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RESEARCH PAPER

Operator workplace design compatibility: A study on mini tractor

Ravi Vala*, Rajvir Yadav **and** S.K. Gaadhe
Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh (Gujarat) India (Email: valaravi0606@gmail.com)

Abstract : Small tractor for agriculture is India's most trending tractor segment for farmers. Looking to the mini tractor industry in India, there is a need to study the ergonomic aspects of mini tractor for operator's better safety, comfort and higher efficiency. Study was conducted in which the tractor workplace configurations of 8 different mini tractor models were measured using different measuring scales. The location of different mini tractor seat and control locations were calculated considering the biomechanical and anthropometric measurements. These values were given as design values for mini tractor operator's workplace design. The ergonomic evaluation of workplaces of 8 different mini tractor models was carried out in laboratory as well as in the field. Studies on evaluation of the optimum location of controls resulted in steering column angle of 70º with horizontal, foot pedals (clutch and brake) distance of 70.5 cm from SRP and the draft control lever distance of 28.6 cm from seat reference point (SRP). Heart rate was significantly influenced by different mini tractor models. It was found that the value obtained from the different mini tractor workplace configurations should be near to design values so that the operator can operate it with efficiently and comfortably.

Key Words : Ergonomics, Mini tractor, Tractor workplace design, Physiological, Subjective evaluation

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INTRODUCTION

Operating the mini tractor in tropical country like India requires high level of human effort. 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. The operator together with the tractor forms a "man–machine" system which is subjected to environmental stresses – temperature, humidity, rain, dust, noise in the atmosphere, solar radiation, work place arrangement and placement of control, that affect the operator. In a similar way, the amount of physical effort required for control of the machine components may limit performance efficiency and operator comfort. Looking to the mini tractor industry in India, there is a need to study the ergonomic aspects of mini tractor operator for better safety, comfort and higher efficiency. Indian mini tractor workplace and location of the hand and foot control levers should be designed to accommodate 90% Indian population. There should be uniformity in placement of

***Author for correspondence:**

these controls on all tractors to accommodate the operator leading to an efficient and comfortable operation. At the same time, though tractorization has reduced the drudgery involved in the farm operations, but it was evident that tractors had ergonomic shortcomings (Dupuis, 1959; Fairly, 1995 and Balasankari *et al.,* 2004).

The design and location of an operator's workplace on mobile equipment is frequently a compromise because of conflicting requirements for the limited space available. The increasing awareness on the potential benefits of good ergonomic design has resulted in a steady improvement of the operator's workplace (Yadav, 1995; Yadav *et al.,* 2007 and Yadav and Jakasania 2020).

MATERIAL AND METHODS

The research work was conducted in the laboratory as well as in the field of Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

Study of mini tractor workplace configuration of different mini tractor models :

The mini tractor models, which are widely used in India were consider. Different mini tractor designated as T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 from mini tractor model TM_1, TM_2, TM_3, TM_4, TM_5, TM_6, TM_7 and TM_8, respectively are measured.

Tractor workplace layout as per given by ISO 4253:1993 and IS 12343:1998 :

The International Standard (ISO 4253:1993) and Indian Standard (IS 12343:1998) lay down a range of dimensions as shown in Fig. A and B for the operator's seat and location of specific controls relative to the SIP within the seating accommodation on agricultural tractor with a track width greater than 1150 mm. the controls included are the steering wheel, brake pedal, clutch pedal and throttle pedal. However, these standards do not specify location of hydraulic control lever relative to the SIP within the seating accommodation.

Biomechanical model of seated tractor operator :

The seated tractor operator model as biomechanical model consisting of a relatively small number of straight line links (representing bones) and joints (representing major articulations). Fig. C shows such a typical link-joint biomechanical model. The details of different angles notations are as follows.

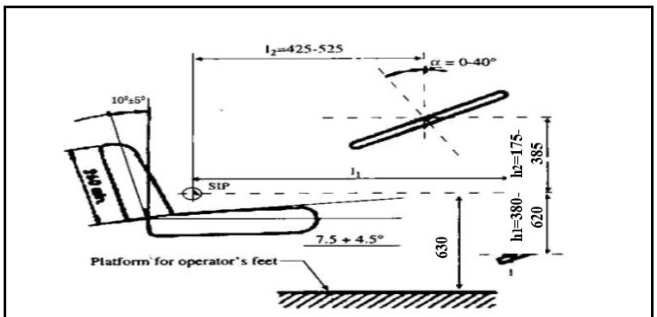

Fig. A : Operator's seating accommodation (IS 12343:1998)

