Ergonomic Evaluation of Manually Operated Knapsack Sprayer for Female Workers

Abstract

Spraying is one of the most important operations in crop production to protect the crops from attack of various ~~pest~~ pests and diseases. Ergonomic intervention in spraying operation can provide a reasonable basis for the recommendation on operating methods and efficient operation for more output and safety. The ergonomic evaluation of the manually operated knapsack sprayer was carried out on the basis of heart rate and oxygen consumption rate. The heart rate of the worker varied from102.69 beats/min~~.~~ to 118.04 beats/min~~.~~ for all the workers in wet land condition compared to 102.56 beats/min. to 110.48 beats/min in dry land condition. It was observed that the oxygen consumption varied from 0.732 lit/min to 1.038 lit/min in wet land spraying and 0.729 lit/min~~.~~ to 0.887 lit/min~~.~~ in dry land spraying.

Keywords: Knapsack sprayer, Heart rate, Oxygen consumption rate and Drudgery

1. Introduction

In India, crops are affected by over 200 major pests, 100 plant diseases, hundreds of weeds and other pests like nematodes, harmful birds, and rodents. Approximately, 18 per cent of Indian crop yield potential is being lost due to insects, disease and weeds which in terms of quantity would mean 30 million tons of food grain. The value of total loss has been placed at Rs 50,000 million, represents about 18 per cent of the gross national agriculture production. (Manncsa, 2009). Control of pests and disease is achieved by various plant protection methods. This includes agro technical, biological, chemical, physico-mechanical and others. But chemical application is the viable option since; it is highly effective, relatively simple and quick to apply. Sprayer is a machine to apply herbicides, fungicides, and insecticides in the form of droplets. Among the others lever operated knapsack sprayer, Power sprayer and manually operated sprayers are commonly used by small farmers to medium farmers. During sprayer operation, the operator's body assumes an awkward position, giving severe discomfort to the body. The frequent up and down movement of the lever in ~~lever operated~~lever-operated knapsack sprayers causes undue fatigue and discomfort to the ~~woman~~ woman's body. Ergonomically well-designed hand

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~~equipment's~~equipment may reduce the ~~discomforts~~ discomfort (Tiwari, *et al.* 2010). It also provides comfortable work for the users and gives high product quality to the consumers. Using ~~ergonomical~~ ergonomic tools, we can evaluate the energy expenditure of workers, their physiological cost and suitable ~~method~~ methods for farm workers and how long they can work continuously without getting fatigue (Gite and Yadav, 1990). Ease of performing an operation affects the output of the worker. Therefore, the study has been proposed for evaluating the performance of knapsack sprayers for female ~~worker~~workers.

2. Materials and Methods

In evaluating the ergonomics of spraying operations, different age ~~group~~ groups of operators and different ~~timing~~ timings in a day are taken. The evaluation is done by using polar heart rate monitor for heart rate measurement, oxygen consumption rate and energy expenditure rate was computed from heart rate while operating the sprayer and grip fatigue was calculated by using grip dynamometer.

2.1 Selection of subjects and collection of data

The ergonomic evaluation of manually operated knapsack sprayer for female workers was conducted to work out heart rate and oxygen consumption rate during the operation. The ergonomic study included four female subjects who were chosen at random. The subjects were carefully selected to ensure that they were medically fit to participate in the trials and that they were representative of the user population for the manually operated knapsack sprayer. Subjects were chosen from the age range of 30 to 45 years old because this is when maximum strength is reached (Yadav *et al.* 2007).

Table 1: Experimental plan of ergonomic evaluation of manually operated knapsack sprayer in field condition

S.No	Independent variables	Levels	Details	Dependent variables
1	Subject (age)	4	30, 35, 40, 45	Heart rate (HR), beats min^{-1} Oxygen consumption rate (OCR), l min^{-1}

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Commented [R9]: Table needs to be cited in text. I would recommend removing it completely as there's a lot of redundancy in what is written and then presenting it as a table.

2.2 Heart rate (HR)

During ~~manually~~ manual operated~~ion of the~~ knapsack sprayer, heart rate was measured by computerized polar heart rate monitor. It consists of ~~polar coded~~polar-coded transmitter, an elastic strap, ~~wristwatch type~~wristwatch-type receiver and interface. The sensor of heart rate monitor was fixed on the chest of the operator and its display was fixed on wrist of the operator, i.e., within the signal range of the device. Duration of continuous work. Afterwards, the data was downloaded for analysis. ~~Work load~~Workload was determined with the help of heart rate readings and grade of physical work based on HR, and OCR is given in Table 2 (Yadav *et al.* 2007).

