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Virtual Ergonomics Evaluation of Thresher for Agricultural Women Workers using Digital Human Modeling

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Abstract: In today's scenario, use of cutting-edge technology like digital human modeling (DHM) is very important and its application is very limited in agricultural sector. Thresher being most dangerous machine to operate, with ill designed from point of view such as safety of operators, improper platform, noisy atmosphere, is a very common sight. The plight of thresher machine operators has to be seen to be believed. So, virtual ergonomic evaluation to assess postural analysis and musculoskeletal loads on women operators working on thresher machine by using Rapid Upper Limb Assessment (RULA) ergonomic evaluation tool in CATIA software have been done in this study. Anthropometric percentile values (5th, 95th) of selected anthropometric parameters were utilized while creating virtual model in CATIA software. This paper analyze existing man-machine system with the purpose to identify high risk postures that result in musculoskeletal disorders that too in virtual environment i.e. Digital Human Modeling and not by conventional method.

Index Terms-*Ergonomics, Thresher, Digital Human Modeling, Posture, CATIA, RULA*

1. Introduction

Women agricultural employees. The design of thresher machine is made indigenously and developed on the basis of conventional norms without consideration of women operators has been found. Therefore, the present paper demonstrates ergonomic evaluation of the prevalence of work-related musculoskeletal disorders by Rapid Upper Limb Analysis by digital human modeling.

Thresher is a machine used for separating grains from earheads or plant stalks and getting cleaned grains and straws at the respective output spouts. Existing thresher machine design that is currently available has not fairly concerned on the working position and posture of the women operators using it. The working posture by women operators when operating a thresher machine tent to cause injury because of dimensions of that machine and body of the women operators that did not conform to each other and leads to musculoskeletal disorders.

This study utilizes aspects of physical ergonomics. There is hierarchy of goals in ergonomics. The fundamental task is to generate 'tolerable' working conditions that do not pose known dangers to human life or health.

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When the basic requirement is assured, the next goal is to generate "acceptable" conditions upon which the people involved can voluntarily agree, according to current scientific knowledge and under given sociological, technological and organizational circumstances. The final goal is to generate "optimal" conditions which are so well adapted to human characteristics, capabilities and desires that physical, mental and social wellbeing is achieved.

Digital Human Modeling is the process of developing digital human models using anthropometric and biomechanical database, for ergonomic evaluation of product and workstation in virtual environment, using 2D or 3D CAD software's. A digital human model is an electronic representation of a human body. Representation of human body has been studied for decades and new technologies have accelerated their use. Human models are created in compliance with biomechanical and anthropometric studies. Biomechanics studies forces effecting living organism such as human body and anthropometry examines human body structure and measures. In addition, digital human models are built on grounds of a kinematic model of human motion and joint angles. An adequate accuracy is attained even though the model does not all-out equate reality. Computer manikin is a 3-D Models of the human body designed to assess compatibility & usability of products, machinery or workplaces with the human users or operators. It is possible to create manikin, both male and female, of different sizes using anthropometric databases based on surveys [2].

In the present work, postural assessment for women operator working on thresher has been carried out by the

Rapid Upper Limb Assessment (RULA) tool using CATIA (an acronym of computer-aided three-dimensional interactive application is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), PLM and 3D, developed by the French company Dassault Systems) ergonomic workbench to identify high risk working postures during the process and improvement which can prevent inducing work-related musculoskeletal disorders.

