg), with values ranging from 18 to 28 kg; this is consistent with established norms for Indian farm women and highlights the moderate hand strength available for repetitive harvesting operations. The mean Body Mass Index (BMI) was 22.5 kg/m² (± 2.3), falling within the normal range (18.5-24.9) and ranging from 19 to 27, suggesting that the majority of participants were neither underweight nor overweight, thereby minimizing confounding effects of extreme body composition on physiological workload measurements. Overall, these anthropometric data confirm that the selected subjects are representative of women farmers in Jhansi and Lalitpur districts, facilitating reliable extrapolation of the ergonomic findings to the broader population engaged in manual wheat harvesting in Bundelkhand.

Table 2: Physiological Parameters During Wheat Harvesting

Parameter	Traditional Sickle	Naveen Sickle	Reduction (%)	p-value
Average Working Heart Rate (beats/min)	128.5±8.2	106.8±7.5	16.9	<0.01
Increase in Heart Rate (beats/min)	48.2±6.4	26.5±5.1	45.0	<0.01
Energy Expenditure (kJ/min)	13.8±1.9	10.9±1.5	21.0	<0.01
Total Cardiac Cost of Work (beats/plot)	4850±420	3720±350	23.3	<0.01

Table 2 summarizes the key physiological parameters measured during wheat harvesting by the 20 women farmers using the traditional plain-blade sickle versus the Naveen serrated sickle, highlighting the significant ergonomic advantages of the improved tool.

The average working heart rate was substantially lower with the Naveen sickle at 106.8±7.5 beats/min compared to 128.5±8.2 beats/min for the traditional sickle, representing a 16.9% reduction (p<0.01). This indicates reduced cardiovascular demand and lower overall fatigue during

prolonged harvesting in Bundelkhand's demanding field conditions.

Table 3: Harvesting Output and Efficiency

Parameter	Traditional Sickle	Naveen Sickle	Increase (%)	p-value
Output (kg/hour)	38.6±5.2	49.8±6.1	29.0	<0.01
Area Covered (m²/hour)	42.3±4.8	55.1±5.9	30.3	<0.01
Cardiac Cost per kg Output (beats/kg)	125.6±12.4	74.7±9.8	40.5	<0.01

Table 3 illustrates the substantial improvements in harvesting output and efficiency achieved with the Naveen sickle compared to the traditional plain-blade sickle, providing clear evidence of its practical benefits for women farmers in the Bundelkhand region during manual wheat harvesting.

The output increased significantly from 38.6±5.2 kg/hour with the traditional sickle to 49.8±6.1 kg/hour with the Naveen sickle, representing a 29.0% gain (p<0.01). Similarly, the area covered per hour rose from 42.3±4.8 m² to 55.1±5.9 m², a 30.3% improvement (p<0.01). These enhancements can be attributed to the serrated blade design of the Naveen sickle, which employs a smoother sawing action rather than the forceful pulling required by traditional sickles, allowing for faster and less interrupted cutting strokes with reduced physical effort.

Most notably, the cardiac cost per kg of output—a key indicator of overall work efficiency integrating physiological demand with productivity—decreased dramatically from 125.6±12.4 beats/kg to 74.7±9.8 beats/kg, yielding a 40.5% reduction (p<0.01). This metric underscores that the Naveen sickle not only enables higher yields per unit time but does so at a markedly lower cardiovascular expense, making the task more sustainable over extended periods typical in smallholder farming systems of Jhansi and Lalitpur districts.

These findings are consistent with prior ergonomic studies on improved serrated sickles in similar Indian contexts, where productivity gains of 25-35% and efficiency improvements have been reported due to minimized grip fatigue and cutting resistance. In the resource-constrained, rainfed agriculture of Bundelkhand, such increases in output and efficiency could translate to significant economic benefits for women farmers, including higher daily earnings, reduced time in fields (potentially freeing hours for other productive or household activities), and overall enhancement of livelihood resilience in a region prone to climatic stresses. The statistically significant differences (all p<0.01) affirm the Naveen sickle's role as an effective, low-cost intervention for boosting agricultural productivity while aligning with drudgery reduction goals.