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2.3 Oxygen consumption rate (OCR)

Oxygen consumption rate is a ~~measured~~ measure to ~~access~~ assess whole body fatigue. However, it was computed from the heart rate (HR) values of the operator by using the ~~equation~~ Equation ~~1~~ given by Singh *et al.* 2008.

$$OCR = 0.0114\,HR - 0.68 \quad \ldots (1)$$

Where,

OCR = Oxygen consumption, ~~l~~ min^{-1}

HR = Heart rate, beats min^{-1}

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Table 2: Grade of physical work based on HR, OCR

Sl. No.	HR, beats min^{-1}	OCR, l min^{-1}	Grade of work
1	<75	<0.5	Very light
2	75-100	0.5-1.0	Light
3	100-125	1.0-1.5	Moderately heavy
4	125-150	1.5-2.0	Heavy

5	150-175	2.0-2.5	Very heavy
6	>175	>2.5	Unduly heavy

Source: Yadav, *et al.,* 2007.

2.4. Construction details of Knapsack Sprayer

~~Knapsack sprayer consists of a pump and a air chamber permanently installed in a 10 to 20 liters tank. The handle of the pump extending over the shoulder or under the arm of operator makes it possible to pump with one hand and spray with the other. Uniform pressure can be maintained by keeping the pump in continuous operation. Knapsack sprayers are used for spraying insecticides and pesticides on small trees, shrubs and row crops~~A knapsack sprayer consists of a pump and an air chamber permanently installed in a tank of 10 to 20 litres. The handle of the pump, extending over the shoulder or under the arm of the operator, allows them to pump with one hand and spray with the other. Uniform pressure can be maintained by keeping the pump in continuous operation. Knapsack sprayers are used for spraying insecticides and pesticides on small trees, shrubs, and row crops.

Power required : One person

Tank capacity (I) : 15 ~~liter~~litres

Number of piston in pump cylinder : One

3. Results and Discussions~~no~~

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The ergonomics studies were carried out with knapsack sprayer with different age groups 30-35 years (A1), 35-40 (A2) years (A2) and 40-45 years (A3) at different timings in a day 10:00am to 11:00am (T1), 3:00pm to 4:00pm (T2) and 4:00pm to 5:00pm (T3) in different field condition (wet land and dry land) respectively during April and ~~may~~May, 2019.

3.1 Heart rate and oxygen consumption of the workers ~~Involved~~ involved in wet land spraying operation.

The heart rate at the beginning is different for the three different age groups and it ranged between 73 beats/min to 92 beats/min at 10:00 to11: 00 am and is increased to 76 beats/min to 106 beats/min at 3:00 to 4:00 pm. It is again decreased to 74 beats/min to 102

beats/min at 4:00 to 5:00 pm which may be due to the variation in the environment temperature.

The average heart rate for different age groups and at different timings using lever operated knapsack sprayer are given in Table 3. The average heart rate was 112.28 beats/min for 30 to 35 years, 115.10 beats/min for 35 to 40 years and 105.24 beats/min for 40 to 45 years at 10:00 am to 11:00 am. Then it is increased to 118.81 beats/min for 30 to 35 years, 121.84 beats/min at 3:00 pm to 4:00 pm and 112.11 beats/min at 4:00 pm to 5:00 pm. Again the heart rate was decreased to 114.30 beats/min, 114.71 beats/min and 103.05 beats/min at different timings. Therefore, the highest heart rate was recorded during 3:00 pm to 4:00 pm for 35 to 40 years of age groups.

Fig~~.~~ure 1 shows that the effect of heart rate on age groups and at ~~-~~different timings in a day was maximum for 35 to 40 years at 3:00 pm to 4:00 pm and is minimum for 40 to 45 years at 4:00 pm to 5:00 pm. This may be due to variations in the ~~environment~~ environmental temperatures.

