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Ergonomic Design Improvement of Pedal Thresher: An Approach Combining Digital Human Modelling and Response Surface Analysis

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Abstract

Rice production in India is an *important* part of the national economy. The use of modern agricultural tools and equipment for paddy threshing are limited to the plain land of India, whereas, traditional methods are still prevalent in most of the parts of the North-East hilly region. Farmer of this region faces substantial difficulties in adoption of modern tools and equipment due to mismatch of the design according to their requirement, lacking portability features, socioeconomic status etc. Therefore, the present study made an attempt to evaluate and improve the existing pedal operated paddy thresher in the digital environment, using digital human models, for the prevention of work-related musculoskeletal disorders. The various postural score of body part obtained from a well-known and validated posture analysis tool called rapid upper limb assessment technique was used for ergonomic design improvement using response surface methodology. Results obtained from the assessment reveals that optimum design height of pedal thresher suitable for 5th to 95th percentile workers of the North-East population was found to be 81 cm with the trunk score of 2.005.

Keywords: Pedal thresher; Ergonomics; Anthropometry; Musculoskeletal disorder (MSD); Rapid Upper Limb Assessment (RULA); Biomechanics

Introduction

India is the second largest rice-producing nation in the world [1] covering about 44 million hectares, which is about 40% of the total cereal cover [2]. Among them, North-East (NE) hilly region has contributed about 3.51 million hectares accounting more than 80% of the total cultivated area of the region and 7.8% of the total rice production area in India [3,4]. Northeastern India consists namely Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura, and Sikkim is predominantly traditional and rice-based except Sikkim where maize is a dominant crop [5,6]. Rice cultivators perform many strenuous activities like spading, uprooting, transplanting, saplings, harvesting or cutting crops, threshing, sweeping and winnowing [7]. Among them, threshing is the most significant activity. Power operated threshers are used extensively in most of the developed and developing countries of the world. Several power-operated paddy threshers have employed in the past, but they have not been successful in the NE mountainous areas because of machine cost, weight, and limited source of electric power availability [8]. Further, mechanised threshing is not feasible for small and fragmented land where land holding is less than 1 hectare [9]. Many parts of India, several pedals operated thresher has developed and practised, but few of them meet the requirement of the farmers of the NE region. Several problems relating to pedal threshing such as less productivity, more threshing loss, injuries, fatalities or may be due to awkward working posture.

An appropriate ergonomic design is imperative to prevent monotonous strain injuries and other work-related musculoskeletal disorders (WMSDs), which can develop over time and lead to long-term disability. WMSDs are reported to occur as a result of jobs that put muscles under excessive physical demand [10]. Human-centred product design approach in a virtual environment (VE) through digital human modelling (DHM) is beneficial for product development. VE is computer generated 3D graphics environment used for various types of modelling and simulation activities [11]. Thus, to achieve better performance and efficiency without compromising comfort and safety to the operator, it is necessary to design tools, equipment, and workplaces considering anthropometric data of the prospective agricultural workers [12]. Hence anthropometric body limitations of both genders have to be taken into consideration for the design of any tools or machinery. The proper matching of machine requirements with the human capabilities and limitations is a basic necessity for optimising the performance of the man-machine system [13]. The various researchers stated that the variations in body dimensions occurred between populations, ethnicity, gender, religion, geographical zones, etc. [14-17]. Studies have reported non-availability of the basic anthropometric data about working populations' handicap the efficiency of the product and process design and accurate analyses [18,19]. Many researchers studied that anthropometric body dimensions are different from one region to another region in India i.e. the anthropometric database of NE region is much lower than the rest of the India [12,16,20]. There are numerous ergonomic assessment methods of manual task exists in the market. For example, REBA, RULA, LUBA, OWAS, PATH, PEO and QEC method [21-23]. The Rapid Upper Limb Assessment (RULA) index is one of the most common and cited tools for evaluating the ergonomic risk of WMSDs [22,24]. DHM software packages used for ergonomic assessment are CATIA-HUMAN Design and Analysis tools, Pro/ENGINEER Manikin Analysis, SAMMIE, JACK, SANTOS and RAMSIS [23]. Through this approach, chosen CATIA software for RULA assessment and biomechanics single action analysis for a peak joint moment, compression force on the spine and shear force on the lumbar spine (i.e. L4-L5) [25-27] to analyse the posture of the targeted user group.

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Optimisation of economic and ergonomic measures can portray through an interactive process of adjustments to workstation parameters and product design [28]. The economic evaluation was associated with the ergonomic measures hence improve both types of measures separately considering several parameters and constraints. Some researcher focused on finding a good solution relative to both measures rather than finding a strict optimal solution [29]. Design and simulation were briefly reviewed in manual assembly layouts and concluded that those are mostly of non-intelligent and sequential nature and are therefore inadequate for concurrent intelligent design [30]. To minimize the drawback pointed out by [30], they suggest a systematic design interrogative based on fractional experiments (FE) and response surface methodology (RSM). Fractional experiments are used to set up candidate configurations of a work envelope and to frame empirical models relating design factors to various objective functions. On the basis of these models, RSM is employed to optimise the RULA results (i.e. RULA trunk score) for multi-objective measures considering economic and ergonomic.