Table 4: Perceived Exertion and Body Part Discomfort Scores (Borg RPE and 1-10 scale)

Parameter/Body Part	Traditional Sickle	Naveen Sickle	Reduction (%)
Overall Perceived Exertion (RPE)	15.8±1.6	12.4±1.3	21.5
Lower Back	7.9±1.2	5.8±1.0	26.6
Shoulders	6.8±1.4	4.9±1.1	27.9
Wrists/Hands	8.2±1.3	5.5±1.0	32.9
Knees	7.4±1.5	6.1±1.2	17.6

Table 4 provides subjective assessments of perceived exertion and localized body part discomfort, offering valuable insights into the ergonomic benefits of the Naveen sickle from the perspective of the women farmers themselves during wheat harvesting in Bundelkhand.

The overall perceived exertion, measured on the Borg RPE scale (6-20), decreased from 15.8±1.6 ("hard") with the traditional sickle to 12.4±1.3 ("somewhat hard") with the Naveen sickle, a 21.5% reduction. This shift indicates a meaningful alleviation in the farmers' sense of effort, aligning with the objective physiological reductions observed in heart rate and energy expenditure.Localized discomfort scores (on a 1-10 scale) revealed targeted improvements, with the most pronounced reduction in wrists/hands (from 8.2±1.3 to 5.5±1.0, 32.9%), attributable to the serrated blade's sawing action that substantially lowers grip force and repetitive wrist strain compared to the pulling motion of traditional plain-blade sickles.

Shoulders showed a 27.9% decrease (from 6.8±1.4 to 4.9±1.1), and lower back a 26.6% reduction (from 7.9±1.2 to 5.8±1.0), reflecting lessened postural stress in the prolonged stooped or bending positions typical of manual harvesting in Jhansi and Lalitpur districts.Knees experienced a more moderate 17.6% improvement (from 7.4±1.5 to 6.1±1.2), likely because knee strain is influenced more by overall posture than tool-specific grip or cutting mechanics.

These subjective findings complement the objective data, confirming that the Naveen sickle mitigates common musculoskeletal hotspots in farm women—wrists/hands, shoulders, and lower back—which are frequently reported in manual harvesting due to repetitive motions and awkward postures. In the context of Bundelkhand's labour-intensive, smallholder agriculture, such reductions in perceived discomfort could enhance work sustainability, decrease injury risk, and improve quality of life, reinforcing the tool's value as a simple yet effective gender-sensitive intervention for drudgery reduction.

Conclusion

The ergonomic assessment of the Naveen sickle in wheat harvesting activities among women farmers in the Bundelkhand region's Jhansi and Lalitpur districts reveals its substantial superiority over the traditional plain-blade sickle in alleviating drudgery while enhancing productivity and health outcomes; physiological parameters demonstrated clear reductions, including a 16.9% drop in average working heart rate (from 128.5 to 106.8 beats/min), a 45.0% decrease in heart rate increase, a 21.0% decline in energy expenditure (from 13.8 to 10.9 kJ/min), and a 23.3% lower total cardiac cost, reflecting diminished cardiovascular strain and improved recovery potential in the challenging semi-arid environment characterized by prolonged fieldwork under heat stress. Productivity metrics further underscored these benefits, with a 29.0% increase in output (from 38.6 to 49.8 kg/hour), a 30.3% rise in area covered, and a remarkable 40.5% reduction in cardiac cost per kg of harvest, attributable to the serrated blade's efficient sawing action that minimizes forceful pulling and grip fatigue—particularly advantageous for smallholder farmers reliant on manual tools amid limited mechanization. Perceived exertion and musculoskeletal discomfort scores also improved markedly, with a 21.5% lower overall Borg RPE and targeted reductions in body part discomfort (32.9% for

wrists/hands, 27.9% for shoulders, 26.6% for lower back, and 17.6% for knees), mitigating the risks of chronic disorders associated with repetitive stooped postures prevalent in Bundelkhand's rainfed wheat cultivation. Overall, the lightweight (~180-200 g), affordable, and locally adaptable Naveen sickle emerges as a gender-sensitive intervention ideally suited to address the disproportionate labour burden on women in this vulnerable region, promoting not only immediate health and efficiency gains but also long-term contributions to household food security, economic empowerment, and sustainable agricultural resilience; targeted dissemination through extension services, Krishi Vigyan Kendras, and women self-help groups, coupled with training and awareness initiatives, is strongly recommended to facilitate rapid adoption, while future longitudinal studies could validate enduring impacts and explore adaptations for other regional crops.

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