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Research Article

ERGONOMIC EVALUATION OF MAIZE SEED SOWING METHOD IN SMALL HOLDINGS AND ITS IMPACT ON MUSCULOSKELETAL DISORDERS BY USING DIGITAL HUMAN MODEL AND VIRTUAL ERGONOMICS TECHNIQUES

KAMATE VIJAY[1]* AND MOHAN KUMAR S.[2]

[1]Department of Mechanical Engineering, SDM College of Engineering and Technology, Dharwad, Karnataka, 580002, India
[2]Department of Mechanical Engineering, Malnad College of Engineering, Hassan, Karnataka, 573202, India
*Corresponding Author: Email-vijay.kamate@gmail.com

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Abstract- Role of ergonomics for sustainable development has become a hot subject in agriculture. To have higher agricultural yield it is essential to study not only basic requirements of agriculture but also human factors in design and in working environment. In this context, an effort has been done to study farmer's postures who involve in growing maize in the traditional farming methods in their small holdings. In addition to scientific discipline, occupation theory, related principles, and novel method to design the sowing equipment in order to optimize human ergonomics, working efficiency and health has been investigated. Hence this present work is undertaken to study maize seed sowing posture of a farmer and ergonomics analysis in sowing process. In this present work, modern CAD techniques like digital human modeling (DHM) and virtual ergonomics (VE) were used to analyze the situation. It is concluded that newly designed proposed sowing equipment for farmers improves the working efficiency with reduced work related injuries.

Keywords- Maize, Sowing, Ergonomics, Digital Human Modeling (DHM), Virtual Ergonomics (VE), Musculoskeletal Disorders (MSDs), RULA

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Introduction

In India, nearly about more than 60% of the population depends on the agriculture and is a largest livelihood provider. It provides a significant contribution in improving the country economy. It is observed nation's GDP contribution by 16% and 10% in nation's overall exports through agricultural sector alone. It is the sector which contributes to the growth of the nation's economy, reduces poverty by offering employment and besides addresses food security and environmental issues. Indian agricultural sector has around 80% farmers having small and marginal farming land. As per the agricultural census 2010-11, the total share of farmers belonging to small and marginal holdings sector accounts for 76% having a maximum cultivating land around 2.2 hectares [1, 2]. The average size of operational holdings has come down marginally from 1.6 hectares to 1.55 hectares due to sub-division and fragmentation of land. The small and marginal farmers play an important role in the development of nation agriculture and economy. The average size of farming land belonging to this category is approximately 2.2 hectares. It has been reported that most of these farmers employ traditional tools and techniques in their day-today farming processes [3]. This could be attributed to the deficiency of modern technologies, lack in affording modern farming implements due to poverty. However, traditional farming tools and implements being used were not designed considering human centric or human well being parameters [4]. Further it is observed that tools being used in one geographic region are still being continued in other geographic region without any modifications [5]. Hence there is need to identify low cost equipments and agricultural tools and specific for a particular region. In this context, seed sowing equipment and better sowing posture is identified and analyzed for its ergonomic evaluation in northern Karnataka region. It is noticed that this study reveals that human comfort is the key area to be addressed in detail in product design [6, 7]. This present work mainly addresses human wellbeing and ergonomic issues for sustainable agricultural practices. Several researchers have reported musculoskeletal disorder extent in agriculture and past perspective effects on the agricultural ergonomics and labor health issues [8-10]. Here, developments in agricultural ergonomics in past and present have been reported. Still several innovative methods are needed to solve problems related to agricultural ergonomics and workplace postures for different activities in agriculture. Such innovations in agricultural scenario were found to be good practices at the farmer's expense, health and safety [11, 12].