In the present study, the ergonomic design modification of pedal operated paddy thresher (POPT) using advanced technology like RSM and DHM based on anthropometric data of NE region of India is presented. This design change involved the optimisation of relevant design parameters (i.e. vertical height) thresher using the integration of DHM and RSM. The design of thresher dimension was done with a permissible adjustment range (suitable for 5^{th} to 95^{th} percentile) to the particular user group. The objective of the study was to optimise the machine parameters and redesign thresher to suit a larger segment of the population so that the best possible fit could be obtained, thereby increasing safety and comfort for the operation.

Materials and Methods

Although the pedal thresher is popular in several parts of India, design suitable for North-East Region of India has not yet established. All the functional and structural dimensions of available thresher were taken by using a metering scale and measuring tape and converted into the 3D model in CATIA software, and it was further simulated with the digital human manikin for ergonomic analysis.

During pedalling and feeding of the paddy, the operator has to exert a sufficient amount of force in addition to some movements. For pedal threshing, body parameters such as acromial height, elbow height, olecranon height, iliocristale height, iliospinale height, trochanteric height, metacarpal III height, knee height, shoulder breadth (bi-deltoid), forearm hand length, buttock-knee length, foot length, foot width, hand length, popliteal height. Selected parameters and their dimension are extracted from [31]. In this study, the zone selected as for Northern Zone-Punjab, Western Zone-Gujrat, Southern Zone-Tamil Nadu, Central Zone-Madhya Pradesh, Eastern Zone-West Bengal and North-Eastern Zone-Arunachal Pradesh. The mean represented as 50 percentile of body dimension. The 5^{th} and 95^{th} percentile of body measurement calculated by the following formula [32]

Percentile value=M ± 1.645 × S.D.

Where, M and S.D. represents the mean and standard deviation respectively.

A subsequent t-test was performed among the selected parameters at 95% confidence interval by Student's t-test. Results showed that most of the parameters were found a significant difference ($p<0.05$) with Arunachal Pradesh anthropometry database for all the body dimensions. However some of the dimensions were found similarity with Arunachal Pradesh like for Northern Region-popliteal height (p=1.00); Southern region-metacarpal III height (p=0.34), buttock-knee length (p=0.13) and foot length (p=0.12); Eastern region-acromial height (p=0.18), hand length (p=1.00) and buttock-knee length (p=0.51); Western region and Central region-metacarpal III height (p=1.00) respectively.

Similarly for female worker, most of the parameter except stature (p=0.13), acromial height (p=0.60), olecranon height (p=0.24), iliocrystale height (p=0.60), popliteal height (p=0.67) of Northern region; hand length (p=1.00) and shoulder breadth (bi-deltoid) (p=0.58) of southern part of the country; iliocrystale height (p=0.51), foot length (p=1.00) of Eastern region; stature (p=0.40), elbow height (p=0.57) olecranon height (p=0.54), hand length (p=0.12), foot length (p=0.27) of western region; metacarpal III height (p=0.19) of central India have shown significant difference ($p<0.05$) with Arunachal Pradesh. It indicated that design suitable in different regions of India might not be compatible for Arunachal Pradesh. A further t-test was carried out for NE states to validate the design suitability among the states. The states of the available database are Arunachal Pradesh, Meghalaya, Assam, and Mizoram. Most of the dimensions of selected parameters are an insignificant difference with Arunachal Pradesh. From this analysis, results show that design suitable in one part of India may not be compatible for NE states, but design suitable for Arunachal Pradesh may be acceptable to other parts of NE states. To resolve the problems recognised with the existing design digital human modelling is incorporated to test the suitability of pedal operated paddy thresher with the selected region of India as well as North-East states.

Virtual simulation

Virtual simulation involves in creating a virtual workplace by incorporating computer aided design (CAD) of POPT and Manikin in CATIA software. The methodology used for obtaining the desired objective on targeted user group has presented in the flow chart as shown in Figure 1.

