Indian Research Journal of Extension Education
ISSN: 0972-2181 (Print), 0976-1071 (e-Print)
NAAS Rating : 5.22
Journal homepage: seea.org.in
RESEARCH ARTICLE
https://doi.org/10.54986/irjee/2022/jul_sep/58-63

Ergonomic and Workload Investigation of Tractor Operators Using Rotavator in Pulverization and Puddling Operations

Vishnu Ji Awasthi[1], Tarun K. Maheshwari[2], Rajat Mishra[3] and Shikha Sharda[4]

1&3. Res. Scholar (Farm Machinery and Power Engg.), GBPUA&T, US Nagar, Uttarakhand, 2. Asso. Prof., CAE&T., CSAUA&T, Kanpur, Uttar Pradesh, 4 Res. Fellow (Farm Machinery and Power Engg.), PAU, Ludhiana, Punjab

Corresponding author e-mail : vawasthi92@gmail.com

Received on April 21, 2022, Accepted on June 02, 2022 and Published Online on July 01, 2022

ABSTRACT

The ergonomic investigation entails assessment of anthropometric dimensions, physiological variations and related workload of 120 respondents having age group between interval 20-50 years for seed bed operation (pulverization and puddling) using rotavator. The study indicated that the average resting heart rate of the tractor operators was 77.56 bpm for secondary tillage operation (pulverization) and 81.46 bpm for puddling operation (for further sowing of paddy crop). The average working heart rate throughout the pulverization and puddling operation were investigated as 95.43 and 103.86(bpm) respectively. The average EER and OCR values for the concerned operations were 6.45 and 7.79(kJ/min) and 0.41 and 0.52(L/min) respectively. The BPDS values of selected subjects were ascertained as 19.5 and 21.4respectively. The study reveals that different farm operations have significant effect on the physiological parameters of the respondents. The findings conclude that the tractor operators were more compatible and comfortable in conducting pulverization by rotavator for given soil conditions. The performance of operators was found superlative for the same operation than by puddling operation. For the safer, smart and effective agricultural operation in rural parts of the nation, the need of ergonomics is onerous and is a key in predicting the daily working capacity of the respondents involved in various farm operations thereby ensuring the proper harmonious and effectual relationship in man-machine interface.

Key words: *Pulse rate; Physiological variation; Rotavator; EER; OCR.*

Tillage operation is one of the major agriculture operations for providing effective seedbed and optimum environmental conditions for the plant growth. It offers a desirable seedbed preparation, control weeds, minimizes soil erosion and manages plant residues effectively. The operation may be primary or secondary or both whichever is required according to the depth and type of soil. It is employed for uprooting weeds and precision levelling of land. With the extent of agriculture in the recent past, the Indian farmers are more concerned in effectively accomplishing various farm operations to enhance productivity (*Pandey et al., 2019*). The mechanical manipulation by means of tillage implements like harrows, rotavator etc. is more preferable than the traditionally used ploughs by the farmers as it enhances the field efficiency, field capacity and in turn productivity of the crop. The performance of the implements cannot be considered feasible unless the ergonomic aspects are given due weightage. Therefore, the ergonomic parameters should be given greater emphasizes for ensuring safety and ease to the working operators (*Pałęga et al. 2018*). The manual method of operating implements has been common site in the country (*Maheshwari et. al., 2022*). But the mechanical means of accomplishing any farm operation requires utmost safety as with the manual means of conducting farm operation. In both the cases, operators engaged in agricultural operation should be given priority in terms of comfort and safety. The operator's performance is one of the most imperative parameters in successfully accomplishing any agricultural operation. The ergonomic contemplation

should always be considered for ensuring comfort and safety to the working operators during any farm operations. Ergonomic evaluation is considered as a safety tool to evaluate the energy expenditure of work, their physiological cost and suitability of the method for farm workers and how long they can work continue without getting fatigue (*Kumar A. et al.,2013*). The assessment of anthropometrical, physiological and body postural discomfort of the operators is the bottom-line in the ergonomic evaluation so as to compare the variations resulting during numerous farm operations (*Awasthi, et al., 2020*). Ergonomics aspects should always be considered for the assessment of the performance of the agricultural operators from ergonomic point of view. Ergonomically designed implements allow ease and comfort to the farm workers during its manipulation and utilization. Hence, it is imperative to apply these aspects in every farm operation for safer and smarter agriculture.