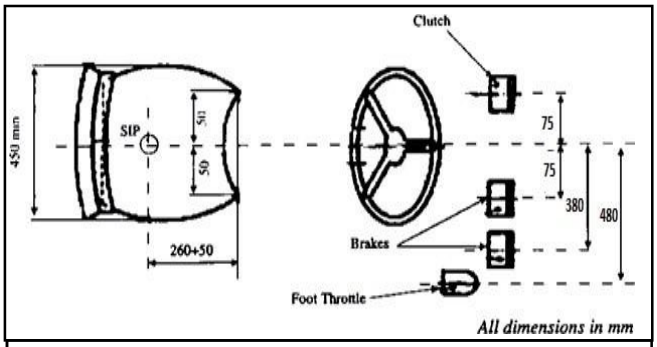

Fig. B : Seat design and its adjustments

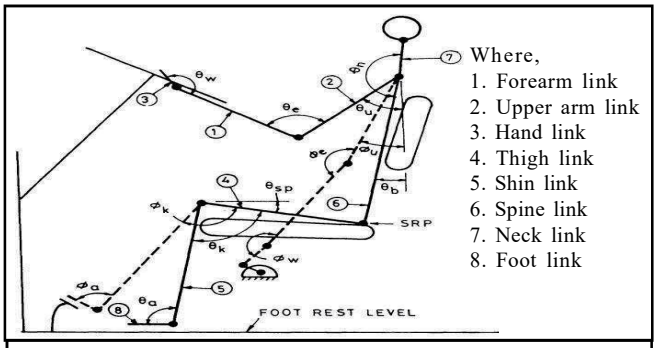

Fig. C : Typical link-joint biomechanical model of seated tractor operator

The number of anthropometric surveys (Sen, 1964; Sen *et al.,* 1977; Gupta *et al.,* 1983; Yadav *et al.*, 1998 and Dewangan *et al.,* 2010) carried out in the country are very small and are based on small sample size and the dimensions included were specific to the requirements. These case studies pointed out that there was a considerable difference between the anthropometric data of Indian and Westerns. Therefore, it was felt necessary to conduct

Table A : Range of comfort and angle used in design of tractor operator workplace

Body angle	Range, deg	Angle used in design	Comments
Back (θb)	10-30	10	-
Hips(θh)	95-120	95	-
Knee (θk)	95-136	95	Foot resting on foot rest
(Φk)		115	Foot pedal operation
Ankle(θa)	90-110	90	-
(Φa)		90	-
Upper arm(θu)	10-45	45	For steering control
(Φu)		10	For hydraulic control
Elbow (θe)	80-120	120	For steering control
(Φe)		165	For hydraulic control
Wrist (θw)	170-190	170	For steering control
(Φw)		170	For hydraulic control
(θsp)	NA	3	-
(θls)	NA	25	-
(θn)	NA	180	-

Table B : Length of links in terms of anthropometric measurements

Link	Link length in terms of anthropometric measurement (cm)
For earm link	(For earm hand length, Lfa-Hand length, Lh)
Upper arm link	(Shoulder elbow length, Le)
Hand link	(Hand length, Lh x 0.5)
Thigh link	(Buttock-popliteal length, Lp x 0.8)
Shank link	(Popliteal height, Hp x 0.8)
Spine link	(Sitting shoulder height, Hs)
Neck link	(Sitting eye height, Heh-Sitting shoulder height, Hs) x 0.5
Foot link	(Foot length,Lf x 0.5)

extensive surveys in different regions of the country to generate the necessary data useful in farm machinery design (Gite and Yadav, 1989).

Anthropometric data of Indian operator :

For the present study, the anthropometric data of randomly selected seven hundred thirty four tractor operators of Gujarat were collected from the Anon. (2005) which are depicted in Table A. Only male operator's data are considered because in India no female operators are employed for tractor driving task in field operations. These data were taken to calculate different configurations for safe and comfortable ride on tractor.

Design of configuration using different equations and anthropometric data :

The design of efficient workplace configuration should be done by considering the anthropometric data of user's population and some equations. The location of hand and foot operated controls and steering wheel should be within easy reach of the operators.