The various dimension of POPT recorded in the form of sketches

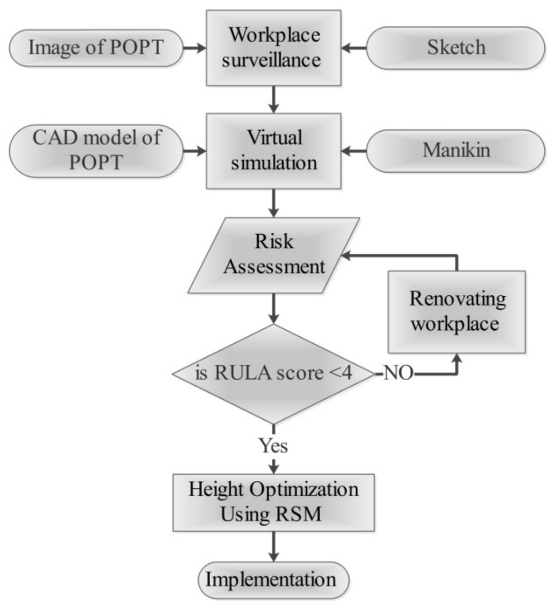

Figure 1: Flow chart for virtual simulation of pedal operated paddy thresher with a manikin.

used to create 3D CAD models and further simulate with Indian manikin as natural working posture. In this methodology, various steps taken into consideration such as workplace surveillance, virtual simulation, risk assessment and optimisation of the postural score concerning to the vertical height of thresher. In workplace operational activity; physical dimensions of POPT, photographs of pedal thresher, existing work posture (Figure 2) and working environment has studied and portrayed into a frame of virtual simulation.

This study divulges that worker has to bend frequently to collect the paddy bunch and to come closer to threshing zone with slight bending. During threshing, several awkward postures adopted while pedalling the thresher. The most commonly followed working position and the existing POPT is simulated in a virtual environment with the 5th, 50th, and 95th percentile manikin of this region for further ergonomic analysis.

Posture analysis

Subjective observation method (i.e. RULA method) for postural analysis focused on the upper part of the body. It ponders on the particular attention of the upper limbs, neck, and trunk and several WMSDs [22,24,33,34]. The final score varied between 1 to 7 based upon the estimated risk due to musculoskeletal loading and also expressed using colour coding [35]. The final scores summarization has given in Table 1.

Results and Discussion

Optimisation of thresher dimension

The existing POPT has selected for posture analysis with the Arunachal Pradesh worker of both genders. The most relevant parameters of the threshing machine where length, breadth, and

Figure 2: Paddy threshing operation.

RULA score	Colour coding	Action required
1		Acceptable
2		Acceptable
3		Investigate further
4		Investigate further
5		Investigate and change soon
6		Investigate and change soon
7		Investigation and change immediately

Table 1: Colour coding for classification of risks according to postural scores.

height. With the observation of usual threshing practices, the vertical height of thresher from the ground was found to be the most significant factor concerned to the operator comfort. Therefore vertical height was selected for posture analysis by simulating with the lower percentile to the higher percentile of the user group.

Prediction of heights

The RULA analysis has executed by taking 5th, 50th and 95th percentile of Arunachal Pradesh male worker for the thresher working vertical height of 77 cm from the ground. From the analysis as shown in Figure 3, the overall postural score found to be 3, 4 and 7 for 5th, 50th, and 95th percentile respectively. Total score 3 and 4 signifies the acceptable range of design and suggested further investigation required for modification. But the total postural score 7 with red colour indicates to investigate and change the design immediately. That is, 95th percentile male worker of Arunachal Pradesh is not compatible with existing POPT. RULA trunk score for this height was 2, 3 and 5 for 5th, 50^{th,} and 95th percentile respectively. The RULA trunk value 3 and 5 was in the range of high value, but for safe operation, it should be lower [36]. Hence to reduce the postural rating, the vertical height of thresher has increased to 2 cm which was taken for further analysis as shown in Figure 4.

With increasing the thresher height (i.e. 79 cm), the total postural score was found to be 3, 4 and 5 for 5th, 50th, and 95th percentile respectively. The outcome indicates that the design is suitable for 5th and 50th percentile only, and further investigation is necessary, but for a 95th percentile worker total postural score was found to be 5 indicating the further examination is needed and change the design soon. The RULA trunk value for height mentioned above were 2, 3, and 4 which indicating more discomfort in L4-L5 region. Likewise, up to 81 cm height as shown in Figure 5, the same process is repeated to overcome the awkwardness based on total postural score resulting in the final grand RULA score for all the percentile to a safe value such as 3, 4, and 4 for 5th, 50^{th,} and 95th percentile respectively. Indicating the acceptable range, but need further investigation. At this stage, the RULA trunk score was found to be 2, 3 and 3 for 5th, 50th and 95th percentile respectively of male worker of Arunachal Pradesh.

Minimum RULA trunk score justifies less discomfort at 81 cm height of pedal thresher for a male worker in NE region. Similarly, for the female operative of Arunachal Pradesh, the above experiment was conducted for 5th, 50th and 95th percentile for the present thresher height of 77 cm as shown in Figure 3. In RULA analysis, the total postural score was found to be 3 for a wider range (5th, 50th and 95th percentile) of female worker indicating the acceptable range, but further investigation is needed whether the present posture is mandatory to change or not shortly. Similarly, the trunk score was found to be 2 for all percentiles of female worker indicates the minimum the value of the trunk score.