In view of these concerns, the present finding aims to determine the ergonomic performance of the tractor operators conducting various secondary tillage operations (pulverization and puddling operation for further sowing of the paddy crop on the well-prepared seed bed) and the effect of workload on the working performance of the operators undergoing the operations for ensuring safer and risk-free agriculture.

METHODOLOGY

The present ergonomic study was conducted in the Agricultural farms, Punjab Agricultural University (PAU), Ludhiana in for assessing the performance of the tractor operators engaged in different tillage operations.

Methodology for implementing the experimental plan in the ergonomic study : The work was governed in Agricultural farms, PAU, Ludhiana. During the foundation of study, the anthropometric aspects of the chosen respondents were precisely measured. Later, the subjects were allowed to conduct the pulverization operation for the preparation of effective seed-bed for the puddling operation and using rotavator at the experimental site prescribed in the field for 20 minutes duration. A total of 120 male subjects (tractor operators) in various age groups ranging between 20 to 50 years were selected according to their proficiency in farm operation and health history. The equipment required in the present research are presented in the Table 1 given follow :

Implements used : Tractor and rotavator was employed in the present study for the ergonomic evaluation of the tractor operators in pulverization as well as in puddling operations. The technical specifications of the implements used are mentioned below in Table 2.

Table 1. The equipment's employed in the current ergonomic study are enlisted below:

Parameters	Variables considered	Equipments/ Tools
Anthropometric data	For measuring body dimensions	Anthropometer, steel scale, measuring tape, vernier caliper, hand grip dynamometer
Physical variables	Weight	Weighing balance
Physiological responses	Pulse rate, blood pressure	Heart rate monitor, pulse oximeter, sphygmomanometer

Table 2. The technical specifications of the tractor and rotavator utilized in the study

Tractor specifications		Rotavatorspecifications	
Tractor (Make)	John Deere	Rotavator (Make)	Harnam
HP	40	Width of cut (mm)	1800
Gear used	A1	No. of blades	36
Tyre diameter (mm)	1310	No. of flanges	7
Tractor engine speed (rpm)	2400	PTO speed (rpm)	540
No. of cylinders	3	Rotor speed (rpm)	210

At the onset of the research investigation, all the anthropometric measurements were carefully taken by deploying anthropometer, measuring tape and steel scale and different body parameters of various age limits of the workers were measured. Subsequently, they were permitted to implement the pulverization and then followed by puddling operation by utilizing 6" rotavator for an interval of 20 min. Before and after the initiation of operation, the physiological contemplations of the particular subjects were taken such as resting and working pulse rate were measured and recorded at one-minute intervals after five minutes from the commencement of work. Next, the other variables whose values are influenced by aforesaid parameters including OCR, EER and BPDS were calculated. Similar procedure was followed for different trials for maintaining the accuracy to obtain pertinent results.

Physiological parameters involved in the study for tractor operators :

Body mass index (BMI) : It was assessed by using the given relation

$$BMI = Weight/Height\ (kg/m^2)$$

Lean body mass (LBM): Refers to component of composition of body, ascertained by subtracting body fat weight from total body weight. LBM is generally estimated by utilizing the relation given by *Hume R (1966).* For men-

$$LBM = (0.32810 \times w) + (0.33929 \times H) - 29.5336$$

Basal Metabolic Rate (BMR) : Also refers to as metabolism. It is the number of calories required by the respondents to keep their body functioning at rest. Its value is dependent on body mass, age, and height and is different for male and female. By Harris Benedict Equations, the relation for BMR for female is obtained by the following equation:

For men-

$$BMR = 66.47 + (13.7 \times Weight) + (5 \times Height) - (6.8 \times Age)$$

VO_{2max}- The maximum rate of oxygen consumption measured during any duration of physical activity (puddling and pulverization operation). Also refers to as maximal oxygen consumption, or maximal aerobic capacity. The name is derived from V- volume, O2- oxygen and max- maximum. VO_{2max} is expressed in liters of oxygen per minute (L/min) or mL/kg min.