There are numerous ergonomic assessment methods of manual task exists in the market. For example, REBA, RULA, LUBA, OWAS, PLIBEL, HUMOSM, STRAIN-INDEX, JACK, ANYBODY, NIOSH SURVEY, PATH, PEO and QEC method [2-3]. After reviewing and comparing various methods RULA method would best suit the need of study. The Rapid Upper Limb Assessment (RULA) index is one of the most common and cited tools for evaluating the ergonomic risk of WMSDs and is chosen for the study due to working cycle involved movement of upper extremities [3,4]. DHM software packages used for ergonomic assessment are CATIA-HUMAN Design and Analysis tools, Pro/ENGINEER Manikin Analysis, SAMMIE, JACK, SANTOS and RAMSIS [4]. Through this approach, chosen CATIA software for RULA assessment V5 R14 included with Ergonomic Design and Analysis (EDA) module. CATIA provides a variety of efficient ergonomic analysis tools and methodologies which can analyze comprehensively all factors among the man machine interactive processes and can offer detailed solutions of ergonomic design for designers. The ergonomic applied research platform provided by CATIA can build 3D models for human body and device through the establishment of virtual human body model and body posture simulation, which improves the efficiency and structural performance of device design, and makes a scientific and accurate evaluation on its safety and comfort, thus providing designers with a most efficient and effective way to design humane devices. Factors such as structure, size, shape, material and quality in each part of gymnastic device may influence the handling, flexibility, stability and comfort in using, so all the design basis is decided by the human data of users. In order to solve the problem among human, Machine and environment in the product designing process, CATIA is the first to propose the solutions for man-machine design and analysis.

RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. A coding system is used to generate an action list which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator. It is of particular assistance in fulfilling the assessment requirements of both the European Community Directive (90/270/EEC) on the minimum safety and health requirements for work with display screen equipment and the UK Guidelines on the prevention of work-related upper limb disorders. RULA is a postural targeting method for estimating the risks of work-related upper limb disorders. RULA worksheet is used to assess body posture, force, and repetition. Based on the evaluations, scores are entered for each body region in section A (arm and wrist) and section B (neck and trunk). After the data for each region is collected and scored, tables on the worksheet are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk. RULA score sheet takes into account the scores of muscle use score, muscle load/ force score for both arm and wrist score and that of neck, leg and trunk score. These scores allowed us to see if any of the participants had any physical force being applied on their body parts. Apart from the combined score, the RULA score sheet also can be used for looking at different scores for individual parts. The RULA assessment can be carried out swiftly, so several postures and tasks within one work cycle can be evaluated without any noteworthy time and endeavor. While assessing with RULA, only one side (right or left) is evaluated at a time. After observing the worker, the evaluator can decide if the evaluation is required for both sides. After the data for each region were collected and scored, tables on the form were then used to compile the risk factor variables, generating a single score that represents the level of MSD.

The procedure of the RULA analysis means an analysis of every posture of the manikin in proposed assembly workstation. The RULA analysis researches following risk factors: the number of movements, static work of the muscles, body posture by assembly executing and time of working without pause. All these factors are combined into the final score. The final score can have a value from 1 to 7and is also expressed in color. The meaning of several values is following:

1. 1 and 2 (green) – indicates, that the posture can be accepted under the assumption, that it is not the same for a long time or it is not often repeated for a long time

2. 3 a 4 (yellow) – indicates the need of further detailed research and then, maybe be necessary to change the postures,

3. 5 a 6 (orange) – indicates, that the research and the changes are necessary in very short time,

4. 7 (red) – indicates, that is necessary immediate to research and to change of the postures.

This final score is accounted as a middle value from the partial scores of the particular body parts. For every body part exists a separate evaluating scale, you can see the analysis of worker reaching to the magazine containing the part needed in the next assembly step. The result of the RULA analysis will be displayed in the 3D model also as a color part of the manikin model. The four basic colors have a defined meaning. The red color represents a not applicable posture, which must be changed; the orange color presents a position that also may be changed. Yellow color gives information about a need for further optimization and the green means that the loading of the worker is ok. In such a way can, be step by step analyzed all assembly operations - postures at the designed assembly workstation. All "not green" assembly operation can be changed and so can be realized the assembly workstation optimization. The obtained result is of course often a compromise solution [6,7].