Hand operated control :

The location of hydraulic control w.r.t. SRP is expressed by following eq.:

Horizontal distance from SRP,

$$= (L\,fa - 0.5\,L\,h)\,Sin\,(\Phi e - \Phi u) + Le\,Sin\,(\Phi u) - H\,s\,Sin\,(\theta b) + (Lh/2)\,Sin(\Phi w + \Phi e - \Phi u - k) + 0.07Hst \quad ...(1)$$

Vertical distance from SRP,

$$= Hs\,Cos(\theta b) - Le\,Cos(\Phi u) + (Lfa - 0.5\,Lh)\,Cos\,(\Phi e - \Phi u) + (Lh/2)\,Cos\,(\Phi w + \Phi e - \Phi u - k) + 0.043Hst \quad ....(2)$$

where,

Lfa = Forearm hand length, cm

Lh = Hand length, cm

Le = Shoulder elbow length, cm

Hs = Shoulder height (sitting), cm

Hst = Stature, cm

Steering wheel :

From the geometry of bio-mechanical model given in Fig. C and considering palm remains parallel to the plane passing through the steering wheel surface. Steering column angle in degrees with the horizontal can be given as:

$$\theta sc = \theta w + 180 + \theta e - \theta u \quad .... (3)$$

Horizontal distance from SRP,

= (Lfa - 0.5 Lh) Sin(θe - θu) + Le Sin(θu) - Hs Sin (θb) + (Lh/2) Sin (θw+ θe- θu - K)+0.07Hst .....(4)

Vertical distance from SRP,

= HsCos (θb) - Le Cos (θu) + (Lfa - 0.5 Lh) Cos (θe - θu) + (Lh/2) Cos (θw+θe- θu - K) +0.043Hs. .... (5)

Foot controls :

The position angle of the fulcrum (if pedal is hinged) and the maximum force required to operate the pedal are important parameters. An optimum angle between 25º to 35º produces the highest forces. Horizontal location of foot control (brake or clutch) from SRP may be given below as per Fig. C.

Horizontal distance from SRP,

=Lp Cos (θsp) + Hp Sin (ϕk + θsp - K/2) + (Lf / 2) Cos (ϕk + θsp+ ϕa) + 0.07st …(6)

Vertical distance from SRP,

= Hs Cos (θb)-Le Cos (θu) + (Lfa - 0.5 Lh) Cos (θe -θu) + (Lh/2) Cos(θw+ θe- θu - K) +0.043Hs ....(7)

where,

Lp = Buttock popliteal length, cm

Hp = Popliteal height, cm

Lf = Foot length, cm.

Comparison of selected mini tractor workplace configurations with design values :

A comparison was made between the selected tractor workplace configurations and design values to evaluate the optimum tractor workplace among the different selected tractor models. The values obtained from the selected tractor workplace configurations should be nearer to design values for higher efficiency and comfort.

Selection of mini tractors :

Eight different popular Indian mini tractors of different makes, models and sizes; *viz.,* TM_1 (15 hp), TM_2 (26 hp), TM_3 (20 hp), TM_4 (13 hp), TM_5 (20 hp), TM_6 (12 hp), TM_7 (18 hp) and TM_8 (22 hp) were randomly selected for the study.

Selection of subjects :

Three male subjects were randomly selected for the study. The subject should be medically fit to undergo the trials. They should also be a true representative of the user population in operation of tractor.

Ergonomic evaluation :

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 rated perceived 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 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 stethoscope and the measured values are presented in Table C. The HR measurements of selected subjects were taken at rest and after 5, 10, 15 and 20 minutes duration respectively, while operating on selected tractors and after 5 minutes rest.

Table C : Initial HR of subjects

Subject	Heart rate, (Beats/min)
S_1	75
S_2	77
S_3	82

Subjective evaluation :

The subjective evaluation of the operator's feelings was also carried out using Borg scale (1962) and this scale was presented in front of the operators while they were performing the tasks. 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 mini tractor workplace configurations.

RESULTS AND DISCUSSION

All the measurements of workplace of selected mini tractors were carried out in the laboratory and ergonomic evaluation in the field of Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

Measurement of mini tractor workplace configurations :

Workplace configurations of selected mini tractor

models available were measured using suitable measuring tape, scale, clamp and a protector for angle measurements. The comparison of dimensions and their mean are shown in Tables 1. Wide variations were found in the case of dimensions such as steering column angle, position of hydraulic control lever, horizontal and vertical distance of clutch and brake pedal from SRP.

Anthropometric data of tractor operators from Gujarat :

The anthropometric data were measured and analysed for 5th, 50th and 95th percentile values (Anonymous, 2005) and are shown in Table 2.

