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RESEARCH ARTICLE

Physiological and subjective evaluation of tractor operator workplace

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ABSTRACT

Tractors are the major source of farm power. Tractor driving imposes a lot of physical and mental stress upon the operator. This study was aimed at evaluating the physiological and subjective response of tractor operators while driving a tractor. Five tractor models and three male tractor operators were randomly selected for the study. The physiological evaluation was carried out in terms of heart rate and data were analyzed on the basis of two Factor Completely Randomized Design. The results showed that the effect of tractors on the heart beat was significant but the effect of subjects was found to be non-significant. The energy expenditure rate was ranged from 6.34 to 10.94 $kJmin^{-1}$; indicating that in some tractors, operation requires a lot of physical effort. Rated Perceive Exertion scores were also in match with the physiological evaluation. The results call upon the manufactures to ergonomically design the tractor workplace to make it more comfortable for the operator.

KEY WORDS : Tractor, Operator, Heart rate, Energy expenditure rate, Rated perceive exertion score

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INTRODUCTION

In tropical country like India, the tractor operation requires a high level of human effort. The extreme conditions of climatic parameters such as temperature, humidity solar radiation impose stress on the operator health and working efficiency (Choudhry, 1989) so the health of the operator becomes an important issue. While driving, the operator has to perform many activities like steering, controlling the speed of the vehicle, reacting quickly and appropriately, observing the instruments and also the happenings around him, all the time, and continuously. Fig. A shows the tractor and the operator as a man-machine system and the effect of environment on the operator, as the operator has to perform the activities in open area.Rosegger and Rosegger (1960) showed that the tractor driving, which induces unnoticed discomfort, including mental and physical stress, has a deleterious effect on the operator's health over a long period, particularly, in connection with spinal and stomach disorders. Though tractorization has reduced the drudgery involved in the farm operations, but it was evident that tractors had ergonomic shortcomings (Dupuis, 1959); Fairly (1995), Balasankari *et al*. (2004)).Mohan and Patel (2003) studied that largest number of traumatic injuries is caused by fodder cutting machines and threshers. The design of these machines has been made safer using ergonomic principles. The physiological cost of human beings in performing physical work is described mainly by the indices, such as, heart rate (HR), oxygen consumption rate, sweat rate, skin temperature and blood pressure. These measurements help to measure the worker's physical capacity to perform strenuous work; and to estimate the rest allowance required to permit the recovery from fatigue (Yadav, 1995). Christensen (1953) and Zander (1972) suggested the physical workload

on the basis of estimation of energy expenditure and heart rate under field or laboratory conditions would be an acceptable and fairly accurate method for operator's performance assessment. The EER can be measured indirectly by measuring the Oxygen consumption rate (OCR) since the two are interrelated (Grandjean, 1963). When 1 litre of oxygen is consumed in the human body, there is on an average, a turnover of 4.8 kcal of energy.Anonymous (1973) stated that the classification of work of average Indian workers should be done on the basis of energy expenditure per unit body weight. Accordingly the EER for exceptionally heavy work could range from 42-62 kcal per day per kg body weight for men.

Dupuis (1959) investigated the strain on operators due to operation of different controls and reported that the energy expenditure of tractor driving varies from 4.18- 16.74 kJ min^{-1} depending on the particular agricultural task performed.Saha *et al.* (1979) reported that acceptable workload for average young Indian worker varies between 30 per cent - 40 per cent of an individual maximum aerobic power under comfortable environment conditions. The corresponding heart rate and energy expenditure reported by the author were 110 beats/minand 18 kJ min^{-1}, respectively. He also reported that the limit for acceptable workload (AWL) for Indian workers is considered as 14.6 kJ min^{-1}. In addition to the physiological response, the subjective assessment score of the operator's feelings while performing the allotted task is also important. Yadav and Tewari (1998) said that an optimum workplace configuration would be one in which the location of the essential tractor controls such as clutch, brake, draft control lever and steering wheel are so located that minimum energy is spent in operation as well as the operator would feel comfortable.

EXPERIMENTAL PROCEDURE

In this study, five different popular Indian tractors of different makes, models and sizes; *viz.*, TM_1 (40 hp), TM_2 (25 hp), TM_3 (45 hp), TM_4 (35 hp) and TM_5 (25 hp) and three male tractor operators were randomly selected. The anthropometric data of the selected operators are presented in Table A. The physiological evaluation was carried out by measuring heart rate (HR) and then by calculating energy expenditure rate (EER) using measured data. The experiment was carried out with the selected subjects. Each subject was allowed to sit on different tractors and operate the clutch, brake, draft control lever and steering task for 20 minutes. The HR of the subjects was measured by polar heart rate monitor. The HR measurements of selected subjects were taken at rest and after 5, 10, 15 and 20 minutes duration, respectively, while operating on different tractors and after 5 minutes rest. The tractor operation was carried out in rough terrain *i.e.* at field condition.