A similar trial was taken for 79 cm of height, showing the identical results as 77 cm height. A slightly higher impact occurs in lumber portion of 95th percentile worker. As our approach was to design a suitable pedal thresher for both gender likewise and 81 cm height was fit for male operative already. So the further trial was carried out to 81 cm height for female workforces. From the experiment showing in Figure 5, the total postural score for 5th, 50th and 95th percentile of a woman were 3 for all and trunk score were 2 for the three percentile (5th, 50th and 95th percentile).

Biomechanical approach in L4-L5 spinal segment

In CATIA, Human activity analysis work bench, the biomechanics

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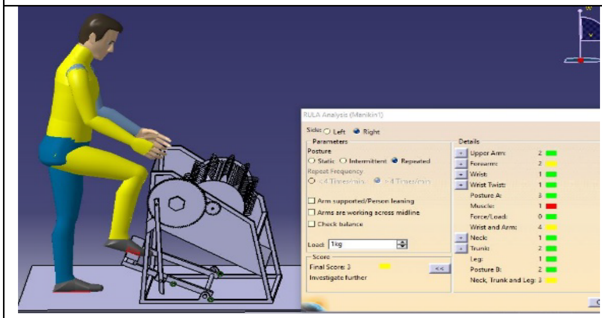
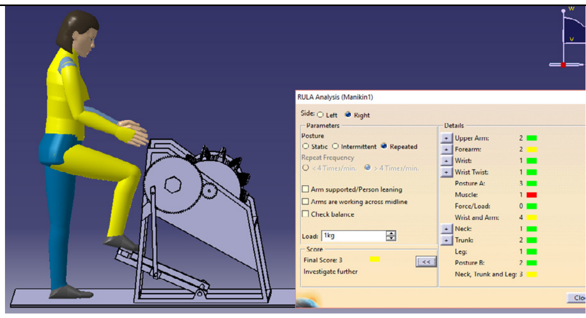
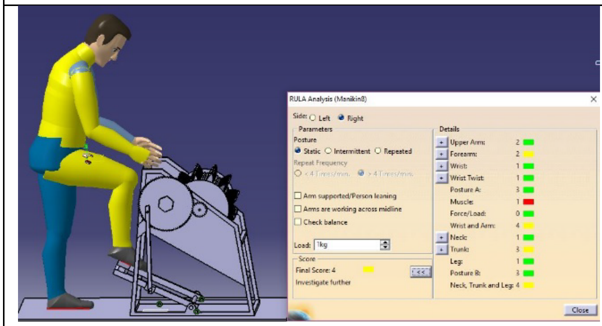
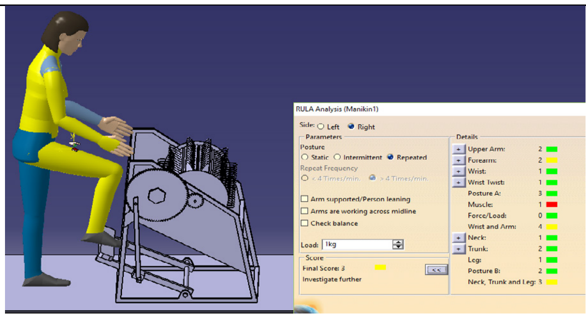
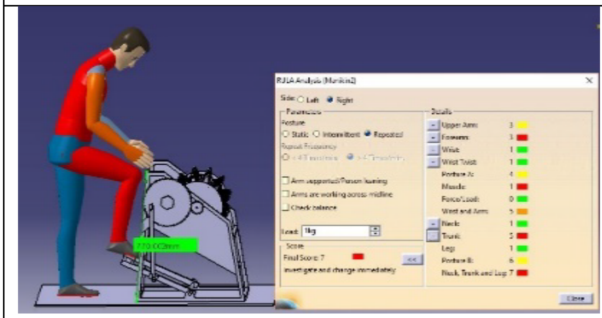
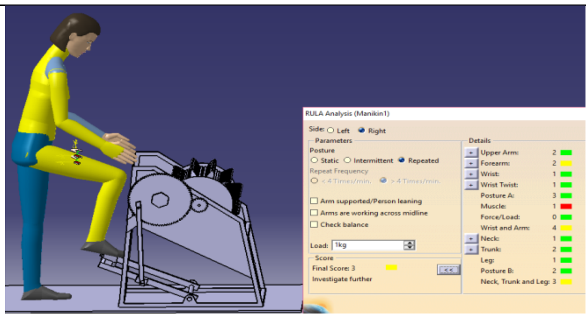
Height 77 cm	
Male	**Female**
RULA score	Biomechanical single acting force
	
5th percentile	
	
50th percentile	
	
95th percentile	

Figure 3: Risk assessment of male worker for thresher height of 77 cm.

single action analysis which is commonly used for peak joint moment, peak compression force on the spine and peak shear force on the lumbar spine (i.e. L4-L5). [25-27]. This analysis was carried out for force calculation on the L4-L5 spinal segment for all three percentile user group of both genders for a load of 1 kg at the intermittent stage and compared with the NIOSH (National Institute for Occupational Safety and Health) limit as shown in Table 2. The biomechanical analysis was carried out with the existing posture of threshing operation with increasing the thresher height.