Design of configuration using different equations and anthropometric data :

The design values were calculated using eq. 1 to 7 and anthropometric data are shown in the Table 3. The computed location of controls for the 50th percentile was depicted as design values in Table 3 which shows that the difference in vertical distance of controls for the 5th to 95th percentile tractor operators stature varied from a minimum of 0.45 cm (for hydraulic control) to a maximum of 10.12 cm (for steering wheel). Whereas the difference in horizontal distance of controls for the 5th to 95th percentile tractor operator's staturevaried from a minimum of 3.61 cm (for hydraulic control) to a maximum of 17.00 cm (for clutch and brake pedal).

Comparison of measured workplace configurations in selected mini tractors with design values :

The design values given in Table 6 were considered as optimum workplace configurations. The comparison of selected mini tractor workplace configurations with the optimum workplace configuration was made and presented in Table 4. It was found that, steering angle of 70º, the foot pedals (clutch and brake) distance of 70.5 cm from SRP, and the hydraulic control lever distance of 28.6 cm from SRP were optimum values for Indian operators.Table 4 indicates that the steering column angle of the selected mini tractor models needs to be shifted by +5.0°, +1.0°, -5.0°, 0.0°, -5.0°,-5.0°, +2.0°, and +3.0° with respect to the configurations model TM_1, TM_2, TM_3, TM_4, TM_5, TM_6, TM_7 and TM_8, respectively. Further, foot pedal and hydraulic control lever locations need to be shifted; likewise for the clutch pedal by +5.5,

Table 1 : Anthropometric data of male agricultural workers of Gujarat **(n=734)**

Sr. No.	Dimension	5th	50th	95th	SD
1.	Stature	152.44	163.12	173.79	6.46
2.	Weight, kg	39.24	55.25	71.26	9.73
3.	Grip diameter (inside)	4.24	5.07	5.91	0.51
4.	Shoulder breadth	38.27	43.12	47.97	2.95
5.	Arm reach from the wall	76.02	83.32	90.62	4.44
6.	Shoulder grip length	63.90	77.48	70.69	4.13
7.	Foot length	22.55	24.74	26.93	1.33
8.	Sitting height	73.71	80.83	87.95	4.33
9.	Sitting eye height	64.39	71.24	78.08	4.16
10.	Sitting shoulder height	50.23	55.68	61.14	3.32
11.	Elbo wrest height	16.18	19.61	23.05	2.09
12.	Knee height sitting	44.99	50.41	55.84	3.30
13.	Sitting popliteal height	39.49	44.11	48.73	2.81
14.	Buttock popliteal length	40.01	44.67	49.33	2.83
15.	Buttock knee length	45.59	52.82	60.04	4.39
16.	Functional leg length	87.08	93.02	98.96	3.61
17.	Thigh clearance height sitting	10.81	13.25	15.70	1.48
18.	Hip breadth sitting	27.47	32.01	36.54	2.76
19.	Shoulder elbow length	34.05	36.07	38.09	2.33
20.	Fore arm hand length	41.81	45.61	49.40	2.31
21.	Hand length	15.58	17.68	19.78	1.28