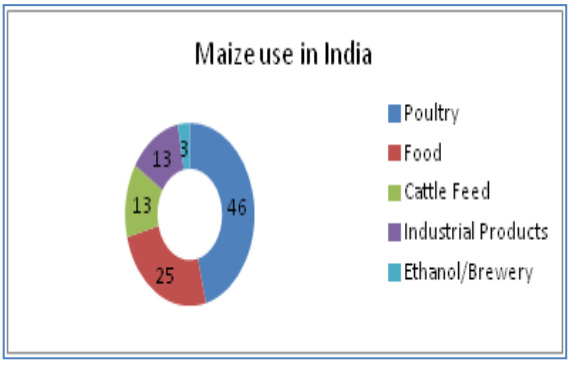

Fig-1 Application of maize in different sectors

Indian agricultural scenario, maize production is severely lagging compared to other countries. The maize production has almost doubled around 12 million tons in the early 2000s to around 23 million tons today. Even though the production has doubled, still the country's contribution to the world in maize market is only 2%. One of the key reasons for this is farmers having small farm holdings, lack of resources and seldom use of scientific farming methods. In the present Indian agricultural sector, maize production contributes nearly about 9% in food basket. It is emerging as the third most important crop cultivation after wheat and rice [13]. The crop not only used for human consumption but also in poultry, dairy, meat and ethanol industries making it one of the fastest growing cash crop as shown in [Fig-1]. Maize is grown in the country throughout the year in most of the states and it can be grown in all environmental conditions [14]. The major maize grown states which contribute 80% of the total maize production in India, include Andra Pradesh (21%), Karnataka (17%), Maharastra (13%), Rajasthan (9%), Bihar (9%), Uttar Pradesh (7%) and Madhya Pradesh (6%). As per the Indian agriculture report, there is a significant enhancement in the maize cultivation due to short cultivation period, crop adoption to a wide range of soil and climate conditions and also high yield per hectare. The present study is made on the farmers having small and marginal holdings and involving in maize cultivation. Seed sowing is an art of placing the seed in the soil to get better yield and good germination in the field. Perfect sowing results in seed placed at correct depth, uniform seed sowing distance and hence maximum yield per area. The maize seed sowing method in majority of the farmers having small and marginal holdings is examined and the working postures were analyzed for its ergonomics to determine the risk factors involved in the working postures.

Digital Human Model and Virtual Ergonomics: Important tool in product development.

Including ergonomics in product design helps to improve the health and wellbeing of the user or worker. The man-machine-environment is a complex scenario to analyze in product development. Most of the product failures in history are directly linked to the mismatch between the user and machine or its working environment. The conventional method of evaluation of ergonomics is tedious, imperfect and time consuming which involves stages like building full scale physical model, creating the similar working environment [15]. DHM and VE are now widely recognized tools in the area of ergonomics in various industrial sectors like FMCG, automotive, aerospace, military, health care, service industries etc. DHM and VE tools give complete information to the designers in analyzing the ergonomic situations like posture motions, posture position, repetitive movements, body loading, maximum reach and eye vision range [16]. Unfortunately, this novel method of ergonomic evaluation is still in less use in the agricultural sectors. The necessity of applying these tools in agricultural situations in solving the complex problems is an advantage to the product designers by designing human centric agricultural products and reducing the work related injuries.

Present work

Based on the literature, in Indian agricultural scenario, the maize production is severely lagging compared to other nations. The objective of this present work is to provide to accumulate and distribute the development and computer technology application to the areas of agricultural ergonomics and safety. In view of this, present work mainly addresses human wellbeing with appropriate ergonomic goals. In addition to agricultural related principles, a novel method for sowing equipment in order to optimize human ergonomics, working efficiency and health has been investigated. Hence this present work is undertaken to study the development of sowing equipment, maize seed sowing posture of a farmer and ergonomics analysis. In this present work, modern CAD techniques like digital human modeling (DHM) and virtual ergonomics (VE) were used to analyze the situation. It is concluded that newly designed proposed sowing equipment for farmers improves the working efficiency with reduced work related injuries.