2. Methodology

The primary methods of research included internet searches, references to ergonomics, digital human modeling and agriculture. Search of library archives for relevant research. In this research, the main area is related to virtual/digital human modeling ergonomics. As, Virtual Human modeling (VHM/DHM) is ergonomic concept which usually refers to modeling physical aspects of human with main focus on anthropometry and physical strain. The ergonomic analysis is performed in the virtual environment using CATIA software [8,9,10,11,12,13,14,15,16] and for methodology is designed by referring the methodology [17,18,19,20,21,22,23] used in this study can be divided into following parts:

- Selection of workplace and Problem Identifications and its impact
- Selection of tasks (Tools used-videos, photographs) Identify Physical Postures which lead to MSD-Task identified for ergonomic evaluation is the elements of task performance. The identified task contained "task element" that will be used to create simulations and generate data with regards to load, balance, strength exertion, posture and other task performance descriptions.
- Anthropometry Database: Anthropometry is the science dealing with measurement of the size, weight and proportions of the human body. For data, it can be divided into several types: work design dimensions and anthropometric data for designing the dimensions of ergonomic workstations.
- Simulation and Virtual Human Body Modeling-DHM
- The movement simulated can be divided into several phases as follows:

1. Creating a virtual environment
2. Creating a Human model
3. Positioning the Virtual Human Model in virtual environment in accordance with the real situations
4. Providing assignments or work on a virtual human according to the desired working movement
5. Performing verification and validation of the model have been made
6. Analyzing the performance of virtual human model by using Ergonomic interventions.

From the results of this simulation, the ergonomics value will be seen, which will indicate how workstation have an effect on the performance of the women operator with an indicator and views based on the use of simulation software.

In depth study during field data collection, analysis of videos, Discussion with workers -Work-Related Musculoskeletal Disorders (WMSDs) are

- The greatest complaint-Problem in waist while operating thresher machine and after operating also.
- Unnatural body postures requiring frequent bending from waist (standing,bending,twisting) –higher postural strain-origin of discomfort,Pain in upper back (Very severe)
- Pain in Shoulders, Upper arm, Lower arm
- Twist of trunk frequently-So spinal rotation causes chronic strain
- Great amount of static load is imposed on upper leg muscles during working under bend or erect position
- Lower back pain due to stooping posture (to bow or bend)-bending and twisting awkwardly.
- During threshing, bend a little in forward direction while in standing posture also.
- Frequency of movement of arm very high
- The problems in eye are found –dust particles and small fragments of straws in air and generally come in contact with the eyes
- Very high noise –during machine operation (95-98 decibel)
- Prolonged work activity, high repetitiveness, and remaining constantly in an awkward posture for a prolonged period of time were the major factors of

drudgery, acute pain and discomfort among farm workers.

Fig. 2 Photograph Shows process of Woman working in feeding process

Fig. 1 Photograph Shows Thresher operation

3. Results and Discussion

As per the methodology and procedure, Listing of MSDs for thresher has been done.All operators were female between the age range- 22-50.Investigation under an analytical-descriptive study has been done for women agricultural workers working on thresher, are the research participants. All of them underwent pre-interview for obtaining some information about their job characterization. Photographs/Videos of workers working on thresher. Various postures were identified for the analysis. The digital human manikin was created in human builder of the CATIA. Identified postures were applied to the DHM one by one and RULA analysis (Rapid Upper Limb Assessment) has been carried out. The manikin is modelled using CATIA human builder module and six key working postures were chosen and modelled. As RULA allows manikins upper limb analysis and used to canvas many aspects of manikin posture based on various variables and user data such as lifting distance, lowering distance, action duration, object weight and task frequency which was noted carefully on field by taking photographs and videos.

Various postures identified are as follows-

Bending to reach the bundle of grain by twisting trunk (2 postures)

Picking bundle and again twisting back with load by both hands (2 postures)

Feeding to hopper by both hands and holding till inserted (2 postures)

Working Posture 1: Standing on work platform

It could be clearly seen because the women operator back formed an angle and did not stand straight as the farmers need to keep balance the machine height. As work platform is not proper, not at all designed as per requirement. Sometimes bullock-cart or sometimes simple table is used was observed during study.