Table 2 : Placement of mini tractor operator controls and seat

Sr. No.	Parameters	TM_1	TM_2	TM_3	TM_4	TM_5	TM_6	TM_7	TM_8	Mean	C.V.
1	**Steering wheel**										
	i) Steering column angle from horizontal, deg.	65?	69?	75?	70?	75?	75?	68?	67?	70.5	5.67
	ii) Horizontal distance of steering wheel centre from SRP, cm	72	65	66	65	68	62	69	64	66.37	4.76
	iii) Vertical clearance of steering wheel centre from SRP, cm	23	26	14	28	17	33	25	24	23.75	25.23
2	**Foot control**										
	a) Clutch										
	i) Horizontal distance from SRP, cm	65	62	66	65	66	61	64	63	64	2.89
	ii) Vertical clearance from SRP, cm	-39	-35	-46	-43	-36	-31	-40	-41	-38.87	-12.25
	iii) Clutch pedal angle from horizontal, deg.	55?	58?	60?	55?	58?	55?	58?	56?	56.87	3.31
	b) Brake										
	i) Horizontal distance from SRP, cm	70	65	66	60	71	58	68	65	65.37	6.93
	ii) Vertical clearance from SRP, cm	-40	-40	-46	-40	-38	-34	-41.5	-40	-39.93	-8.37
	iii)Brake pedal angle from horizontal, deg.	75?	71?	70?	55?	56?	45?	72?	69?	66.62	11.14
3	Footrest height from SRP, cm	-52	-50	-70	-82	-70	-72	-52	-65	-64.12	-18.11
4	**Hydraulic control lever**										
	i) Horizontal clearance from SRP, cm	40	28	24	10	27	15.5	38	26	26.06	38.78
	ii) Vertical clearance from SRP, cm	-7	-8	-2	-12	-4	-9	-8	-7	-7.12	-42.72
5	Horizontal distance of seat edge from steering wheel edge, cm	18	15	13.5	6.5	10	8	17	13	12.62	32.84
6	Vertical distance of seat edge from steering wheel edge, cm	14	18	13	23	11	25	14	15	16.62	29.97
7	Lever pedal										
	i)Horizontal distance from SRP, cm	58	55	56	55	61	52	56	57	56.25	4.63
	ii) Vertical clearance from SRP, cm	-45	-47	-53	-43	-54	-43	-45	-43	-46.62	-9.58
8	**Hand lever**										
	i) Horizontal clearance from SRP, cm	76	74	73	64	78	77	77	75	74.25	6.01
	ii) Vertical clearance from SRP, cm	19	22	10	26	14	21.5	17	15	18.06	28.32
9	**Gear control**										
	i) Horizontal clearance from SRP, cm	35	48	45	49	43	47	34	44	43.12	13.20
	ii) Vertical clearance from SRP, cm	10	9	5	15	-6	-18	9	8	4	268.5
10	**Seat**										
	Seat length, cm	63.5	64	62	60	62	49	51	60	58.93	9.7
	Seat pan width, cm	43	40	45	43	45	40	42	43	42.62	4.51
	Seat backrest height, cm	26	23	26	24	26	23	25	25	24.75	5.17
	Seat backrest width, cm	38	40	45	37	45	40	37.5	44	40.81	8.28
	Seat height, cm	53	51.5	55	52	54	49	51	53	52.31	3.57
11	**Hood**										
	Hood width, cm	114	118	96	109	96	121	107	106	108.37	8.5
	Hood height, cm	94	100	106	102	104	81	92	103	97.75	8.51
12	Foot rest										
	Foot rest height from ground, cm	50	40	47	45	47	44.5	51	46	46.31	7.36
	Foot rest width, cm	20	19.5	21.5	20	21	19.5	20	20	20.18	3.48
	Foot rest length, cm	40	30	45	33	45	37	40	38	38.5	13.67
13	Steering wheel diameter, cm	39.5	43	36	41	36	42	41	42	40.06	6.75
14	Entry-exit width, cm	33	60	40	63	34	78	30	35	46.65	38.29

Table 3 : Design value of placement of mini tractor operator controls and seat

Sr. No.	Parameters	Design value for percentile			Range
		5th	50th	95th	
1.	Steering wheel				
	Horizontal distance of steering wheel centre from SRP, cm	65.94	72.33	73.21	7.27
	Vertical clearance of steering wheel centre from SRP, cm	20.03	25.79	30.15	10.12
2.	Foot control				
	Clutch				
	Horizontal distance from SRP, cm	62.20	70.50	79.20	17.00
	Vertical clearance from SRP, cm	-34.03	-37.82	-41.59	7.56
	Brake				
	Horizontal distance from SRP, cm	62.20	70.50	79.20	17.00
	Vertical clearance from SRP, cm	-34.03	-37.82	-41.59	7.56
3.	Foot rest height from SRP, cm	-57.90	-55.40	-52.90	5.00
4.	Hydraulic control lever				
	Horizontal clearance from SRP, cm	26.91	28.62	30.52	3.61
	Vertical clearance from SRP, cm	-14.73	-14.24	-15.18	0.45

Table 4 : Comparison of existing mini tractor workplace configurations with the design values

Sr. No.	Control locations from SRP	Tractor workplace locations							
		Design value (T)	TM_1	TM_2	TM_3	TM_4	TM_5	TM_6	TM_7	TM_8
1.	Steering column angle degree,	70	65 (+5.0)	69 (+1.0)	75 (-5.0)	70 0	75 (-5.0)	75 (-5.0)	68 (+2.0)	67 (+3.0)
2.	Clutch pedal location, cm	70.5	65 (+5.5)	62 (+8.5)	66 (+4.5)	65 (+5.5)	66 (+4.5)	61 (+9.5)	64 (+6.5)	63(+7.5)
3.	Brake pedal location, cm	70.5	70 (+0.5)	65 (+5.5)	66 (+4.5)	60 (+10.5)	71 (-0.5)	58(+12.5)	58(+12.5)	65(+5.5)
4.	Hydraulic control lever location, cm	28.6	40 (-11.4)	28(+0.6)	24 (+4.6)	10 (+18.6)	27(+1.6)	15.5(+13.1)	38(-9.4)	26(+2.6)