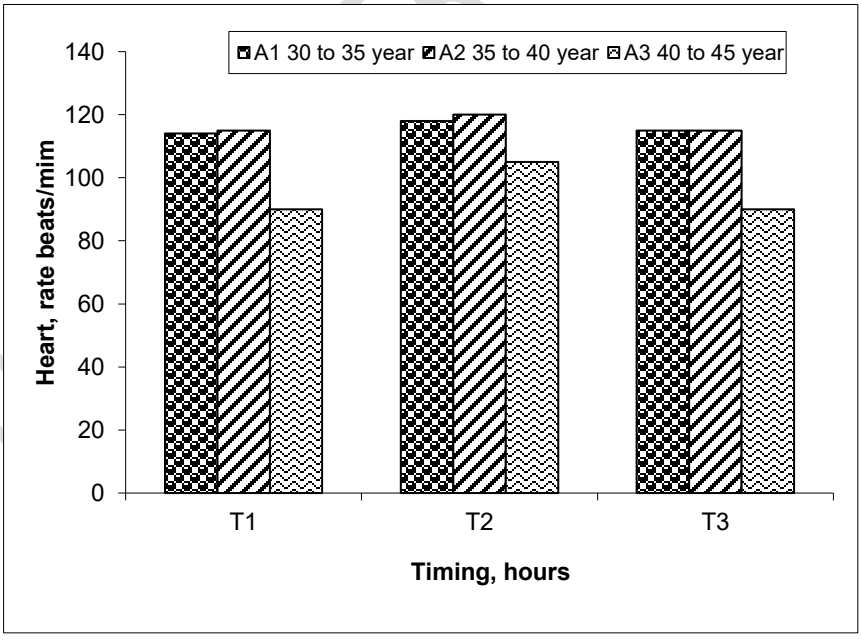

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Fig.1 Effect of heart rate on age groups and timings in wet land spraying with lever operated knapsack sprayer

From Table 4, the average oxygen consumption during spraying operation with lever operated knapsack sprayer is 0.924 lit/min for 30 to 35years, 0.981 lit/min for 35to 40years and 0.784 lit/min during 10:00 am to 11:00 am. This was increased to 1.050 lit/min, 1.110 lit/min and 0.917 lit/min during 3:00 pm to 4:00 pm, and then it decreased to 0.964 lit/min, 0.972 lit/min and 0.740 lit/min during 4:00 pm to 5:00 pm for different age groups of workers respectively.

Fig. 2 shows that the effect of oxygen consumption on age groups and timings in a day using lever operated knapsack sprayer. The oxygen consumption was maximum during 3:00 pm to 4:00 pm for 35 to 40 years and minimum for 30 to 35 years at 10:00 am to 11:00 am. This may be due to the variations in temperature. The decrease in oxygen consumption may be due to environmental cool temperature.

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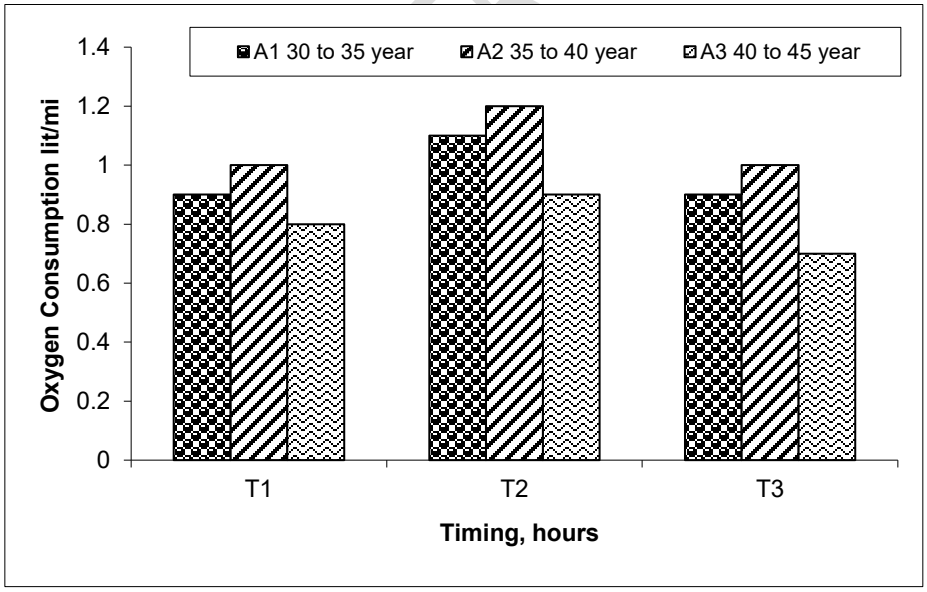

Fig.2 Effect of oxygen consumption on age group and timings in wet land spraying with lever operated knapsack sprayer

Table 3: Effect of heart rate on age group and timings in a day during spraying operation in wet land condition.

