Ergonomic Evaluation of Knapsack Sprayer used in Agricultural Application

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Abstract— In India most of the agricultural operations are performed manually by agricultural workers using hand tools and equipments. The economic growth and technological improvements have lead to greater demand and development of machines and devices used in industrial settings. With these dramatic changes there has also been greater interaction between man and machines. It is important to design these tools using ergonomic principles for increasing efficiency of the operation, safety and comfort of user. This paper presents ergonomic assessment of knapsack sprayer which is commonly used by farmers for spraying insecticides and pesticides. Present study analyzes various postures of farm worker during the operation of knapsack sprayer. Analysis uses modules of CATIA like Human Builder, Human Activity Analysis and Rapid Upper Limb Assessment (RULA) analysis. Improvements in the design of knapsack sprayer were made to make sprayer ergonomically suitable for 5th to 95th percentile population.

Index Terms— Agricultural equipments, Anthropometry, Ergonomics, Human Activity Analysis, RULA, Maharashtra, Knapsack sprayer,

1 INTRODUCTION

In a large number of agriculture applications, hand equipments are important equipments [1]. In many occupations, some of the major reasons of work-related injuries and disease are linked to the use of hand equipments [2]. It has shown that tool design may play an important role in development of work related problems in the upper limbs. Poor design of hand equipments may result in cumulative trauma disorders [3]. Occupational accidents can be linked directly to the use of specific hand equipments.

Ergonomically well designed hand equipments may reduce the discomforts. It also provides comfortable work for the users and gives high product quality to the consumers. As the use of hand equipments may play an important role in the development of disorders and accidents, it is obvious that improvements in the design of hand equipments are essential for promoting professional users health, particularly where there is intensive exposure. Newly adopted design software techniques can use for ergonomic evaluation.

Ergonomic evaluation will consist of an initial assessment, which includes looking at the overall posture of your head, neck, back, upper body, forearms, wrists, hands, legs and feet. It includes things like repetitious movement, forces, contact stress, static loading and environmental factors. Ergonomic dimensions correspond best to the orientation of the designed hardware which is registered in different positions and postures that simulate the real working postures and positions in the conventional form. Hence, to achieve better efficiency, human comfort and safety, it is necessary to design the equipment keeping in view the operator's capabilities and limitations.

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2 METHODS

2.1 Anthropometric data for digital manikin

This study uses 33 anthropometric parameters of male agricultural workers from four districts of Western Maharashtra [4]. Table 1 presents standard deviation and mean.

Table 1: Anthropometric Data Analysis Sheet

S. No.	Dimension	Mean	SD
1	Right Hand Grip Strength (Kg)	28.01	6.75
2	Left Hand Grip Strength (Kg)	27.90	7.75
3	Stature	164.43	5.61
4	Wrist-wall Length	64.13	3.00
5	Wrist-wall Length, Extended	66.91	2.89
6	Acromion – Radiale Length	32.57	2.40
7	Radiale Stylion Length	26.81	2.50
8	Shoulder-Elbow Length	37.32	2.96
9	Forearm Hand Length	45.70	2.02
10	Forearm Centre of Grip Length	34.31	3.23
11	Waist back Length, Omphalion	41.15	3.33
12	Interscyle I	31.64	3.18
13	Chest Breadth	26.89	1.98
14	Waist Breadth, Omphalion	26.06	2.59
15	Hip Breadth, Standing	30.18	2.31
16	Elbow–Elbow Breadth-Sitting	40.23	3.82
17	Waist Depth, Omphalion	20.07	4.15
18	Sleeve Length, Outseam	60.15	2.99

19	Wrist circumference	15.76	0.81
20	Elbow Circumference, Straight	23.54	1.69
21	Knee Circumference, Standing	33.53	2.90
22	Waist Circumference, Omphalion	82.38	8.82
23	Acromion-wall Length	10.40	1.13
24	Hand Length	18.19	1.22
25	Wrist-Index Finger Length	16.76	0.84
26	Palm Length	10.35	0.60
27	Hand Breadth(At Metacarpal-III)	8.06	0.48
28	Hand Breadth Across Thumb	9.83	0.55
29	Grip Diameter(Inside)	4.81	0.41
30	Grip Diameter (Outside)	8.23	0.53
31	Middle Finger Palm Grip Diameter	3.08	0.29
32	Grip Span (Standing/sitting)	8.76	0.82
33	Age (years)	45.23	11.10