Table 5: Effect of tractors and subjects on heart rate

Treatments	Heart rate (beats/min)					
	Initial	5 min	10 min	15 min	20 min	At rest
Tractor (T)						
T_1	78.15	82.21	83.65	85.67	83.25	78.55
T_2	81.1	92.43	95.32	98.59	99.25	84.18
T_3	79	80.26	82.19	81.11	81.62	77.56
T_4	83.89	86.33	89.88	92.45	88.22	84.42
T_5	83.96	96.37	92.43	98.65	94.77	85.73
T_6	81	82.26	83.16	82.22	83.84	78.68
T_7	82.88	84.45	87.86	94.25	86.54	82.69
T_8	83.52	95	93.22	96.64	93.77	86.42
S.E.±	0.3768	0.6048	0.4615	0.4698	0.3889	0.4547
C.D. (P=0.05)	1.0725	1.7213	1.3135	1.3371	1.1069	1.2943
Subject (S)						
S_1	81.57	86.47	88.85	92.12	90.32	82.18
S_2	83.09	89.52	88.56	90.76	89.83	84.15
S_3	82.27	88.47	90.72	90.77	90.23	85.83
S.E.±	0.2307	0.3703	0.2826	0.2877	0.2381	0.2785
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction: T x S						
S.E.±	0.6526	1.0475	0.7993	0.8137	0.6736	0.7876
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
C.V. %	1.3813	2.1005	1.5612	1.5676	1.3054	1.66

NS= Non-significant

Table 6 : Energy expenditure rates of subjects on selected mini tractor workplace configuration in kJ min-1

Sr. No.	TM_1	TM_2	TM_3	TM_4	TM_5	TM_6	TM_7	TM_8
S_1	6.52	10.26	6.41	8.34	10.56	9.37	8.61	7.54
S_2	6.37	10.56	6.34	8.9	10.48	9.66	8.98	7.22
S_3	7.15	10.22	7.08	9.53	10.68	9.89	9.11	7.89

Table 7: RPE scores of subjects for steering wheel of selected mini tractors

Sr. No.	S_1	S_2	S_3
TM_1	11	10	9
TM_2	16	16	14
TM_3	9	9	9
TM_4	8	10	10
TM_5	10	12	8
TM_6	14	13	11
TM_7	12	11	14
TM_8	15	14	13

Table 8 : RPE scores of subjects for foot operated controls of selected mini tractors

Sr. No.	S_1	S_2	S_3
TM_1	10	10	9
TM_2	14	14	12
TM_3	9	9	8
TM_4	14	12	11
TM_5	14	13	12
TM_6	16	15	14
TM_7	15	14	12
TM_8	13	12	11

Table 9: RPE scores of subjects for hand operated controls of selected mini tractors

Sr. No.	S_1	S_2	S_3
TM_1	12	11	12
TM_2	16	16	14
TM_3	9	9	8
TM_4	12	10	14
TM_5	14	13	12
TM_6	11	12	13
TM_7	15	14	16
TM_8	13	11	12

Table 10: Average subjective rating of mini tractor operated controls

Sr. No.	S_1	S_2	S_3
TM_1	11	10.33	10
TM_2	15.33	15.33	13.33
TM_3	9	9	8.33
TM_4	11.33	10.67	11.67
TM_5	12.67	12.67	10.67
TM_6	13.67	13.33	12.67
TM_7	14	13	14
TM_8	13.67	12.33	12

+8.5, +4.5, +5.5, +4.5, +9.5, +6.5, +7.5 cm; the brake pedal by +0.5, +5.5, +4.5, +10.5, -0.5, +12.5, +12.5, +5.5 cm; and the hydraulic control lever by -11.4, +0.6, +4.6, +18.6, +1.6, +13.1, -9.4 and +2.6 cm, respectively for the tractor configurations TM_1, TM_2, TM_3, TM_4, TM_5, TM_6, TM_7 and TM_8, respectively.

Ergonomic evaluation :

For getting ergonomic evaluation, either physiological or subjective response of the subject must be recorded.