VO_{2max} is evaluated in the present findings by deploying the equation which is dependent on weight and age of the operators formulated by *Verghese et al (1994).* It is given by:

$$VO_{2max} = 0.023W - 0.034A + 1.652$$

Acceptable work load (AWL) : It is the amount of work which is prescribed for the operators as safe from physiological point of view. It is equal to 35 per cent of the VO_{2max} of the subjects (for young Indian worker).

Maximum heart rate : In the concerned research, it was determined by utilizing the formula derived by *Martiz et al., (1961).*

$$HRm = 220 - Age\ (years)$$

Physiological parameters involved in the study for female subjects :

Pulse rate : The pulse rate was measured and recorded by deploying the heart rate monitor and pulse oximeter. It was recorded before and after the inception of the sowing and weeding operation.

Energy Expenditure Rate (EER) : EER was determined and estimated using the following formula suggested by *Verghese et. al., (1994)* in determining the EER of the workers.

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

Oxygen consumption rate (OCR) : Calculated from the heart rate values (previously measured of the operator. OCR is represented by the equation (*Singh et al., 2004*) enumerated as follows :

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

Body part discomfort score (BPDS)-*Corlett and Bishop (1976)* technique was employed to assess the localized discomfort. In this procedure, the body of subjects is divided into 27 regions. Each body region was numbered distinctly to avoid a respondent marking on body region only. The selected subjects were asked to mention to all body parts with discomfort, starting with the most painful, the next painful in descending order till no further areas are referred. In the mentioned findings, it was determined by the following relation enlisted below:

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

Where, X_i = Number of body parts

S = Discomfort score (6 to 1)

The anthropometric data of the selected tractor operators was ascertained. The dimensions were measured by using anthropometer and measuring tape to maintain exactness and meticulousness in the results. Sixteen anthropometric measurements were taken, which were considered useful in utilizing tractor for conducting puddling and pulverization operation by rotavator. The anthropometric strength data is enumerated in the Table 3.

In the current research findings, the atmospheric conditions including average temperature, humidity and amount of sunshine was also assessed during puddling and pulverization operation consisting of several replications of the method taken for the month of July (Table 4).

The physical characteristics possess by the working tractor operator were also taken into consideration for predicting their past health issues (Table 5).

RESULTS AND DISCUSSION

Effects of physiological parameters in the performance of the subjects: The values of average resting heart rate of the tractor operator operators engaged in pulverization and puddling operation having age 20, 25, 30, 35, 40, 45 and 50were recorded as 75, 79, 74, 77, 81, 80 and 84 respectively. During the secondary tillage operation i.e pulverization by rotavator, the average of all the respondents was 77.36 bpm. While, in case of puddling operation, it was 79.76 bpm.