Working Posture 2: posture 2 in the threshing cycle is basically slight bending for picking up bundle. Once the operator straight stand, they have to bend down to balance the machine position as well as body position.

Working Posture 3: posture 3 represents threshing cycle action of picking up the crop bundle, which is frequent bending and reaching around 180 times per hour and repetitive in a work day to accomplish threshing task. In these actions, worker often bend their back severely and mostly without support. Every time worker has to bend and grab the bundle. Ergonomically awkward posture has been detected in this operation. Higher WMSD risk (Back pain). During threshing job the movement of upper limb is very less and therefore great amount of static load is imposed on the upper leg muscles under bend position. Most problematic part are neck, trunk, leg.

Working Posture 4: posture 4 in the threshing cycle is picking up bundle in bending position as well as trying to keep balance on uneven platform.

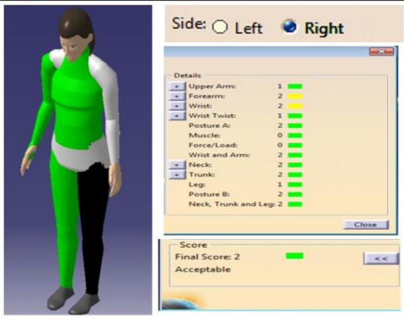
Working Posture 5: posture 5, pick up the bundle and with bundle in hand twisting back in awkward way as well as trying to keep balance on uneven platform. To great extent ergonomically awkward position. However, bending and twisting of back impose higher postural strain than straight back posture and leads to postural stress

Working Posture 6: posture 6 completes the threshing cycle wherein operator insert the bundle in hopper, continuously hold in material in hand still the action completes

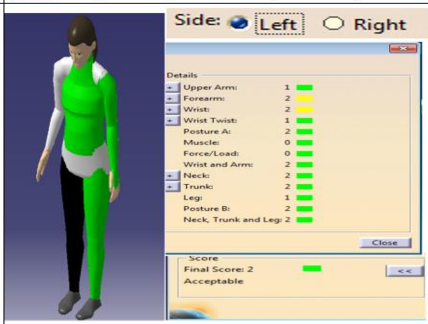
Table I RULA ANALYSIS SCORE WITH RECOMMENDATIONS FOR FIELD CASE STUDY, 5TH PERCENTILE, 95TH PERCENTILE OF WORKING POSTURE 1

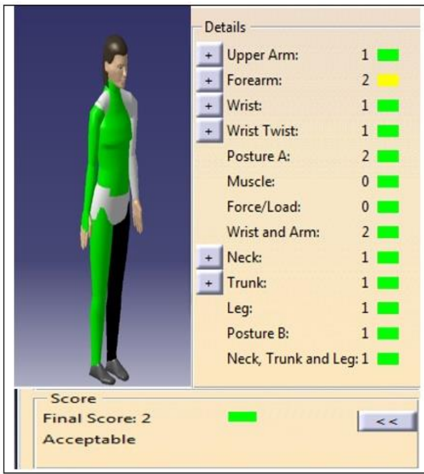
RULA	**Case 1- Field case study**		**Case 2 – 5th percentile**		**Case 3 - 95th Percentile**	
	Right	Left	Right	Left	Right	Left
Final Score	2	2	2	2	2	2
Recommendation : Improvement in platform can reduce the discomfort problem. Construction or designing of proper platform is must considering ergonomics						

Rula analysis for position 1 (Right side)



Rula analysis for position 1 (Left side)





4. Conclusion

DHM technology can be successfully used to stimulate and analyze the various postures attained by the women workers working on thresher machine. Moreover, the use of virtual model of the worker (manikin) for the analysis purpose reduces cost of the analysis for improvement of the workstation. RULA can be effectively used for postural analysis. In thresher machine working where women workers are working in standing position, lack of knowledge of ergonomics is studied and analyzed and musculoskeletal disorders are also found.