T1				T2				T3			
A1	A2	A3	Mean	A1	A2	A3	Mean	A1	A2	A3	Mean
112.4	115.2	105.3	110.95	118.9	121.9	112.3	117.7	114.3	114.7	103.7	111
			Result	S. Ed. (±)	C.D. at 5%						
Due to time			**S**	0.906	1.9025						
Due to age			**S**	0.906	1.9025						

Table 4: Effect of age of operator and time duration on oxygen consumption during spraying operation in wet land condition.

1				T2				T3			
A1	A2	A3	Mean	A1	A2	A3	Mean	A1	A2	A3	Mean
0.925	0.982	0.783	0.897	1.055	1.116	0.923	1.031	0.964	0.972	0.752	0.896
			Result	S. Ed. (±)	C.D. at 5%						
Due to time			**S**	0.018	0.0382						
Due to age			**S**	0.018	0.0382						

3.2 Heart rate and oxygen consumption of the workers involved in dry land spraying operation.

The average heart rate for different age groups and at different timings using lever operated knapsack sprayer are given in Table 5. The average heart rate was 116.47 beats/min for 30 to 35 years, 106.28 beats/min for 35 to 40 years and 107.17 beats/min for 40 to 45 years at 10:00 am to 11:00 am. Then it is increased to 119.68 beats/min for 30 to 35 years, 108.79 beats/min at 3:00 pm to 4:00 pm and 110.22 beats/min at 4:00 pm to 5:00 pm. Again the heart rate was

decreased to 115.67 beats/min, 103.97 beats/min and 109.99 beats/min at different timings. Therefore, the highest heart rate was recorded during 10:00 am to 11:00 am for 30 to 35 years of age ~~groups~~group.

Fig. 3 shows that the effect of heart rate on age groups and at different timings in a day was maximum for 30to 35 years at 10:00 am to 11:00 am and is minimum for 35to 40 years at 3:00 pm to 4: 00 pm. This may be due to variations in the environmental temperatures and soil conditions.

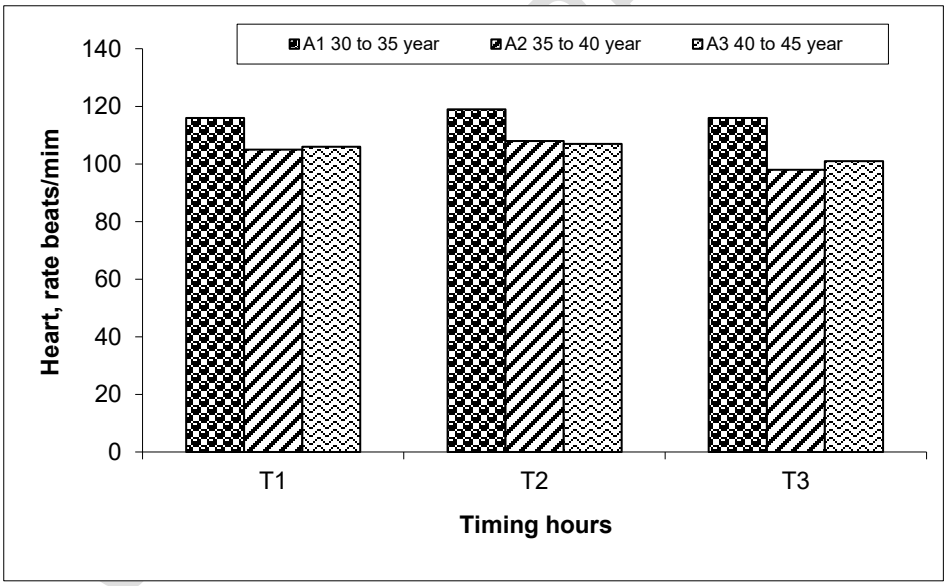

Fig. 3 Effect of heart rate on age group and timing in dry land spraying with lever operated knapsack sprayer

From Table 6, the average oxygen consumption during spraying operation with lever operated knapsack sprayer is 1.000 lit/min for 30 to 35 years, 0.800 lit/min for 35 to 40 years and 0.814

lit/min during 10:00 am to 11:00 am. This was increased to 1.070 lit/min, 0.842 lit/min and 0.885 lit/min during 3:00 pm to 4:00 pm, and then it decreased to 0.842 lit/min, 0.757 lit/min and 0.785 lit/min during 4:00 pm to 5:00 pm for different age groups of workers respectively.