Table 3. The anthropometric strength data of the selected tractor operators

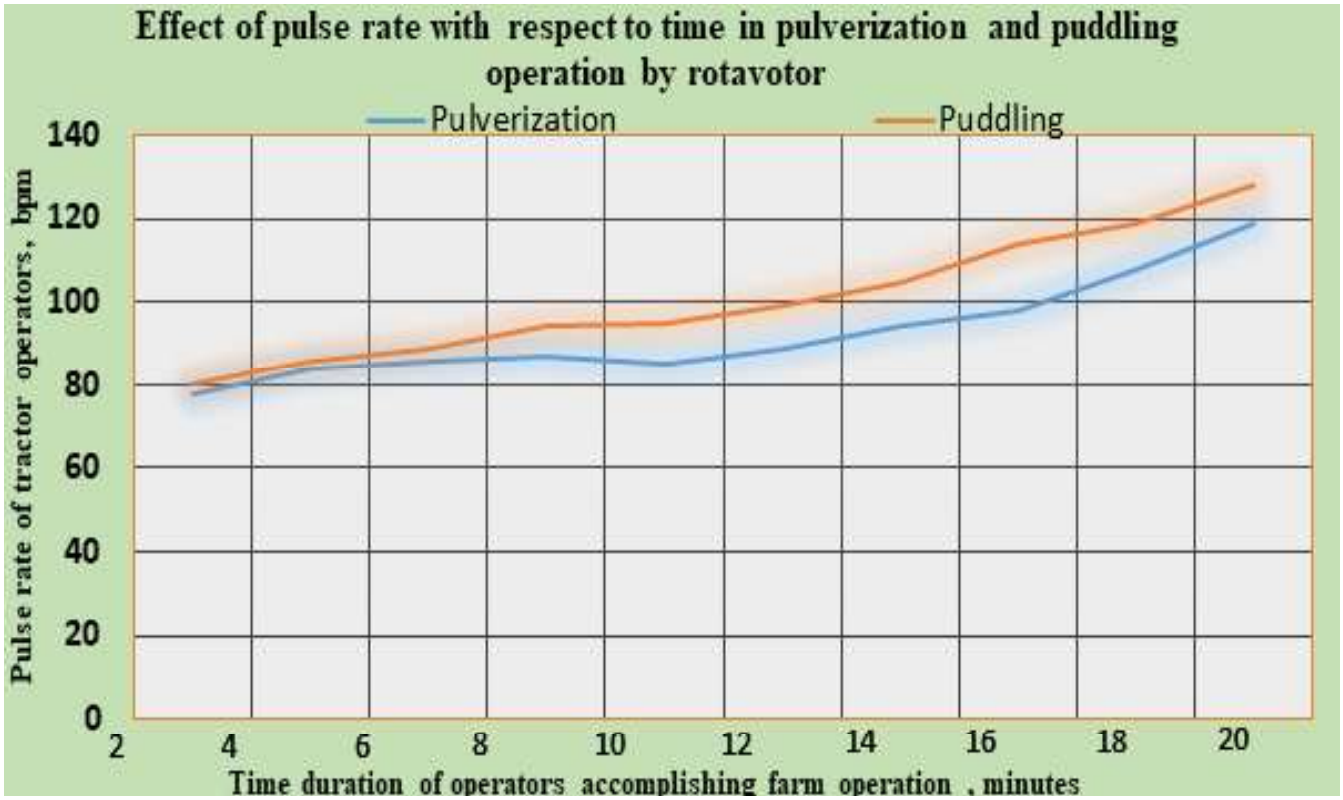
Anthropometric dimensions	Age of operators (years)					
	21-25	26-30	31-35	36-40	41-45	46-50
Weight	51	55	48	58	63	46
Stature	157	160	152	155	161	148
Elbow height	94	97	91	93	98	89
Illiocrystable height	83	85	79	81	84	79
Illiospinal height	143	147	139	142	148	137
Knee height	49	50	47	48	49	43
Arm reach	74	77	71	72	76	64
Vertical reach	191	190	186	189	188	183
Olecranon height	90	89	83	86	89	82
Hand length	63	65	66	67	68	64
Head length	19	19	17	18	19	17
Foot length	23	24	21	23	24	21
Biacromial breadth	32	36	38	34	41	35
Bideltoid breadth	40	42	43	39	44	39
Acromial height	124	129	122	124	128	121
Eye height	143	148	140	142	147	135

Table 4. Enumeration of operating conditions

Operational parameters	Puddling operation	Pulverization operation
Average temperature, ^{0}C	34	38
Average humidity, %	52	55
Average sunshine, hours	8.4	8.3