Mostly, Working Posture 3, which represents threshing cycle action of picking up the crop bundle, which is frequent bending and reaching around 180 times per hour and repetitive in a work day to accomplish threshing task. In these actions, worker often bend their back severely and mostly without support. Every time worker has to bend and grab the bundle. Ergonomically awkward posture has been detected in this operation. Higher WMSD risk (Back pain) .During threshing job the movement of upper limb is very less and therefore great amount of static load is imposed on the upper leg muscles under bend position .Most problematic part are neck, trunk, leg. Even other postures are which shows score '6' and '7' showing very high risk, justified by RULA.

RULA showed that there is need of corrective action including further assessment necessary. From the results of data collection and the process of RULA method,it was clear that measures must to be taken to redesign/modification of the thresher machine and /or workstation modification based on working postures. One of the ways may be

- by adjusting the dimensions of the machine
- by the use of adjustable concept in the design could probably assist farmers to adjust the working position with the machinery.
- by the adjustable platform could probably eliminate postural discomfort

so, it can be concluded that awkward posture could be detected using RULA assessment in CATIA. Furthermore, RULA states that ergonomic problems have mainly postural origin and it may be improved by redesigning/modification in thresher machine or workstation. So, due to useful support offered by CATIA in ergonomic assessment, evaluation can be extended by redesigning platform as per modification suggested and posture of women workers can be tested, analyzed repeatedly, comprehensively and systematically from various aspects so as to evaluate the comfort of user. This study illustrates urgent need of ergonomic interventions for other machineries of agricultural field and check compatible mode of working. This study provides evidence supporting recommendations for redesigning/modifying of machine/workstation. Based on the analysis that has been done it can be determined that this research has high prospect if continued.

References

[1] Hurst, P., & Kirby, P. (2004), "Health, Safety and Environment: A Series of Trade Union Education Manuals for Agricultural Workers", ILO.

[2] Vignais, N. et al. (2013), "Innovative system for real-time ergonomic feedback in industrial manufacturing", *Applied Ergonomics*, 44: 566-74.

[3] Magistris, D. et al. (2013), "Dynamic control of DHM for ergonomic assessments" , *International Journal of Industrial Ergonomics*, 43: 170-180.

[4] Meksawi, S . et al. (2012) , "Musculoskeletal problems and ergonomic risk assessment in rubber tappers: A community based study in southern Thailand", International Journal of Industrial Ergonomics, 42: 129-135.

[5] Käsnänen, R. (2011), "Manual Work Evaluation in Virtual Environment Utilizing Digital Human Model".

[6] McAtamney, L. and Corlett, N. (1993) RULA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders. Applied Ergonomics, 24, 91-99.

[7] McAtamney, L. & Corlett, E.N. (2004) Rapid Upper Limb Assessment (RULA) In Stanton, N. et al. (eds.) Handbook of Human Factors and Ergonomics Methods, Chapter 7, Boca Raton, FL, pp. 7:1 - 7:11.

[8] Bubb, H. (2007), "Future Applications of DHM in ergonomic design", *Springer*, Heidelberg.

[9] Septyan, T., & Nurtahyo, B. (2013), "Virtual Human Modeling and simulation for Toll Booth Design in Indonesia", Advanced *Engineering Forum*, Vol. 10, pp3-8, Trans Tech Publications, Switzerland, doi: 10.4028/www.scientific.net/AEF.10.3

[10] Bertoloni, E., Fenaroli, M., Marciano, F., and Rossi D. (2012), "Sonographers' Workplace Improvement: Ergonomics Evaluation using Modeling and Simulation Software", *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management,* Istanbul, Turkey, July 3 – 6.