Table A : Anthropometric dimensions of selected subjects

Subjects	Age (Year)	Height (cm)	Weight (kg)
S_1	24	179.8	66.5
S_2	27	179.2	85.0
S_3	24	176. 8	73.5

For statistical analysis, to predict the effect of tractor and subject, two factor Completely Randomized Design with three replications was used. The EER (kJ min^{-1}) was calculated by using the formula given by Saha *et al.* (1979).

$$\mathbf{EER} = \frac{\mathbf{(HR - 66.0)}}{\mathbf{2.4}}$$

The subjective evaluation was carried out in terms of ratedperceived exertion(RPE) score. RPE score is defined as the score given by the operator based on his feelings while performing the task. The evaluation of the operator's feelings was also carried out using Borg scale (1962) and this scale as shown in Fig. B was presented in front of the operators while they were performing the tasks. All the selected subjects were familiar to experimental protocol to get accuracy in the measurement and expressed their feelings in terms of selected scale. They were asked to indicate their scores on the basis of their feeling in a given configuration. This procedure was followed for each of the selected tractor model.

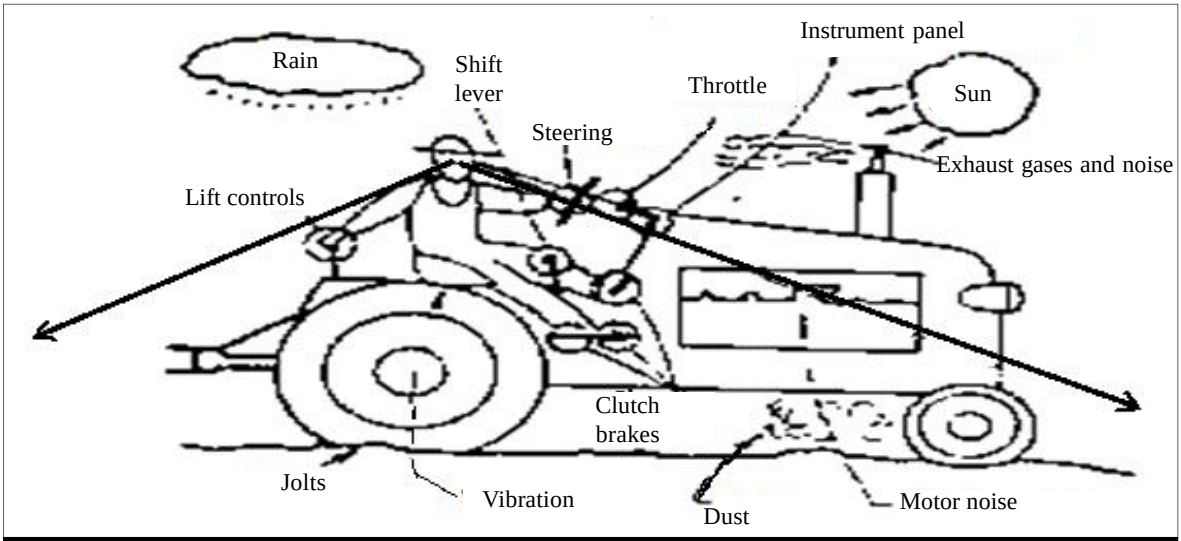

Fig. A : Concept of the tractor and the operator as a man-machine system in its environment (Balasankari *et al.*, 2004)

(6)	
(7)	Very, Very light
(8)	
(9)	Very light
(10)	
(11)	Fairly light
(12)	
(13)	Somewhat hard
(14)	
(15)	Hard
(16)	
(17)	Very hard
(18)	
(19)	Very, Very hard
(20)	

Fig. B: Subjective scale (After Borg, 1962)

EXPERIMENTAL FINDINGS AND ANALYSIS

The ergonomic evaluation was carried out in terms of physiological and subjective evaluation. The physiological evaluation was carried out by measuring HR and then by calculating EER using measured data. The subjective evaluation was carried out in terms of ratedperceived exertion(RPE) score. All the selected subjects were familiar to experimental protocol to get accuracy in the measurement and expressed their feelings in terms of selected scale.

Physiological evaluation :

The effect of tractor and subjects on the heart beat was analyzed by two Factor Completely Randomized Design. A perusal of data presented in Table 1 and Fig. 1 revealed that the effect of tractor models on the heart beat of subjects was found significant.