Table 5. Physical attributes of the tractor operators

Attributes	Age (years)						Av.
	21-25	26-30	31-35	36-40	41-45	46-50	
Height (cm)	157	160	152	155	161	148	155.5
Weight (kg)	51	55	48	58	63	46	53.5
BMI (kg/m^2)	20.69	21.48	20.78	24.14	24.30	21.00	22.07
LBM	37.43	39.87	34.45	38.67	42.66	32.19	37.55
BMR	1310	1300	1225	1303	1338	1128	1268
VO_{2max} (l/min)	1.98	1.90	1.57	1.63	1.57	1.01	1.61
AWL (l/min)	0.69	0.67	0.55	0.57	0.55	0.35	0.56
Max. heart rate (bpm)	195	190	185	180	175	170	183



Similar findings pertaining to the resting heart rate were obtained by *Bini et. al. (2014)*. Correspondingly, the average working heart rate of the subjects during pulverization and puddling operation was 95.43 and 103.86(bpm) respectively as depicted in the Table 6.

The average resting and functional pulse rate of operators was significant for different rotavator operations at 5 per cent level of significance. The subjects were more comfortable and compatible in accomplishing pulverization operation by rotavator as it involved light work load rather than in puddling operation which involved larger exertion and slight moderate work. Continuous exposure of vibrations due to high load exerted on the implement (rotavator) with clogging of rotavator blades with the puddled soil in case of puddling operation may also be responsible for the operators' high pulse rate. The other reasons for large physiological variations might be soil conditions and prevailing environmental conditions. Both of which are different in different working conditions (*Verghese et. al 1994*).

Similarly, the average EER for the respondents operating rotavator for secondary tillage (pulverization of land to prepare it suitable for further sowing operation) and puddling was assessed as 6.45 and 7.79 KJ/min respectively as enumerated in Table 7.

The selection of different operations has a significant effect on the energy expenditure rate of operators at 5% level of significance. Age of the operators also has a substantial effect on the EER of the respondents. It is concluded that the tractor operators required more energy during puddling of land as it requires considerable energy in manipulating the implement. For pulverization operation, the operators were adaptable to the soil conditions and other working conditions thereby, they retained optimum energy level resulting in less fatigue and lassitude. (*Verghese et. al., 1944*).

Similarly, the average OCR for the selected tractor operators during pulverization and puddling operation were 0.41and 0.52 (L/min) respectively as enlisted in Table 8.

Various farm operations have a significant effect on the oxygen consumption at 5 per cent level of significance. Age of the selected operators also has a considerable effect on the OCR of the respondents. Therefore, the subjects were more comfortable and quite familiar with the working conditions while conducting pulverization operation by rotavator as it involves less effort and offer more ease and maneuverability.

This might be the reason for less oxygen uptake during the pulverization procedure rather than in puddling operation involving maximum oxygen uptake on account of discomfort and fatigue ensuing during operation that calumniated in continuous exposure of vibrations due to high load induced on the implement (rotavator) with clogging of rotavator blades with the puddled soil. The prevailing environmental conditions like the slightly high operating temperature and relative humidity might also affected the operators engaged in the puddling operation and therefore, the operators required maximum oxygen consumption (*Verghese et. al, 1944)*.

The average BPDS values of selected subjects were ascertained as 21.4 and 19.5 respectively for pulverization and puddling operation presented in the Table 9. Similar results were investigated by *Kumar et al. 2013*.

The body discomfort arising while operating rotavator for pulverization includes fatigue in knee

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

Operation by rotavator	Average pulse rate (bpm)							
	21-25	26-30	31-35	36-40	41-45	46-50	21-25	Av.
Av. resting heart rate	75	79	74	77	81	80	84	78.57*
Pulverization operation	87	85	84	94	97	106	115	95.43*
Puddling operation	89	91	89	103	109	117	129	103.86*

*Significant at 5% level of significance

Table 7. Assessment of average EER of the tractor operators

Operations	Av. energy expenditure rate (EER) (KJ/min)							
	21-25	26-30	31-35	36-40	41-45	46-50	21-25	Av.
Pulverization	5.11	4.80	4.64	6.23	6.70	8.13	9.57	6.45*
Puddling	5.40	5.75	5.43	7.66	8.61	9.88	11.79	7.79*