Physiological response of the subjects :

For the ergonomic evaluation of workplaces of different mini tractor workplace configuration, subjects were allowed to drive the different mini tractor models

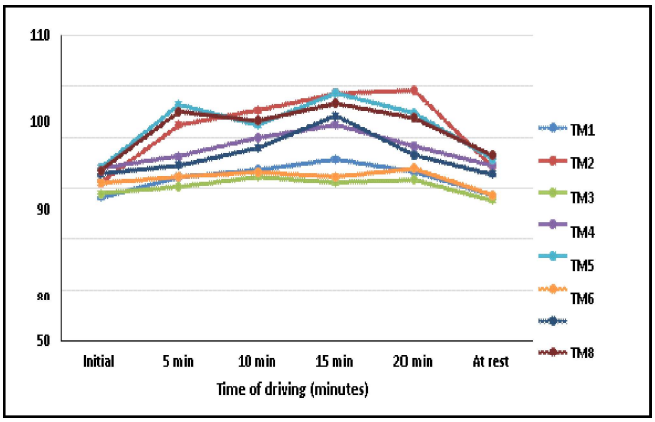

Fig. 1: Effect of tractors on the heart rate of subjects

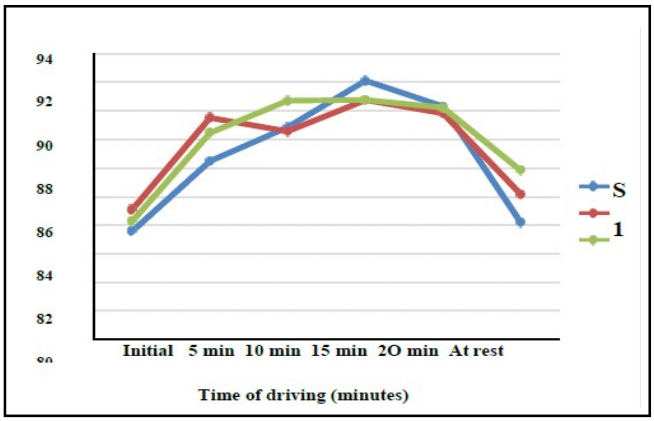

Fig. 2: Effect of subjects on the heart rate

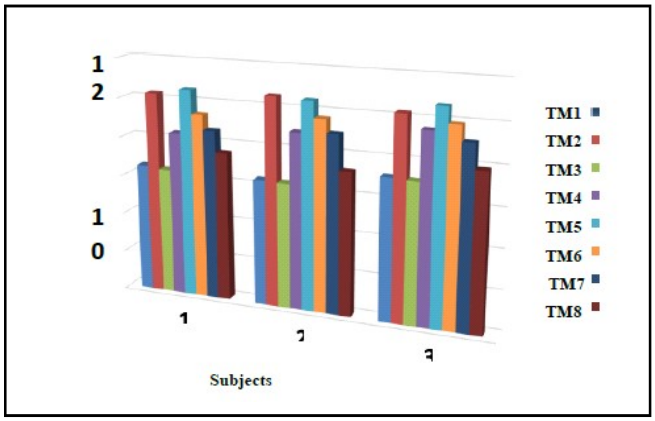

Fig.3 : Energy expenditure rate comparison of subjects on selected mini tractor workplace design

