

## Original Research Article

### **Investigation of the Ergonomics and Workload of Women Operators in Planting and Weeding Operations**

#### **ABSTRACT**

The study was done to determine the anthropometric, physical, physiological, and workload characteristics of female operators during manual sowing and weeding activities for several medicinal plants. The planting and weeding activities were done using a shovel and a hand hoe. Anthropometric measurements were taken for women aged 20 to 50. The physiological fluctuations in chosen participants' energy and strength during different agricultural operations, as well as the implications in body part discomfort score, were evaluated. The average resting and working heart rates, EER, OCR, and BPDS are all measured to assess physiological characteristics. Female responders reported an average resting heart rate of 78.91 bpm for weeding and 81.46 bpm for planting. Planting and weeding had an average working heart rate of 100.85 and 97.14 (bpm, respectively). The average EER and OCR values for the relevant procedures were 6.35 and 5.31 (kJ/min) and 0.52 and 0.45 (l/min), respectively. The BPDS levels of the chosen participants were 19.5 and 21.4, respectively. The data imply that the workers were more compatible and comfortable when weeding using a hand hoe. Workers performed better in the same operation than in the digging and planting operations. For simple, feasible, and effective agricultural farm operations in rural areas of the country, ergonomics is critical in determining the quotidian functioning performance of respondents involved in farm operations, thereby ensuring appropriate efficiency in the man-machine interface.

**Keywords:** Workload, Pulse rate; ~~E~~energy expenditure; ~~and O~~oxygen consumption rate.

**Commented [SSPV1]:** Arrange in alphabetical order

#### **1. INTRODUCTION**

Indian farmers are increasingly concerned with properly carrying out different farm activities to increase production (Pandey, 2016; Pandey *et al.*, 2019). They prioritize agricultural output over safety and comfort (Goel *et al.*, 2008). The man-machine interaction should be harmonic enough to provide safe and dependable horticultural operations while increasing farmers' working efficiency (Sahoo *et al.*, 2017). Since ergonomics are employed in agriculture to analyze the performance of the working operators undertaking any agricultural process, it may be readily useful in horticulture operations as well (Benos *et al.*, 2020).

Ease of operation influences worker production (Gangopadhyay *et al.*, 2014). [Ergonomic-An ergonomic](#) assessment is a technique for determining the energy expenditure of labor, its physiological cost, the method's appropriateness for farmworkers, and how long they can work without becoming weary (Sam, 2015). Every farm job includes some drudgery, which causes physical and mental strain (Tiwari *et al.*, 2021). [Women generally face greater drudgery than men](#). The necessity for ergonomics is critical to determining the daily working performance of respondents involved in drudgery-inducing agricultural tasks (Awasthi *et al.*, 2020).

**Commented [SSPV2]:** Give the reason why?

**Commented [SSPV3]:** This reference is not listed in the reference section

The final step in the ergonomic evaluation to examine the variations arising throughout [the weeding operation](#) is the assessment of the operators' anthropometrical, physiological, and body postural discomfort (Mushobozi, 2010). The current anthropometric data of agricultural workers may be relevant in the design and development of manually operated weeders (Khogare *et al.*, 2011). The most common horticultural chores for most farms are planting and weeding. Typically, all farm activities begin with the actions listed above. As a result, ergonomic characteristics should be given appropriate weightage to guarantee the safety and comfort of working operators (Palega *et al.*, 2018).

As a result, the current findings stress the ergonomics considerations of female farm operators in horticulture ~~in order~~ to provide a safe and adaptive environment for working operators engaged in planting and weeding activities involved in medicinal plant production. [Studies on the ergonomic assessment of a hand-operated linseed thresher. Ergonomics is the scientific study of the connection between humans and their working environments \(Yadav and Pund, 2007\).](#)

**Commented [SSPV4]:** This sentence doesn't make any sense. Please remove it or modified the sentence to carry the meanings

**Commented [SSPV5]:** This sentence may be kept at the beginning of the introduction

In India, agricultural operations need a lot of work (Fathallah, 2010). [Physiological examination of manual weeders and sprayers used on farms \(Hemanth, K. \*et al.\*, 2015\).](#) Ergonomics should always be addressed when evaluating horticulture operators' performance (Kirkhorn *et al.*, 2010). Ergonomically constructed tools provide convenience and comfort to female farmworkers during handling and use (Karwowski, 1997). As a result, it is critical to include these elements in all farm operations ~~in order~~ to achieve safer and more efficient horticulture.