From the biomechanical single acting force analysis as shown in Figure 6 and 7, the compressive forces on L4-L5 lumbar spines, due to a load acting on hand and trunk plus the mass of the body were observed. The results showed that all the compression force at lumber section were below the safe limit [26] but for 77 cm height, 95th percentile worker has maximum value among them which indicating more bending towards the working zone. It also points out that the compression force is gradually decreasing with increasing the vertical height of thresher. Similarly, in the case of a female worker, it also shows a similar trend which is below the safe limit. These results indicate that existing thresher is not suitable for a higher percentile of the user group and hence the height should be increased to reduce the bending.

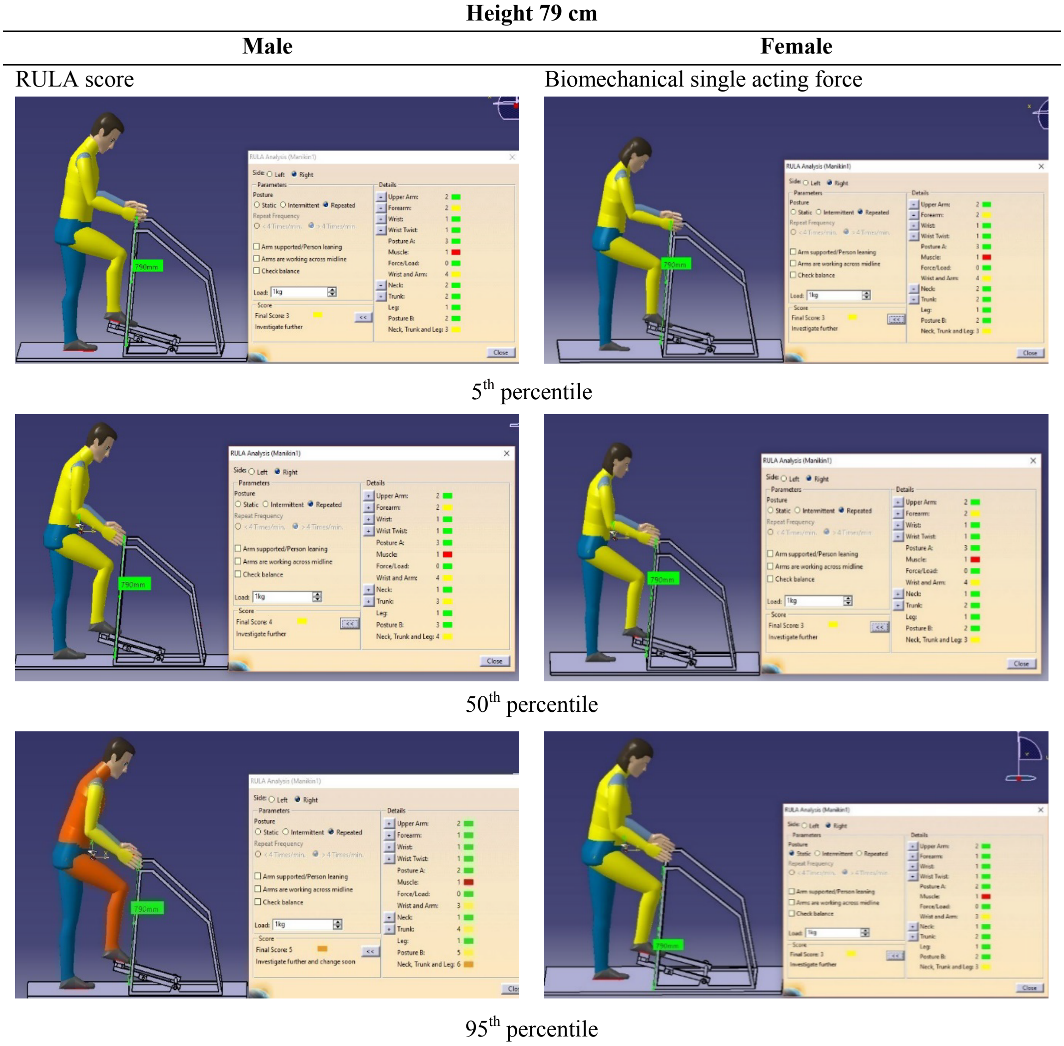


Figure 4: Risk assessment of male worker for thresher height of 79 cm.

RULA score for different body parts

RULA analysis was carried out to access the comfort threshing position and posture of the worker. The participant posture has analysed with the natural working condition, and RULA score for most significant body part viz. upper arm, forearm, wrist and arm, wrist, trunk, neck, leg, etc. observed which has shown in Table 3.