Initially minimum heart rate was recorded in the configuration TM_3 (79.00 beats/min) which was found at par with TM_1 (79.11 beats/min) and TM_2 (81.00 beats/min). There was sudden increase in the heart rate of subjects after 5 min of driving; minimum heart rate was recorded on treatment TM_3 (82.22 beats/min) which was at par with TM_1 (84.11 beats/min) and significantly differs with other treatments, whereas maximum heart rate was recorded on TM_5 (95.00 beats/min). Similar trends were obtained after 10, 15 and 20 minutes of driving. After giving 5 minutes of rest to the subjects, the minimum heart rate was recorded on TM_3 (79.44 beats/min) whereas maximum heart rate was found on TM_5 (83.89 beats/min).

It was found that the effect of subjects on heart rate was non-significant (Fig. 2). While working, the heart rate was almost stabilized after 10 minutes of working and HR remain almost stable onward. And after 20 minutes of the duration, the rest was given. The similar trend was obtained for all the selected subjects.

It is evident from the data, the tractor model TM_3 was easier to drive and operate, among all the selected tractors as minimum heart rate and change in the heart rate during 20 minutes of driving was recorded minimum on this tractor.

Physiological responses of all the three subjects during evaluation of workplace configuration are presented in Table 2. It is evident that configuration TM_3 requires minimum energy, indicating that the controls arrangement on this tractor were properly arranged and also operators feel comfortable to operate the controls of this tractor model. It is also apparent that configuration TM_2 shows maximum physiological effects on the operators.

The operators spent more energy on TM_2 and TM_5 as compared to other tractor models; it indicates controls like gears, steering wheel, clutch, brakes etc. were difficult to operate for the selected subjects.

Table 1 : Effect of tractors and subjects on heart beat.

Treatments	Heart beat (beats/min)					
	Initial	5 min	10 min	15 min	20 min	At rest
Tractor (TM)						
TM_1	79.11	84.10	84.78	84.67	83.57	79.78
TM_2	81.00	94.33	97.67	99.56	97.00	83.22
TM_3	79.00	82.22	83.22	83.00	82.33	79.44
TM_4	82.78	87.89	88.67	90.56	89.00	83.56
TM_5	82.56	95.00	94.44	97.67	95.88	83.89
S.E. ±	0.96	1.01	0.91	1.009	1.19	0.903
C.D. (P=0.05)	2.77*	2.92**	2.63**	2.91**	3.46**	2.607**
Subject (S)						
S_1	80.47	88.40	89.93	91.20	89.27	81.13
S_2	81.07	88.13	89.13	91.20	89.93	82.07
S_3	81.33	89.60	90.20	90.87	89.47	82.73
S.E ±	0.74	0.78	0.71	0.78	0.928	0.69
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
TM x S						
S. E ±	1.66	1.75	1.58	1.74	2.07	1.56
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
CV%	3.56	3.43	3.05	3.32	4.01	3.3

NS=Non-significant * and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2: Energy expenditure rate of subjects on different tractor workplace configurations in kJ min^{-1}

Sr. No.	TM_1	TM_2	TM_3	TM_4	TM_5
S_1	6.98	10.48	6.34	8.17	10.81
S_2	6.73	10.93	6.52	8.93	10.46
S_3	7.11	10.44	7.03	9.23	10.69

Table 3 : RPE scores of subjects for steering wheel of selected tractors

Sr. No.	S_1	S_2	S_3
TM_1	12	11	10
TM_2	17	17	15
TM_3	9	10	10
TM_4	11	11	11
TM_5	15	13	9

Subjective evaluation:

The lowest RPE score (very light) was obtained for TM_3 workplace configuration from all the selected subjects as shown in Table 3. Therefore TM_3 workplace configuration is comfortable for steering wheel operation among other selected tractor models. It can also be said that the TM_2 workplace configuration is the most difficult because the highest RPE score (very hard) was obtained for it from all the selected subjects.

For TM_3 workplace configuration lowest RPE score (very light) was obtained from all the selected subjects as shown in Table 4. Therefore TM_3 workplace configuration is comfortable for foot operated controls operation among other selected tractor models. It can also be said that the TM_2 workplace configuration is the most difficult because the

Table 4 : RPE scores of subjects for foot operated controls of different tractors