**Commented [SSPV6]:** Please improve this sentence to convey some message. It seems incomplete or some words are missed out

## 2. Materials and Methods

### 2.1 Method for implementing the experimental strategy in the ergonomic study.

The study took place on agricultural lands at Krishi Vigyan Kendra in Sheikhpura, Bihar, India. The selected respondents' anthropometric characteristics were assessed at the start of the investigation. Later, the [subject's patients](#) were permitted to seed medicinal plants such as tulsi and lemongrass using a shovel and hand hoe at the experimental location designated in the field, with a row-to-row spacing of 1.3 m and a period of 30 minutes. Fifteen female respondents from each age group (20-50 years old) were chosen at random based on their previous health history.

At the start of the experimental trials, all anthropometric measures were obtained with caution using an anthropometer, measuring tape, and steel scale, and different bodily characteristics of workers of all ages were recorded. They were then allowed to carry out the excavating and planting operations using the equipment.

The physiological observations of the individual participants were obtained before and during the procedure. Measurements of their resting and working pulse rates were made, and one-minute intervals were recorded after five minutes of work started. The additional variables, such as OCR, EER, and BPDS, were then estimated based on the parameters given above. A similar approach was used for weeding around the therapeutic plants.

## 2.2 Physiological and Psychological Characteristics of the Study for Female Participants

### 2.2.1 Body mass index

The BMI is defined as the body mass divided by the square of the body height. The relation of BMI is given as.

$$\text{BMI} \left( \frac{\text{kg}}{\text{m}^2} \right) = \frac{\text{Weight}}{(\text{Height})^2}$$

### 2.2.2 Lean body mass

Lean body mass is a component of body composition, calculated by subtracting body fat weight from total body weight. Hume's Equations of LBM for female respondents is [given as follows represented by the following equations.](#)

$$\text{For female: LBM} = (0.29569 \times W) + (0.41813 \times H) - 43.2933$$

### 2.2.3 Basal metabolic rate

Commented [SSPV7]: Provide references

Basal metabolic rate is the number of calories required to keep your body functioning at rest, also known as the metabolism. It is related to body mass, age, weight, and height. It is also affected by gender. According to By Harris Benedict's Equations, BMR for female respondents is represented by the following equations as follows.

$$\text{For female: BMR} = 655.1 + (9.563 \times W) + (1.850 \times H) - (4.676 \times \text{age in years})$$

Where,

- W = Body weight in kg
- H = Body height in cm

Formatted: Indent: Left: 0.5", No bullets or

### 2.2.4 Pulse Rate

The pulse rate was monitored and recorded using the heart rate monitor and pulse oximeter. It was recorded before and after the start of the planting and weeding.

**Table 1. An illustration of materials (equipment) utilized during the study**

Commented [SSPV8]: Please cite Table 1 in the context

Characteristics	Variables	Equipment's / Tools
Anthropometric	To measure body dimensions	Anthropometer, steel scale, measuring tape
Physical variables	Weight	Weighing balance
Physiological responses	Pulse rate, blood pressure	Heart rate monitor, Pulse oximeter

**Table 2. Technical specifications of the tools used in the ergonomic research.**

Commented [SSPV9]: Please cite Table 2 in the context

Specifications and working features of the mentioned weeding implements			
Shovel		Hand hoe (khurpa)	
Overall length (mm)	735	Overall length (mm)	320
Width of cutting edge (mm)	315	Width of cutting edge (mm)	105
Weight (kg)	2.5	Weight (kg)	1.1
Working depth (mm)	155	Working depth (mm)	88

