Original Research Article

Investigation of the Ergonomics and Workload of Farm Women during in Planting and Weeding Operations

ABSTRACT

The study was done to determine the anthropometric, physical, physiological, and workload characteristics of women operators (N=7) 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.

Keywords: Energy Expenditure, Oxygen Consumption Rate, Pulse rate and Workload

1. INTRODUCTION

Indian farmers are increasingly concerned with properly carrying out different farm activities to increase production (Pandey, 2016 and 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).

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 (Moharana *et. al.*, 2017). The necessity for ergonomics is critical to determining the daily working performance of respondents involved in drudgery-inducing agricultural tasks (Awasthi *et. al*., 2020).

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 (Singh *et. al.,* 2023). 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 to provide a safe and adaptive environment for working operators engaged in planting and weeding activities involved in medicinal plant production.

2. Materials and Methods

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

The study was conducted 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 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 taken and 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 selected for farm women 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.

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

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.

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

2.2.3 Basal metabolic rate

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 Harris Benedict's Equations, BMR for female respondents is represented as follows.

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

Where,

W = Body weight in kg

H = Body height in cm

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. The corresponding strength data is an illustration of materials utilized during the study in the table 1 given below. Specifications and working features of the mentioned weeding implements are presented in table 2.

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

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. 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 Rate (EER)

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

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

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):

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

2.2.7 Body Part Discomfort Score (BPDS)

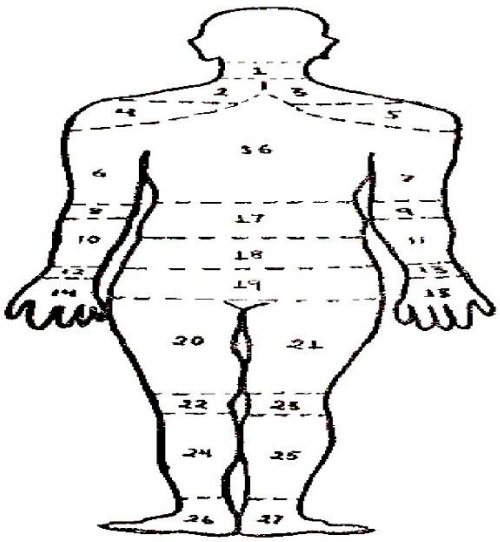
Techniques from Corlett *et. al.,* (1976) were used to measure the localized discomfort. This approach divides the individuals' bodies into 27 regions. To discourage a response marking only one body region, each was assigned a separate number. The selected individuals were asked to list all body locations 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.

$$BPDS = S\ X_i \times S\ (3.40)$$

Where,

X_i = Number of body parts

S = Discomfort score (is this on a scale of 6 to 1?)



1: Neck
2: Clavicle left
3: Clavicle right
4: Left shoulder
5: Right shoulder
6: Left arm
7: Right arm
8. Left elbow
9: Right elbow
10: Left forearm
11: Right forearm
12: Left wrist
13: Right wrist
14: Left palm
15: Right palm
16: Upper back
17: Mid back
18: Lower back
19: Buttocks
20: Lift thigh
21: Right thigh
22: Left knee
23: Right knee
24: Left leg
25. Right leg
26. Left foot
27. Right foot

Fig 1: Region for evaluating body part discomfort score

Anthropometric data of chosen participants were collected using a measuring anthropometer in total resting state. Seven subjects were selected from agricultural farms of different selected in age subject (Table 3 and Table 4).

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**
1	Weight(kg)	47	45	49	52	56	61	59
2	Stature (cm)	156	151	145	158	161	166	163
3	Elbow height(cm)	98	93	89	96	101	105	96
4	Olecranon height(cm)	95	89	86	94	97	98	91
5	Illiocrystable height(cm)	88	81	80	85	87	89	84
6	Illiospinal height(cm)	143	146	136	141	148	153	145
7	Knee height(cm)	49	51	42	48	49	53	50
8	Arm reach(cm)	75	71	62	72	76	78	75
9	Vertical reach(cm)	192	185	181	190	194	198	186
10	Hand length(cm)	63	65	63	67	69	72	69
11	Head length(cm)	17	18	17	19	18	19	18
12	Foot length(cm)	22	21	20	22	23	24	22

(Measurement is taken in cm unless otherwise specified)

Table 4: Physical traits possessed by operators

S. No.	Physical characteristics	Age (years)							Average
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/m2)**	19.31	19.74	23.31	20.83	21.60	22.14	22.21	**21.30**
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**

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 the table 5 given below.

Table 5. Enumer Operating conditions during different farm operations

S. No.	**Months**	**Planting**	**Weeding**
		July (2022)	**August (2022)**
1.	Average temperature, ^{0}C	36	39
2.	Average humidity, %	71	75
3.	Average sunshine, hours	8.3	7.7

3. Results and Discussion

3.1 The influence physiological characteristics of selected subjects performing variance farm operators

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 72, 76, 73, 79, 76, 78, and 80, respectively.

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

S. No	**Operations**	**Average pulse rate (bpm)**							**Average**
	Age (years)	**20**	**25**	**30**	**35**	**40**	**45**	**50**	
1.	Planting operation	89	95	96	99	105	111	118	101.86*
2.	Weeding operation	84	90	88	95	101	109	111	96.86*

**Significant at 0.05 level of significance*

Similarly, the individuals' average working heart rates throughout planting and weeding activities were 101.86 and 96.86 bpm, respectively. As a result, the subjects were more comfortable and familiar with weeding with a hand hoe since it is a light 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 7.48 kJ/min, while the average EER for using a hand hoe to carry out weeding operations was 6.68 (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) at varying age							
	Age (years)	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**Average**
1.	Planting operation	5.43	6.39	6.54	7.02	7.98	8.93	10.04	7.48*
2.	Weeding operation	4.64	5.59	5.27	6.39	7.34	8.61	8.93	6.68*

**Significant at 0.05 level of significance*

The recent showed that more energy demand was doing digging with shovel for weeding. However energy expenditure during weeding with hand hoe was less due to its lightweight

Similarly, the average OCR for the selected operators during planting and weeding operation were 0.48 and 0.42 (L/min) respectively as enumerated in the table 8. Therefore, the subjects were more comfortable and quite familiar while weeding operation by hand hoe as it involves effort and ease

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^{-1})							
	Age (years)	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**Average**
1.	Planting operation	0.33	0.4	0.41	0.45	0.52	0.59	0.67	0.48*
2.	Weeding operation	0.28	0.35	0.32	0.4	0.47	0.56	0.59	0.42*

**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 body part discomfort score on the performance of the respondents

Table 9 shows the average BPDS values of the participants selected for planting and weeding activities, which were 22.05 and 20.89, 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)

	Age (years)	20	25	30	35	40	45	50	Average
1.	Planting operation	19.04	20.4	22.44	22.44	22.44	23.12	24.48	22.05*
2.	Weeding operation	18.02	19.72	20.4	21.08	21.42	22.44	23.12	20.89*

**Significant at 0.05 level of significance*

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

3.4. 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 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.

4. 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.

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