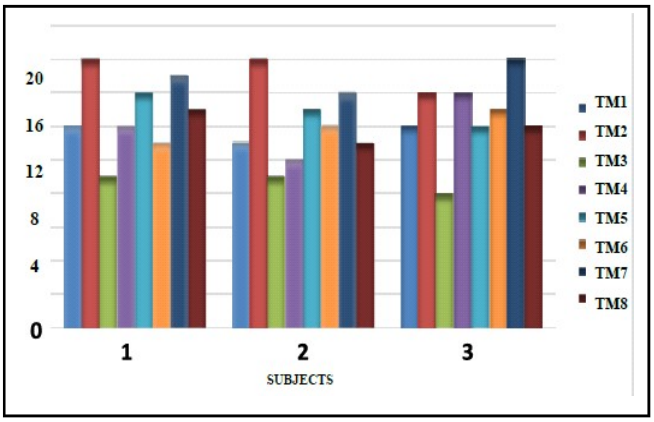

Fig. 6 : Subjective rating of hand operated controls of selected mini tractor

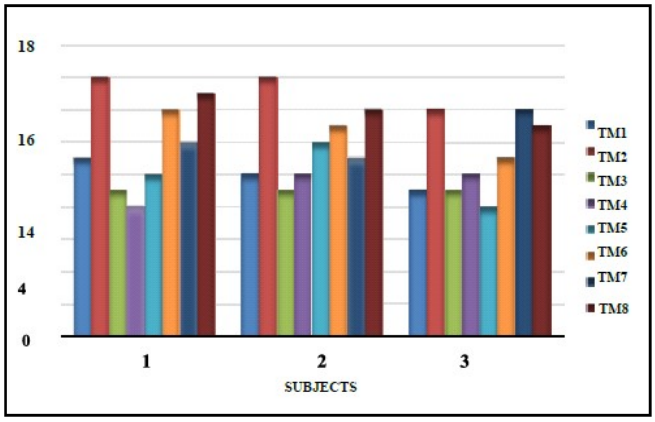

Fig.4 : Subjective rating of steering wheel of selected mini tractor

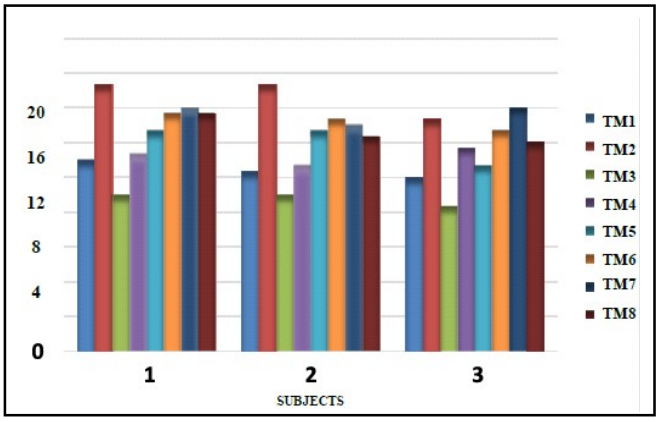

Fig. 7 : Average subjective rating of mini tractor operated controls

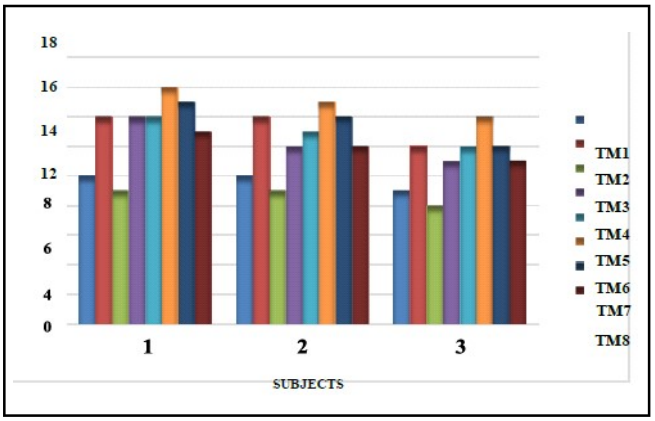

Fig. 5 : Subjective rating of foot operated controls of selected mini tractor

in the field and asked to operate all of the controls for a predetermined period and physiological evaluation was made in terms of heart rate measurement. An appraisal of data on the effect of different mini tractors and subjects on the heartbeat of subjects is presented in Table 8 and the comparison was made and presented in Fig. 1 and 2. It is evident that the interaction effect of mini tractor and subjects on the heart rate was found non-significant. Similar trend was observed by Shukla *et al.,* (2017) study conducted on different tractors.

Conclusion:

The mini tractor workplace configurations vary widely in the case of dimensions such as steering column angle, position of hydraulic control lever, and horizontal and vertical distance of clutch and brake pedal from seat reference point. The reason of variation is that different companies manufacture their own models and there is no consideration of anthropometric data of Indian population. Studies on evaluation of the most efficient location of controls resulted in steering column angle of 70º with horizontal, foot pedals (clutch and brake) distance of 70.5 cm from SRP and the draft control lever distance of 28.6 cm from SRP for Indian operators based on

anthropometric data and biomechanical mode l. The values obtained from the different mini tractor workplace configurations under study should be nearer to design values so that the operator can operate it with efficiency and comfort. From the comparison, made between existing workplace configurations and most efficient configuration (design values), T_3 is concluded as superior to other configurations studied. This result is in match with the ergonomic evaluation, in which the minimum energy expenditure rate and minimum rated perceived exertion score were obtained for T_3 configuration.

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