### 2.2.5 Energy expenditure → Expenditure Rate (EER)

Varghese et al. (1994) proposed the following method for determining and estimating EER in their research of workers.

$$\text{EER} = 0.159 \times \text{Average heart rate} - 8.72 \text{ (KJ/min)}$$

### 2.2.6 Oxygen Consumption Rate (OCR)

Oxygen Consumption Rate was computed using the heart rate data that the operator has previously recorded. The following is an equation that depicts OCR (Singh *et al.*, 2008):

$$\text{OCR (L/min)} = 0.0114 \times \text{HR} - 0.68$$

### 2.2.7 Body Part Discomfort Score (BPDS)

Techniques from Corlett *et al.* (1976) were used to measure the localized discomfort. This approach divides the individuals' bodies into 27 regions. To discourage a response marking only one body region, each was assigned a separate number. The selected individuals were asked to list all body locations that caused discomfort, beginning with the most severe and progressing in decreasing order until no more places were mentioned. The aforesaid conclusions were determined by the following connection, which is listed below.

$$\text{BPDS} = \sum X_i \times S \quad (3.40)$$

Where,

- $X_i$  = Number of body parts
- $S$  = Discomfort score (is this on a scale of 6 to 1?)

In the current study, the meteorological conditions prevalent during planting and weeding operations, such as average temperature, humidity, and quantity of sunshine, were also examined throughout replications of the procedure taken in corresponding months, as illustrated in [Table 5](#).

**Table 3: Anthropometric information regarding the chosen participants**

S.No.	Anthropometric & strength data	Age of women operators (years)							
		20	25	30	35	40	45	50	55
1	Weight(kg)	47	45	49	52	56	61	55	55
2	Stature (cm)	156	151	145	158	161	166	166	166
3	Elbow height(cm)	98	93	89	96	101	105	96	96
4	Olecranon height(cm)	95	89	86	94	97	98	91	91
5	Illiocrystable height(cm)	88	81	80	85	87	89	84	84
6	Illiospinal height(cm)	143	146	136	141	148	153	145	145
7	Knee height(cm)	49	51	42	48	49	53	50	50
8	Arm reach(cm)	75	71	62	72	76	78	75	75
9	Vertical reach(cm)	192	185	181	190	194	198	186	186
10	Hand length(cm)	63	65	63	67	69	72	69	69
11	Head length(cm)	17	18	17	19	18	19	18	18
12	Foot length(cm)	22	21	20	22	23	24	22	22

(Measurement is taken in cm unless otherwise specified)

Formatted: Indent: Left: 0.5", No bullets or

Formatted: Default, Justified, Indent: Left: 0.5", No bullets or numbering, Tab stops: Not at 2.78"

Commented [SSPV10]: Please cite Table 3 in the context

Commented [SSPV11]: How many subjects were involved in each age group? For e.g., how many subjects were involved under 20 years age or only a single person is involved. It was not mentioned in the context the total number of subjects involved in the experiment

Commented [SSPV12]: Choosing/selecting the participants with exact 5 years age gap doesn't seem realistic. Is it so?

Table 5 lists the physical features of working female operators used to forecast their prior health difficulties. The current environmental variables, such as temperature, humidity, and sunlight hours, were also measured because these characteristics influence the farm operators' operating performance.

**Table 4: Physical traits possessed by operators**

Commented [SSPV13]: Please cite Table 4 in the context

S. No.	Physical characteristics	Age (years)							Average
		20	25	30	35	40	45	50	
1.	Age (years)	20	25	30	35	40	45	50	
2.	Height (cm)	156	151	145	158	161	166	163	157.14
3.	Weight (kg)	47	45	49	52	56	61	59	52.71
4.	BMI (kg/m <sup>2</sup> )	19.31	19.74	23.31	20.83	21.60	22.14	22.21	21.1 <sup>Formatted: Superscript</sup>
5.	LBM	35.83	33.15	31.82	38.15	40.58	44.15	42.31	38.00
6.	BMR	1299.641	1247.89	1251.66	1281.02	1301.44	1335.12	1287.07	1286.26