2.2 Generation of Digital manikin in Human builder

In CATIA V5R18, Anthropometric data is fed to CATIA in sws format using Human Builder tool, which creates digital manikin of particular anthropometry (Fig. 1). Human Builder gives many options like gender selection, percentile selection, editing human anthropometry. In this study two percentile values 5th and 95th percentile are considered.

2.3 Design of manually operated sprayer in CATIA

Most used model of sprayer was taken into consideration. All parts of sprayer like tank, stand, handle, straps and handle were modelled in CATIA (Fig. 2 and 3)

Fig. 1. Digital manikin designed in Human Builder

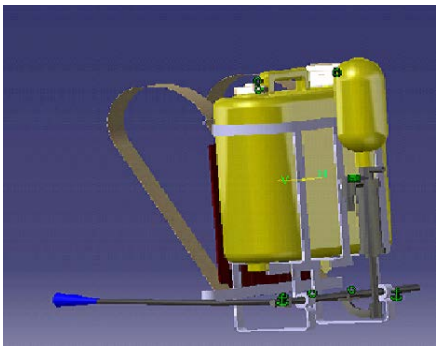

Fig. 2. Existing sprayer model modelled in CATIA

Fig. 3. Lance model of existing sprayer modelled in CATIA

3. Analysis of Postures and Simulation

3.1 Analysis of postures of existing sprayer in Human Activity Analysis

Angle of stroke of handle is calculated as well as lance movements were also taken into consideration. Model of sprayer was adjusted to digital manikin as per posture. In this analysis right handed person was considered. As per calculated angles simulation was created. From the simulation, three postures for left side of body (upper extreme, middle, lower extreme) were taken into consideration and RULA score was calculated (Table.2 and 3). For right handed person, sprayer handle and lance were in left and right hand respectively.

Fig. 4 (a) Upper Posture

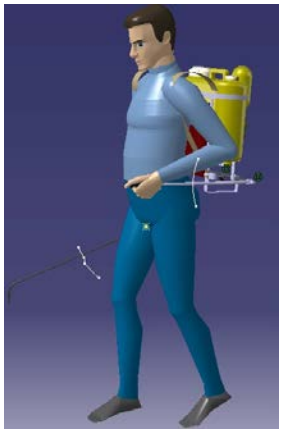

Fig. 4 (b) Middle posture

Fig. 4(c) Lower Posture

Table 2: RULA Score of left side of body for existing sprayer

Part of body	95th			5th		
	U	M	L	U	M	L
Upper arm	3	4	4	3	3	3
Forearm	2	3	3	3	3	3
Wrist	3	3	3	2	2	2
Wrist twist	1	1	1	2	2	2
Posture A	4	5	5	4	4	4
Muscle	1	1	1	1	1	1
Wrist and arm	5	6	6	5	5	5
Neck	1	1	1	1	1	1
Trunk	1	1	1	1	1	1
Leg	1	1	1	1	1	1
posture B	1	1	1	1	1	1
Neck, trunk and leg	2	2	2	2	2	2
Final score	**4**	**4**	**4**	**4**	**4**	**4**

(U-upper posture, M-middle posture, L- lower posture)

In this analysis upper arm abduction, shoulder elevation, arm rotation and wrist deviation observed beyond the critical values. From above table it is clear that for all postures of left side, final score is 4. In For right side of body, whole simulation shows same RULA (Rapid Upper Limb Assessment) score which is 3(Table 3).