[11] Bhuse, P., & Vyavahare, R. (2014), "Ergonomic Evaluation of knapsack Sprayer used in Agricultural Applications", *International Journal of Scientific &Engineering Research*, Volume 5, Issue 12, December.

[12] Kamate, V. (2015), "Ergonomic Assessment of Traditional Weeding Tools Usage and their management in Indian Agricultural Practices", *International Journal of Engineering Research &Technology*, Vol 4, Issue 09, September.

[13] Zhene, Y., Xin, Li., and Ying, Li. (2013), "The virtual prototyping design and Evaluation of ergonomic gymnastic based on CATIA", *International journal of Hybrid Technology*, Vol 6, Issue 5.

[14] Kumar, P., et al. (2015), "Design and ergonomic Evolution of Multipurpose students bed", *ICORD'15 International conference on research into Design*, IIT, Bangalore, Jan.

[15] Chakravarthy, S., et al., "Ergonomic Study of Automobile Assembly Line", *International Journal of Recent Technologies in mechanical and electrical engineering (IJRMEE).*

[16] Yadhu, G., and Raghunath, R. (2014), "Ergonomic interventions in a warehouse of a Food Processing

Industry", *IJIRSET*, Vol.3, Issue 9, Sep.

[17] Zhang, B., Rodríguez, P.M., Talavera, N. (2011), "Evaluation research by CATIA ergonomics software tool to address the needs of digital human modeling systems for occupational risk prevention", Presentation of work at congresses, *Proceedings of the 9th international conference on occupational risk prevention*.

[18] Karmakar, S. P., Majumdar, M. S., Majumdar., Dhurjati, (2012) " Application of digital human modeling and simulation for vision analysis of pilots in a jet aircraft: a case study",*18th World congress on Ergonomics - Designing a sustainable future*. DOI: 10.3233/WOR-2012-0617-3412,Journal: Work, vol. 41, no. Supplement 1, pp. 3412-3418.

[19] Sanjog, J. , Karmakar, S., Patel, T., Chowdhury, A. (2012), " DHM an Aid for Virtual Ergonomics of Manufacturing Shop Floor: A Review with Reference to Industrially Developing Countries", *International Journal of Computer Application's*, 54(14):18-23. DOI:10.5120/8634-2541.

[20] Sanjog, J. , Karmakar, S., Patel, T., Chowdhury, A. (2012) , "Designing and Ergonomic Evaluation of a Shoe-Rack in CAD Environment", *International Journal of Computer Applications*, 49(20):38-41, DOI: 10.5120/7890-1275.

[21] Lambros, L.(2009), "Ergonomic evaluation and redesign of children bicycles based on anthropometric data, Ergonomics Research Group", *Applied ergonomics*, 41(3):428-35. DOI: 10.1016/j.apergo.2009.09.006.

[22] Chenyu, H., et al.(2014), "Ergonomic assessment of patient under-arm lifting technique using digital human", IIE Annual Conference Proceedings, January1.Andreoni, G. et al. (2009) "Method for movement and gesture assessment (MMGA) in ergonomics", Digital Human Modeling,591-598.

[23] Carmen Rodriguez, Predictive Analytics for Disease Outbreak Prediction and Prevention , Machine Learning Applications Conference Proceedings, Vol 3 2023.

[24] Mark White, Thomas Wood, Carlos Rodríguez, Pekka Koskinen, Jónsson Ólafur. Machine Learning for Adaptive Assessment and Feedback. Kuwait Journal of Machine Learning, 2(1). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/169

[25] Talukdar, V., Dhabliya, D., Kumar, B., Talukdar, S. B., Ahamad, S., & Gupta, A. (2022). Suspicious activity detection and classification in IoT environment using machine learning approach. Paper presented at the PDGC 2022 - 2022 7th International Conference on Parallel, Distributed and Grid Computing, 531-535. doi:10.1109/PDGC56933.2022.10053312 Retrieved from www.scopus.com