**Table 5. Enumeration of operating conditions in different farm operations**

S. No.	Months	Planting	Weeding
		July (2022)	August (2022)
1.	Average temperature, °C	36	39
2.	Average humidity, %	71	75
3.	Average sunshine, hours	8.3	7.7

### 3. Results and Discussion

#### 3.1 The influence of physiological characteristics on the participants' performance

In all agricultural activities, the average resting heart rate values of the respondents, who were 20, 25, 30, 35, 40, 45, and 50 years old, were recorded as 74, 78, 75, 82, 79, 80, and 82, respectively. During planting, the average heart rate for all the subject's was responses was 81.46 bpm. However, as table-Table 6 shows, it was 78.91 bpm in the case of the weeding operation.

Commented [SSPV14]: Give the units

Commented [SSPV15]: Give reason why?

**Table 6. Assessment of the average pulse rate of the female operators in various farm operations**

S. No	Operations	Average pulse rate (bpm)							Average
		20	25	30	35	40	45	50	
1.	Planting operation	88	94	95	98	105	109	117	100.85*
2.	Weeding operation	85	91	89	96	99	108	112	97.14*

\*Significant at 0.05 level of significance

Similarly, the individuals' average working heart rates throughout planting and weeding activities were 100.85 and 97.14 (bpm, respectively). As a result, the subjects were more comfortable and familiar with weeding with a hand hoe since it is a small workload, as opposed to weeding with a shovel, which requires more effort and entails moderate work (Swapnali and Nilakshi, 2020).

Similarly, the average EER for respondents using a shovel to dig and sow herbal plants (planting) was 6.35 kJ/min, while the average EER for using a hand hoe to carry out weeding operations was 5.31 (kJ/min), as shown in Table 7.

**Table 7. Assessment of average EER of the female operators in planting and weeding operations**

S.No	Operations	Average Energy Expenditure Rate (EER)(kJ/min)							
		20	25	30	35	40	45	50	Average
1.	Planting operation	4.83	5.26	5.75	6.40	7.05	7.21	7.62	6.35*
2.	Weeding operation	4.52	4.65	4.97	5.13	5.75	6.12	6.57	5.31*

\*Significant at 0.05 level of significance

As a result, the participants used more energy during planting because controlling a weighted shovel for digging demands significant effort, however for weeding, the operators were flexible and accustomed ~~with to~~ using a hand hoe due to its lightweight (Swapnali and Nilakshi, 2020).

**Commented [SSPV16]:** If tillage is done before planting, would it be easier to plant than to weed out the weeds?

**Table 8: Assessment of average OCR of the female operators in sowing/planting and weeding operations**

S. No	Operations	Average Oxygen Consumption Rate (OCR)(L min <sup>-1</sup> )							
		20	25	30	35	40	45	50	Average
1.	Planting operation	0.39	0.43	0.48	0.51	0.56	0.61	0.63	0.52*
2.	Weeding operation	0.33	0.36	0.40	0.45	0.51	0.54	0.59	0.45*

\*Significant at 0.05 level of significance

This provides less oxygen consumption throughout the operation than a shovel, which requires maximal oxygen uptake since pain and tiredness occur while operating a shovel. The latter procedure requires continual arm action to elevate and lower the implement, hence the operators needed the most oxygen (Swapnali and Nilakshi, 2020).

### 3.2 Effect of workload on the performance of the respondents

Table 9 shows the average BPDS values of the participants selected for planting and weeding activities, which were 21.4 and 19.5, respectively. Previous research found similar results (Kumar et al., 2013).