Field observations, materials and methods

The traditional seed sowing method by most of the farmers having small and marginal holdings were observed in Dharwad district of North Karnataka region. Manual method of seed sowing is practiced where the farmer moves forward in bend posture in a particular row. Manual method of sowing results in non-uniform seed placing, varied seed depth and Musculoskeletal Disorders (MSDs) in farmers. These are injuries happens at work place due to unsatisfactory design of tools, implements or practicing unhealthy working postures. The injuries affect human musculoskeletal system like joints, ligaments, muscles, nerves, tendons and structures that support limbs, neck and back. Commonly observed injuries in the process were neck tension syndrome, Achilles tendinitis, knee bursitis and back pain. [Fig-2] shows the manual seed sowing posture and commonly observed MSDs. Common problems were faced by the formers were discussed below.

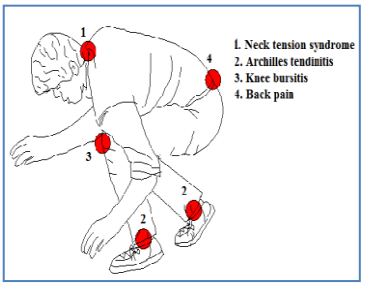

Fig-2 Manual seed sowing posture and commonly observed MSDs

Neck tension syndrome: It is a syndrome that includes a variety of disorders involving the neck and shoulder area. It is usually known as "Cervicobrachial". It is characterized by pain, numbness, weakness swelling in the neck and shoulder region.

Achilles tendinitis: It is an injury of the Achilles tendon, which connects the calf muscle to the heel bone. The main symptoms include pain and swelling in the back side of the heel, limited range of foot motion.

Knee bursitis: swelling of a fluid filled bursa situated at the knee. It causes pain above and below the knee cap, limited motion of knee and painful movement at the knee area.

Back pain: The pain associated with the bone, muscles, nerves and ligaments in the spinal cord. The common symptoms are swelling of the back, persistent back pain, pain down the leg.

The virtual model of manual seed sowing posture was built and risk of work related injuries that may occur in the working environment is analyzed. A Digital Human Model (DHM) is built by taking the average Indian male anthropometric dimensions. Rapid Upper Limb Assessment (RULA) ergonomic evaluation tool is used to capture the risk involved in the working posture. RULA assessment

technique provides a quick result on the loading on human musculoskeletal system due to postures of the neck, trunk, and upper limbs, muscle function, and external loads exerted [17]. The ranking of each posture is given by a score after complete posture analysis. Based on the final score of the assessment, four action levels will indicate the necessary actions to be taken to reduce the risks of injury due to physical loading on the worker in that posture. Various action levels of RULA investigations based on the final score is shown in [Table-1].

Table-1 *Action level and score of RULA working posture*

Action level	*Final Score*	*Proposed Actions*
1	1-2	Posture is acceptable
2	3-4	further investigation is needed and changes may be needed
3	5-6	investigation and changes are required soon
4	7	investigation and changes are required immediately

RULA score is estimated from the manual sowing posture gives a high risk factor of SCORE-7, which reveals that the posture is highly risky and required immediate change. Ergonomic considerations in seed sowing method for such farmers should be addressed to reduce the work related injuries. An alternative low cost seed sowing mechanism for such formers was conceptualized and designed to reduce the MSDs. Further the equipment designed ergonomically was tested on the farmers to observe the changes in the occupational health and safety to address sustainable agricultural practices with high productivity and farmer's wellbeing. [Fig-3] shows the digital human model of manual seed sowing posture.

Fig-3 Digital Human Model of manual seed sowing posture

In present study, for sowing of seed suitable equipment was developed based on several trials. The equipment designed delivers one seed at a time placing it at consistent distance and in proper depth. A detail of equipment is shown in the [Fig-4 and 5].