Female workers have not demonstrated many variations in RULA score, but difference noted in the case of a male operative for which design modification was done to achieve the comfort and minimum RULA score. Hence from the experiment, it is concluded that the vertical height fit for both genders of Arunachal Pradesh which were found to be 81 cm and it was free from worker discomfort in repeated working posture for a load of 1 kg.

Optimisation of thresher height using RSM technique

It has observed that trunk score was found to be most significant among all the parameters which directly related with the bending of operator towards the threshing portion. Due to increases the thresher height, bending of the operator was gradually decreased with decreasing the trunk score and compression force. So to optimise the trunk score with increasing height will give the optimum thresher height with minimum trunk score. For optimum condition, a one-factor design of response surface methodology has chosen, where two independent variables viz. height and human body percentile and one dependent variable i.e. RULA trunk score. From the F-test, the model in the design of expert was found significant ($p<0.0001$) as shown in Table 4. In the design of the experiment, three coded variables used like -1, 0 and +1 for two independent variables such as for height 77 cm, 79 cm and 81 cm and body percentile as 5th, 50th and 95th percentile respectively. The Model F-value of 27.02 implies the model is significant. Values of "Prob>F" less than 0.0500 indicate model terms are significant. In this case, A, B, and AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "lack of fit F-value" of 0.56 implies the lack of fit is not significant relative to the pure error. There is a 64.73% chance that a "lack of fit F-value" this large could occur due to noise. Non-significant lack of fit is good. From the sequential model sum of squares, it was found that F-values of 13.33 with values of "Prob>F" less than 0.05 suggested the 2FI vs. Linear model is significant as shown

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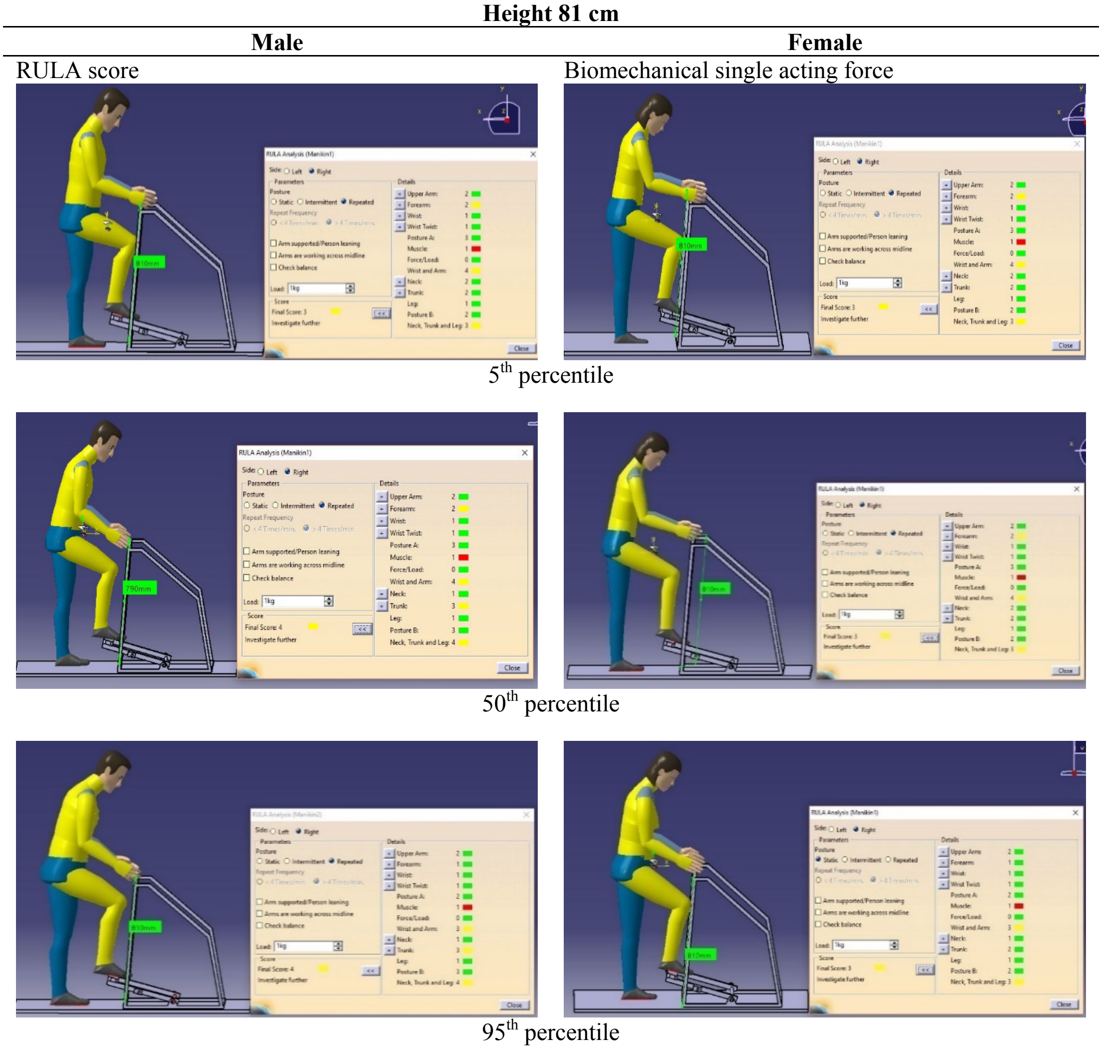