**Table 9. Assessment of average BPDS of the female operators in various farm operations**

S.No	Operations	Average Body Part Discomfort Score (BPDS)							
		20	25	30	35	40	45	50	Average
1.	Planting operation	18.75	20.25	20.90	21.15	21.75	22.35	22.50	21.4*
2.	Weeding operation	17.25	18.20	17.45	19.75	20.50	21.25	22.45	19.5*

\*Significant at 0.05 level of significance

#### 4.1 Regarding Assessment of Physiological Responses of the Subjects

The age of farm women has a substantial impact on their heart rate, EER, and OCR. At the 0.05 level of significance, physiological variables altered more substantially during planting than during weeding. In terms of physiological reactions, female operators were more comfortable in a crouching posture, i.e., hand hoeing rather than digging cum replanting (Panigrahi, 2016). The pulse rate was found to be elevated among responders who used shovels due to the numerous efforts required and the implement's improper design. The operators' fitness difficulties have a direct impact on their heart rate when carrying out the digging and planting activity. As a result, the subjects were more comfortable and familiar with weeding with a hand hoe since it is a small workload, as opposed to weeding with a shovel, which requires more effort and entails moderate work (Swapnali and Nilakshi, 2020). The current findings analyze whether respondents using a shovel consumed more oxygen than those using a hand hoe. Because the tiredness rate among shovel operators was rather high, oxygen consumption increased marginally as respondents' ages increased. As a result, the participants felt more at ease and comfortable when weeding with a hand hoe because it required little effort and was quite simple. This provides less oxygen consumption throughout the operation than a shovel, which requires maximal oxygen uptake due to pain and tiredness caused by using a shovel. The latter procedure requires continual arm movement to elevate and lower the implement, hence the operators needed the most oxygen (Swapnali and Nilakshi, 2020).

The energy consumption rate was negligible when the operators used a hand hoe to weed rather than a shovel to seed. This might be due to the discomfort of continuing to work in a standing position while rising and elevating the arms, as well as the irregularity of using a shovel. Also, the current conditions during strong sunshine may be the cause of increased energy consumption. As a result, the participants used more energy during planting because

**Commented [SSPV17]:** Do oxygen consumption depends only on age?. Does it depends on weight, stature and other parameters?

controlling a weighted shovel for digging demands significant effort, however for weeding, the operators were flexible and accustomed ~~with-to~~ using a hand hoe due to its lightweight (Swapnali and Nilakshi, 2020).

#### 4.2 ~~Regarding the a~~Assessment of the Body Part Discomfort Score (BPDS) of the operators

The BPDS is significantly impacted by the age of farm women, with a greater variance in replanting operations compared to weeding activities at the 0.05 level of significance. The current investigation demonstrates that the bodily pain experienced was weariness in the knee and shoulder during the weeding operation, but it was an arm, knee, wrist, and shoulder during the sowing operation done by hand hoe due to the significant effort required by the arms to uproot the weeds. It became apparent that the hand hoe was well-designed, and its sharp blade ~~requires-required~~ little effort to clear weeds. As a result, the research findings show that the hand hoe is more adaptive and stable when weeding in a sitting stance than managing a shovel in a standing position.

#### 5. Conclusion

The respondents preferred to use a hand hoe over a shovel, which may be attributed to the former's consistency and ease of adaptation, as well as the latter's substantial weight, which made handling difficult. Furthermore, while weeding and planting, workers were compelled to frequently elevate and drop their arms in a bending position, which imposed additional strain on their shoulders. This generated physical pain and an increase in physiological variables.

#### 6. References

- Benos, L., Tsaopoulos, D., Bochtis, D., 2020. A review on ergonomics in agriculture. Part I: Manual operations. *Applied Sciences* (Switzerland).
- Corlett, E.N., Bishop, R.P., 1976. A technique for assessing postural discomfort. *Ergonomics*, 19, 175–182.
- Fathallah, F.A., 2010. Musculoskeletal disorders in labor-intensive agriculture. *Applied Ergonomics*, 41(6), pp.738–743.
- Goel, A.K., Behera, D., Behera, B.K., Mohanty, S.K. and Nanda, S.K., 2008. Development and ergonomic evaluation of manually operated weeder for dry land crops. *Agricultural Engineering International: CIGR Journal*. Manuscript PM 08 009. Vol. X. September,