Sr. No.	S_1	S_2	S_3
TM_1	11	11	10
TM_2	15	15	13
TM_3	10	10	9
TM_4	15	13	13
TM_5	15	14	12

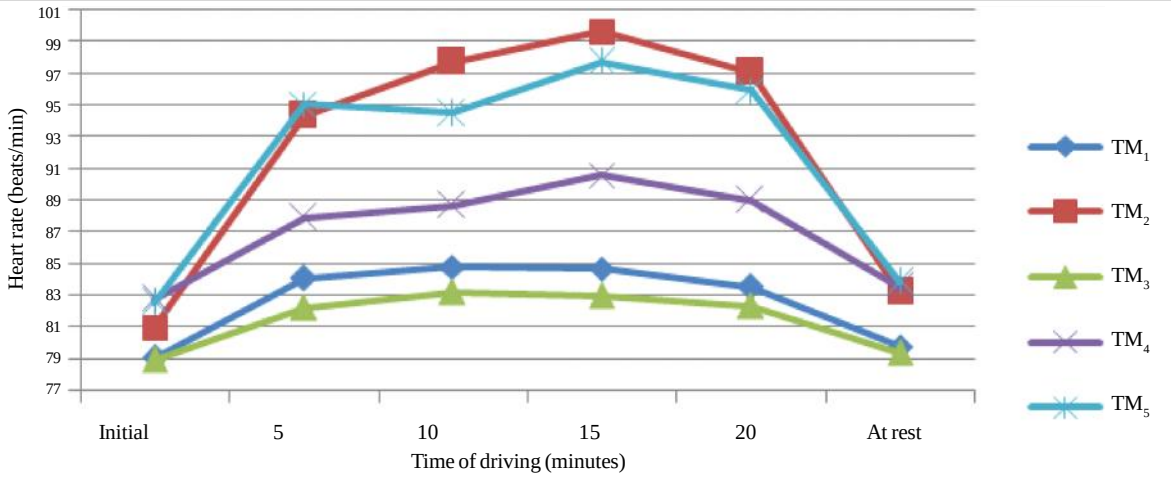

Fig. 1 : Effect of tractors on the heart rate of subjects

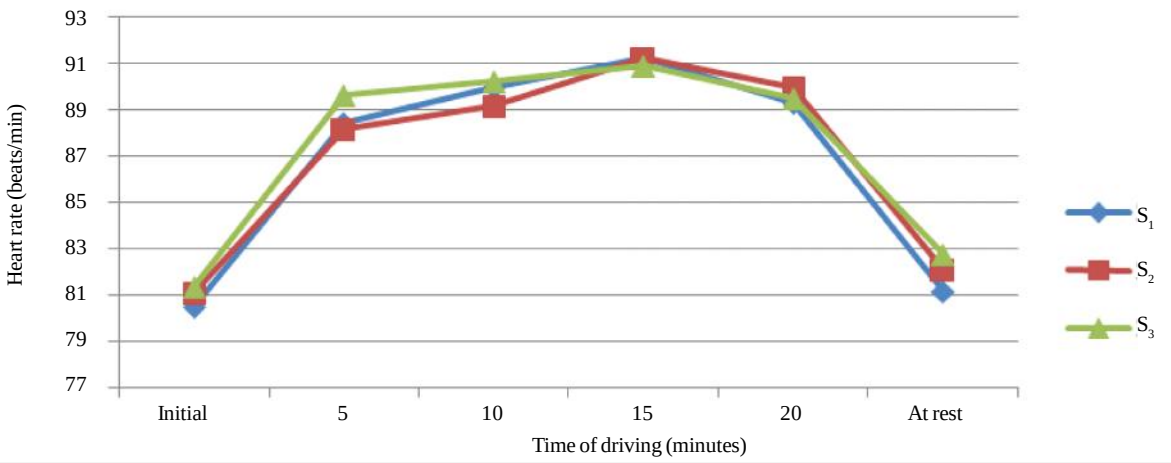

Fig. 2 : Effect of subjects on the heart rate

Table 5 : RPE scores of subjects for hand operated controls of different tractors			
Sr. No.	S_1	S_2	S_3
TM_1	13	12	13
TM_2	17	17	15
TM_3	10	10	9
TM_4	13	11	15
TM_5	15	14	13

highest RPE score (hard) was obtained for it from all the selected subjects.

Table 5 shows that the hand operated controls of TM_3 were easily accessible for the selected subjects as lowest RPE score (very light) was obtained it.

Conclusion :

The physiological behaviour appears quite similar for subjects S_1, S_2 and S_3 during operating different tractor models, indicating the fact that the subjects experienced identical load conditions. Heart rate was significantly influenced by different tractor models. Minimum heart rate was recorded on tractor TM_3 (79.00 beats/min) whereas maximum recorded on TM_2 (99.56 beats/min) and the corresponding mean energy spent in TM_1, TM_2, TM_3, TM_4 and TM_5 worked out to be 6.94, 10.62, 6.63, 8.78, 10.65 kJ min^{-1}. From physiological response, it is concluded that tractor operator model TM_3 required minimum energy expenditure as compared to other tractor models.

For steering wheel operation, hand and foot operated controls, the lowest RPE score (very light) was obtained for TM_3 workplace configuration from all the selected subjects; it is concluded that TM_3 was efficient and comfortable to operate than that of other tractor selected models.

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