Table :3 RULA Score of right side of body of existing sprayer

Part of body	95th	5th
Upper arm	3	3
Forearm	3	3
Wrist	3	3
Wrist twist	1	1
Posture A	4	4
Muscle	0	0
Wrist and arm	4	4
Neck	1	1
Trunk	1	1
Leg	1	1
posture B	1	1
Neck, trunk and leg	1	1
Final score	**3**	**3**

3.2 Design Modifications of handle and lance

For design modification, first various postures were studied in human activity analysis. From that study, simulation of best postures was determined. Ergonomically best suited design of lance and handle was developed according to simulation in CATIA (Fig. 5).

Fig. 5. Modification in lance and handle in CATIA

After modification in CATIA, it was noticed that there was requirement of adjustable length handle for 5th and 95th percentile manikin from 493 mm to 592 mm.

3.3 Analysis of modified sprayer in Human Activity Analysis

Fig. 6. Digital Manikin with modified sprayer

First suitable handle length (592 mm) was taken for 95th percentile digital manikin in simulation (Fig. 7). RULA score was calculated for all posture. For 5th percentile, length was varied to 493mm (Table 4).

Table 4: RULA Score o modified sprayer

Part of body	95th			5th		
	U	M	L	U	M	L
Upper arm	1	1	1	1	1	1
Forearm	2	2	2	2	2	2
Wrist	3	2	2	3	2	2
Wrist twist	1	1	1	1	1	1
Posture A	3	2	2	3	2	2
Muscle	1	1	1	1	1	1
Wrist and arm	4	3	3	4	3	3
Neck	1	1	1	1	1	1
Trunk	1	1	1	1	1	1
Leg	1	1	1	1	1	1
posture B	1	1	1	1	1	1
Neck, trunk and leg	2	2	2	2	2	2
Final score	**3**	**3**	**3**	**3**	**3**	**3**

(U-upper posture, M-middle posture, L- lower posture)

From table it is observed that final score for all posture is 3. For right side of body final score are 2.

Table 5: RULA Score of right side of body for modified sprayer

Part of body	95th	5th
Upper arm	1	1
Forearm	2	2
Wrist	2	2
Wrist twist	1	1
Posture A	2	2
Muscle	0	0
Wrist and arm	2	2
Neck	1	1
Trunk	1	1
Leg	1	1
posture B	1	1
Neck, trunk and leg	1	1
Final score	**2**	**2**

3.4 Physical validation

According to CATIA modification, lance and handle was developed in proper dimension (Fig 5 and 6). Five male operators who had good experience at the controls and operating sprayer were selected. Overall discomfort rating (ODR) was used which was developed by Corlett and Bishop for the assessment of trial. Trial was conducted for both models. The subjects operated the sprayer for half an hour. To determine the discomfort level, overall discomfort rating method (ODR) was used.

In ODR, some questions were asked to worker related to modifications. Farmer's ratings were found improved for adjustable handle length, adjustable angle of grip, modified lance and nozzle.

Table 6: ODR Analysis

Subject no	Subject ODR	
	Existing Sprayer	Modified sprayer
1	6	4
2	7	5
3	7	4
4	5	3
5	7	3
Final	**6.4**	**3.8**

ODR analysis gave final score 6.4 and 3.8 for existing sprayer and modified sprayer respectively. Final score is average of all 5 workers score.

Fig. 7. Modified handle

Fig. 8. Modified lance

Fig.9. Farm worker with modified sprayer

4. RESULTS AND DISCUSSION

From above study, it is observed that final RULA score is reduced for the modified sprayer. ODR analysis also shows that modified product performs better on ergonomic aspect.
Thus the postures of the human body can be analyzed by using RULA analysis in order to analyse existing product or the design of new product. This is because the posture of human body reflect the design of the product ergonomically. If the product is ergonomically sound, the person working will work in the best posture with no risk of injury from the work.

5. CONCLUSION

- This study indicates that an ergonomic design of a hand tool is important.
- Ergonomic evaluation can be a step towards improvement of the product reducing musculascalatan disorders.
- It is possible to make ergonomically sound hand tools using digital human modeling and RULA analysis.
- The design of a hand tool reflects the posture of the users. Hence an ergonomic well design hand tool will improve the user postures.

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