Figure 5: Risk assessment of male worker for thresher height of 81 cm.

Height	Male			NIOSH spine limit
	5th	50th	95th	
77 cm	1296 N	1619 N	1823 N	Cut-off limit 3433 N and Maximum permissible limit 6376 N
79 cm	1295 N	1527 N	1807 N	
81 cm	1273 N	1527 N	1800 N	
	Female			
77 cm	937 N	988 N	1033 N	
79 cm	960 N,	975 N	980 N	
81 cm	960 N	970 N	978 N	

Table 2: Biomechanical single acting force on lumbar (L4-L5) spinal segment.

in Table 5. It was found for a 2FI model that the higher values of coefficient of regression (R^2), adjustable R^2 and predicted R^2 with further precision more than 4 indicate 2FI model desirability for the experiment as shown in Table 6.

The "Pred R-Squared" of 0.7237 is in reasonable agreement with the "Adj R-Squared" of 0.8177."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. In the present study, the ratio of 12.702 indicates an adequate signal. This model can be used to navigate the design space.

Figure 6: Compression force analysis of 81 cm height for 95th percentile male worker.

Std. dev.	0.39	R-squared	0.8492
Mean	2.73	Adj R-squared	0.8177
C.V.%	14.17	Pred R-squared	0.7237
Press	6.59	Adeq. Precision	12.702

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During 2FI integral model analysis, final linear relation in between thresher height (cm) and trunk score was found for different percentile as For 5th Percentile worker,

$$Trunk\ score = +2.0 + 0.0 \times Height$$

For 50th Percentile worker,

$$Trunk\ score = +42.0 - 0.5 \times Height$$

For 95th Percentile worker,

$$Trunk\ score = +42.7 - 0.5 \times Height$$

Figure 7: Compression force analysis of 81cm height for 5th percentile female worker.

From the Interaction graph for optimisation of vertical height with concern to trunk score value was obtained minimum for all three percentiles at around 80 cm ~ 81 cm thresher working height as shown in Figure 8. This suggested dimension can be suitable for design by minimising the worker discomfort. At this optimised condition, the average trunk score for all selected body percentile is 2.0005.

From the above investigation, it results that the vertical height of POPT from the ground surface is dependent on the worker discomfort. The experiment suggests the dimension of vertical height of POPT with reducing worker discomfort is 80 cm ~ 81 cm for the North-East region.

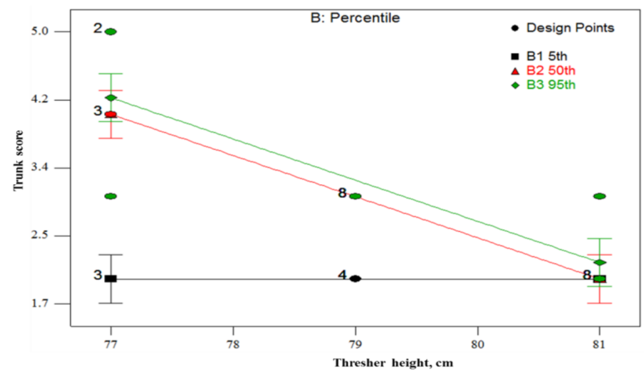

Figure 8: Interaction curve between height of thresher and RULA trunk score.

	77 cm						79 cm						81 cm					
	Male			Female			Male			Female			Male			Female		
Body part	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
Upper arm	2	2	3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fore arm	2	2	3	2	2	2	2	2	1	2	2	1	2	2	1	2	2	2
Wrist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wrist and arm	4	4#	5*	3	3	4#	4#	4#	3	4#	4#	3	4#	4#	3	4#	4#	4#
Neck	1	1	1	1	1	1	2	1	1	2	1	1	2	1	1	2	2	2
Trunk	2	3	5*	2	2	2	2	3	4#	2	2	2	2	3	3	2	2	2
Leg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neck, trunk and leg	3	4#	7*	3	3	3	3	4#	6*	3	3	3	3	3	4#	3	3	3
Grand RULA score	3	4#	7*	3	3	3	3	4#	5*	3	3	3	3	3	4#	3	3	3
*Very high; #moderate																		

Table 3: RULA score for different body parts of male worker.