**Commented [SSPV18]:** How the tools used for different operations (i.e., planting and weeding) be compared. If we used same tool, we can compared between them. Is it not? It is obvious that the workers would prefer lighter weight tools and implements as it is easier to handle. Give your views too

- Gangopadhyay, S., Dev, S., 2014. Design and evaluation of ergonomic interventions for the prevention of musculoskeletal disorders in India. *Annals of Occupational and Environmental Medicine* 26.
- Hemanth, K.G., Harshavardhan, M., Ashok, K.A., Pavan, K.E., Ramana, M.V., 2015. Physiological evaluation of manual operated weeders and sprayers on farm use. *Agricultural Engineering International: CIGR Journal* 17, 173–183.
- Karwowski, W., 1997. *Ergonomics: How to Design for Ease and Efficiency* by Karl Kroemer, Henrike Kroemer, & Katrin Kroemer-Elbert 1994, 766 pages, \$86.00 Englewood Cliffs, NJ: Prentice-Hall ISBN 0-13-278359-2. *Ergonomics in Design: The Quarterly of Human Factors Applications* 5, 33–35.
- Khogare, D.T., Sunita, B., 2011. Anthropometric data of agricultural workers for suggesting dimensions of manually operated weeder. *Asian Journal of Home Science* 6, 57–60.
- Kirkhorn, M.P.H., Steven, R., Earle-Richardson, G., Banks, C.I.E., Banks, R., 2010. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *Taylor & Francis.*, 15, 281–299.
- Kumar, A.A., Haribabu, B., Rao, A.S., Someswararao, C., 2013. Ergonomical evaluation of manually operated weeder under wet land condition. *Scientific Research and Essays* 8, 249–255.
- Mushobozi, W.L., 2010. Good agricultural practices (GAP) on horticultural production for extension staff in Tanzania: Training Manual. FAO GAP working paper series 13, 101–110.
- Palega, M., Rydz, D., 2018. Work safety and ergonomics at the workplace an excavator. *International Scientific Journal 'Trans Motoauto World'* 29, 25–29.
- Pandey, N.G., 2016. Small Farmers in India: Challenges and Opportunities. *Golden research thoughts.* 5.
- Panigrahi, C.M.A., 2016. Managing stress at workplace. *Journal of Management Research and Analysis*, 3(4), pp.154-160.
- Pandey, S., Verma, A.K., Sirmour, A., Gandhi, I., Vishwavidyalaya, K., 2019. Ergonomical studies on single row power weeder for rice crop. *cropandweed.com* 15, 145–150.
- Saha, P.N., 1976. Practical use of some physiological research methods for assessment of work stress. *Indian Association of Physiotherapists* 4, 9–13.
- Sahoo, L., Tanuja, S., Argade, S., 2017. Strengthening farm women perspective in quality seed production. Model Training Course "Strengthening Farm Women Perspective in Quality Seed Production 1–4.
- Sam, B., 2015. Ergonomic evaluation of paddy seeder and rotary weeder with women operators. *Proceedings 19th Triennial Congress of the IEA.*, 9–14.

- Swapnali, B., Nilakshi, B., 2020. Physiological Workload and Health Hazards of Tribal Women of Meghalaya Involved in Weeding Operation. *International Journal of Current Microbiology and Applied Sciences.*, 9(12): 2589-2595
- Tiwari, N., Upadhyay, R., Dudi, A., 2021. Adoption of Drudgery Reducing Tools among Farm Women. *Indian Research Journal of Extension Education* 21, 108–111.
- Varghese, M.A., Saha, P.N., Atreya, N., 1994. A rapid appraisal of occupational workload from a modified scale of perceived exertion. *Ergonomics* 37, 485–491.
- Yadav, R. and S.Pund, 2007. Development and ergonomic evaluation of manual weeder. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript PM 07 022. Vol IX, October, 2007.

UNDER PEER REVIEW