Fig. 4 shows that the effect of oxygen consumption on age groups and timings in a day using lever operated knapsack sprayer. The oxygen consumption was maximum during 10:00 am to 11:00 am for 30to 35years and minimum for 35to 40 years at 3:00 pm to 4:00 pm. This may be due to the variations in temperature and soil conditions. The decrease in oxygen consumption may be due to cool temperature.

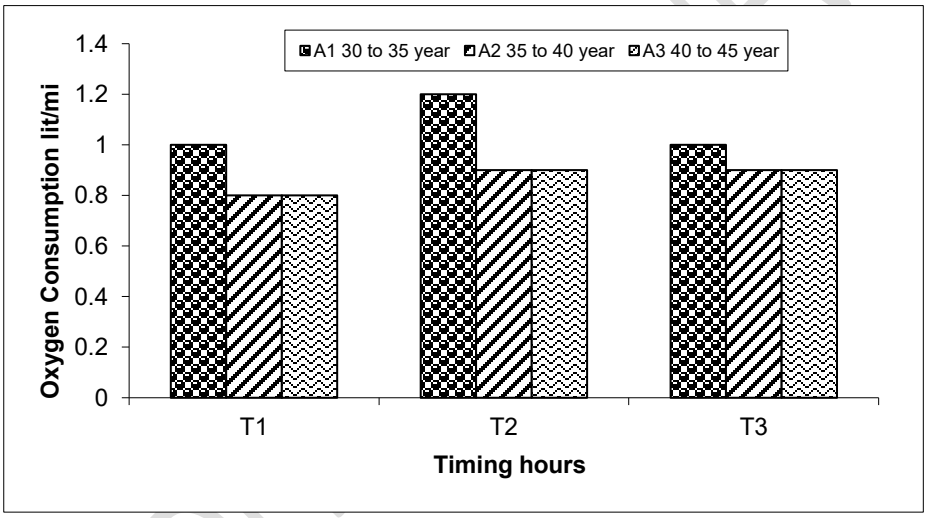

Fig. 4.Effect of heart rate on age group and timing in dry land spraying with lever operated knapsack sprayer

Table 5: Effect of age of operator and time duration on heart rate during spraying operation in dry land condition.

T1				T2				T3			
A1	A2	A3	Mean	A1	A2	A3	Mean	A1	A2	A3	Mean
116.46	106.3	107.2	109.97	119.7	108.8	110.3	112.9	115.6	103.9	106	108
			Result	S. Ed. (±)	C.D. at 5%						
Due to time			**S**	0.330	0.693						

			8						
Due to age	**S**	0.330	0.6938						

Table 6: Effect of age of operator and time duration on Oxygen consumption during spraying operation in dry land condition.

T1				T2				T3			
A1	A2	A3	Mean	A1	A2	A3	Mean	A1	A2	A3	Mean
1.006	0.803	0.821	0.877	1.071	0.853	0.883	0.935	0.989	0.755	0.798	0.816
			Result	S. Ed. (±)	C.D. at 5%						
Due to time			**S**	0.007	0.0141						
Due to age			**S**	0.007	0.0141						

4. Conclusions

It was observed that working during 3:00 pm to 4:00 pm developed maximum working heart rate and oxygen consumption in both the fields compared to 10:00 am to 11:00 am and 4:00 pm to 5:00 pm, which might be due to higher environment temperature. The agricultural worker of 35 to 40 years of age group have developed maximum working heart rate and oxygen consumption higher than the age groups of 30 to 35 years and 40 to 45years in both the operations. The heart rate of the worker varied ~~from102.69~~from 102.69 beats/min. to 118.04 beats/min. for all the workers in wet land condition compared to 102.56 beats/min. to 110.48 beats/min in dry land condition. It was observed that the oxygen consumption varied from 0.732 lit/min to 1.038 lit/min in wet land spraying and 0.729 lit/min. to 0.887 lit/min. in dry land spraying.

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References

Gite, L. P. and Yadav, B. G. (1990). Anthropometric survey for agricultural machinery design. *Applied Ergonomics*, 21(2), 115-119. https://www.sciencedirect.com/science/article/pii/0003687089900768

Manncsa, 2009, Pesticides in Agriculture, *Agropedia*. p. 265.

Commented [R18]: The number and quality of references provided in this study is insufficient for a research article. There is no breadth in the articles themselves and they lack currency.

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