*Significant at 5% level of significance

Table 8. Assessment of average OCR of the tractor operators

Operations	Average oxygen consumption rate (OCR) (L/min)							
	21-25	26-30	31-35	36-40	41-45	46-50	21-25	Av.
Pulverization	0.31	0.30	0.28	0.39	0.43	0.53	0.63	0.41*
Puddling	0.33	0.36	0.35	0.49	0.56	0.65	0.79	0.52*

*Significant at 5% level of significance

Table 9. Assessment of average BPDS of the tractor operators

Operations	Average body part discomfort score							
	21-25	26-30	31-35	36-40	41-45	46-50	21-25	Av.
Pulverization	18.75	20.25	20.90	21.15	21.75	22.35	22.50	21.4
Puddling	17.25	18.20	17.45	19.75	20.50	21.25	22.45	19.5

and shoulder while it was arm, knee and wrist in case of puddling operation. Majority of the tractor operators experienced discomfort and stress in arms, shoulders and knee as effort was required to conduct the operation for 20min continuation.

CONCLUSION

The physiological parameters including working heart rates, energy expenditure rate, oxygen consumption rate and BPDS of the concerned subjects were assessed and the respondents exhibits significant variations during their association in various farm operations for pulverization and puddling. The majority of operators endured light physical work in case of pulverization (dry condition) and moderately heavy physical work in puddling (wet condition). The subjects were more well-suited and comfortable in operating rotavator in dry condition than in wet condition which might be due to their consistency and easy adaptability of the former implement with soil conditions. Also, the prevailing environmental conditions have a strong role to play in affecting the performance of the operators. Furthermore, the workers required more effort on the shoulders in both the operations since they had to work continuously in manipulating the implements for given soil conditions. This culminated in body discomfort and increase in the physiological variables.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

REFERENCES

Awasthi, V. J.; et al. (2020). Ergonomic and workload consideration of rural female workers during different manual farm operations at PAU Ludhiana, Punjab. *Indian J. Ext. Edu.,* **56** (1) : 172-176.

Bini S. (2014). Ergonomic evaluation of a power weeder for homestead gardens. *Intl. J. Agril. Engg.* Bini S. (2014). Ergonomic evaluation of a power weeder for homestead gardens. *Intl. J. Agril. Engg.* **7** (1) : 108–112.

Corlett, E.N. and Bishop, R.P. (1976). A technique for assessing postural discomfort. *Ergonomics*,**19**:175-182.

Hume, R. (1966). Prediction of lean body mass from height and weight. *J Clin Pathol*. **19** (4): 389–391.

Kumar A., Haribabu B., and A. Srinivasa Rao. (2013). Ergonomical evaluation of manually operated weeder under wet land condition, **8** (6): 249-255

Maheshwari T.K. and Singh U. V. (2022). Tractor drawn modular planter for gram-A performance study. *Indian Res. J. Ext. Edu.,* **22** (2) : 139-143.

Martitz, J.S., Morrison, J.F., Peter, J., Strydom, N.B. and Whyndham, C.H. (1961). A practical method of estimating individual's maximal oxygen uptake. *Ergonomics*, **4**: 97.

Pałęga, M., & Rydz, D. (2018). Work safety and ergonomics at the workplace an excavator operator. *Trans Motauto World*, **3**(1), 25-29.

Pandey, S., Verma, A., & Sirmour, A. (2019). Ergonomical studies on single row power weeder for rice crop. *J. Crop and Weed*, **15**(1), 145-150.

Singh, S.P., Gite, L.P. and Agrawal, N. (2004). Ergonomical evaluation of manually operated fertilizer broadcaster with farm women. *J. Agril. Engg.*, **41**: 22-25.

Verghese, M.A., Saha, P.N. and Atreya, N. (1994). A rapid appraisal of occupational workload from a modified scale of perceived exertion. *Ergonomics*, **37** (3): 485-491.

• • • • •