Source	Sum of squares	df	Mean square	F-value	P-value Prob>F	
Model	20.27	5	4.05	27.02	<0.0001	significant
A-Height	8.00	1	8.00	53.33	<0.0001	
B-Percentile	8.27	2	4.13	27.56	<0.0001	
AB	4.00	2	2.00	13.33	0.0001	
Residual	3.60	24	0.15			
Lack of fit	0.27	3	0.089	0.56	0.6473	not significant
Pure error	3.33	21	0.16			
Cor total	23.87	29				

Table 4: Analysis of variance for response surface model.

Source	Sum of square	df	Mean square	F-value	P-value Prob>F
Mean vs. Total	224.13	1	224.13		
Linear vs. Mean	16.27	3	5.42	18.55	< 0.0001
2FI vs. linear	4.00	2	2.00	13.33	0.0001 Suggested
Quadratic vs. 2FI	0.089	1	0.089	0.58	0.4532
Cubic vs. Quadratic	0.18	2	0.89	0.56	0.5795 Aliased
Rasidual	3.33	21	0.16		
Total	248.00	30	8.27		

Table 5: Sequential model sum of squares.

Source	Std. dev.	R^2	Adjusted R^2	Predicted R^2	Press	
Linear	0.54	0.6816	0.6448	0.5546	10.63	
2FI	0.39	0.8492	0.8177	0.7237	6.59	Suggested
Quadratic	0.39	0.8529	0.8145	0.7117	6.88	
Cubic	0.40	0.8603	0.8071	0.6858	7.50	Aliased

Table 6: Model summary statistics.

Discussion

The anthropometric variations among the various zones of India indicated the design unsuitability for tools and equipment design for one place and used the same in another region. The mismatch between the workers and their tools could lead to musculoskeletal discomfort, disorder, and lower productivity [13]. From t-test, a North-Eastern zone of personnel are smaller as compared to another region of India, and among northeastern states, there is a slight variation of some parameters. It suggests tools and equipment designed for covering a wider percentage of the user group. However, it is stated and extensively accepted that the use of 5th, 50th or 95th percentile values are more rational in design situations [13]. Virtual simulation of man-machine would permit the user to quantitatively and qualitatively analyse all aspects of working posture. Information pertaining to posture for all segments of the manikin can obtain from user-friendly dialogue panels. The use of colour coding techniques confirms that problem areas can be quickly identified and iterated to optimise better working posture. The identification of the possible areas of improvement at a new workstation minimizes awkward stances and risk of WMSD among the workers [37]. The ergonomic redesign of work system would mitigate the issues of high physical exertion; WMSD and low productivity, physiological and psychophysical stress [38-40]. From the postural analysis, RULA score is increasing as the increasing human height justifies that the current vertical height of thresher is smaller which further recommends increasing the height to reduce discomfort and WMSDs. The anthropometric body dimensions of the operators associated with the height of the workstation influenced the maximum effort level of lumbar muscle and the comfort level of working posture when workers are performing their jobs. Existing design is affecting on 95 percentile of male worker (i.e. RULA score 7) suggesting an immediate change in design [37]. The similar variation observed in a biomechanical compression force on the spine and a lumbar portion (L4-L5), but it's below the maximum permissible NIOSH limit (i.e. 6376 N) [26]. The mean compressive strength of lumbar segments was found to be 4400 N with a standard deviation of 1880 N [41].

The RULA trunk score has the most significant effect on safety and comfortable working posture, so for best suitable trunk score, optimisation is carried out to getting a minimum trunk score against the vertical height of the thresher.

Conclusion

The state-of-the-art virtual technology (CAD and DHM) and response surface methodology (RSM) used for optimising the working height of pedal operated paddy thresher. Future work in this endeavour may include expanding utilisation and application of these technologies in agriculture for the human centric design of various tools and equipment. The outcomes of the present study based on statistical analysis, ergonomic analysis and optimisation process were listed as given below:

1. The anthropometric database of North-East India significantly differs from other parts of India and found similarity in body dimension within Northeast states of India. It revealed that tools and equipment designed suitable for other regions of India might not be acceptable.
2. The postural assessment analysis performed for all three percentile (5th, 50th and 95th percentile) of the user group of both male and female. It was found higher RULA score i.e. 4 and 7 respectively for male workers with 50th and 95th percentile for thresher working height of 77 cm. Whereas, the score was found to be 4 and 5 respectively for 79 cm thresher working height which depicted unacceptable for male workers and suggesting for an immediate change in design.
3. From the optimisation of trunk score against the working height of thresher, the trunk score was found minimum i.e. 2.0005 for all percentile user group having 81 cm working height of thresher.

The present study, therefore, recommended that the height of pedal operated paddy thresher for safe operation should be 81 cm, which would reduce the discomfort, WMSDs, and enhance the working time and efficiency.

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