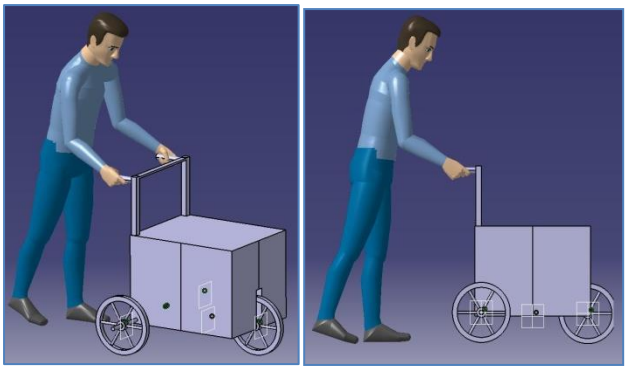

Fig-4 Ergonomic analysis in virtual environment

Fig-5 Ergonomically improved seed sowing equipment

Results and Discussions

This section presents theoretical analysis results obtained by conducting field experiments and software analysis for the study of novel method of sowing equipment in order to optimize human ergonomics, working efficiency and health. Test set-up thus designed and developed was made to operate in agricultural field to understand the human interactions and factors while operating the equipment. A standard RULA worksheet was prepared to capture the different human body part positions and orientations in order to determine the final RULA score. Different measurements were made for different posture conditions. The new concept designed was tested for its ergonomics using RULA in virtual environmental conditions. The results of investigation obtained with field test was compared with software analysis and suitably analyzed. Data were generated from a field test from the ergonomic data sheet and the results were tabulated in [Table-2, 3 and 4].

Table-2 *Arm and wrist analysis*

Table A		Wrist score							
		1		2		3		4	
Upper arm	lower arm	Wrist twist		Wrist twist		Wrist twist		Wrist twist	
1	1	1	2	1	2	1	2	1	2
	2	1	2	2	2	2	3	3	3
	3	2	2	2	2	2	3	3	3
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Posture score A = 3 (from table A)
Muscle use score = 0
Load score =0 (from step 7)
Total score for table A = 3

Table-3 *Neck, trunk and leg Analysis*

Trunk												
	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
Neck	1	2	1	2	1	2	1	2	1	2	1	2
1	1	2	1	2	2	3	3	4	4	4	4	4
2	1	2	2	2	3	4	4	5	5	5	5	5
3	2	2	2	3	3	4	4	5	5	5	6	6
4	2	3	2	3	3	4	4	5	5	6	6	6

Posture score B= 5 (from table B)
Muscle use score = 0
Load score =0
Total score for table B = 5

Table-4 *Final RULA score*

Table C		Neck, trunk, leg score						
		1	2	3	4	5	6	7
Wrist/arm score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8	5	5	6	7	7	7	7

The final RULA ergonomic assessment tool score from the field study obtained SCORE-4. Further, a software RULA ergonomic assessment tool was used for analyzing the same conditions in virtual environment. The results obtained are suitably shown in [Fig-6]. It is observed that the new seed sowing equipment acquired the final SCORE-4 which is similar to the score obtained from the field test. The equipment thus designed has lower risk factors involved in its operation.

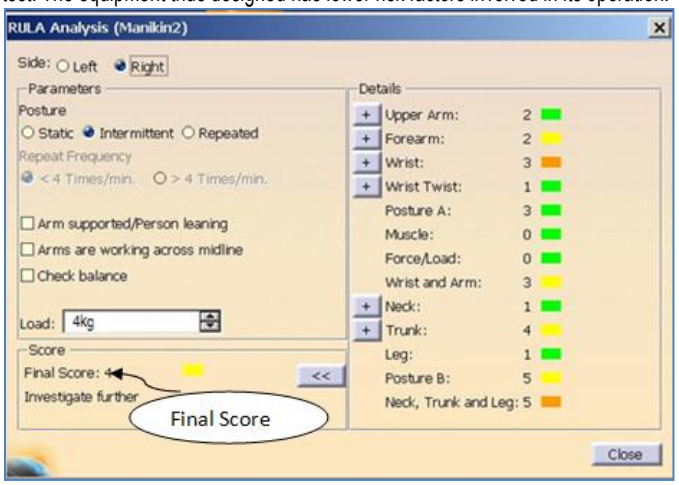

Fig-6 RULA ergonomic assessment using software

Conclusion

The application of a DHM and VE methods shows that agricultural process is muscularly influenced by the posture. Methods used are successful in achieving the goals human comfort, ease of operation and socio-economy as well. The following specific conclusions are drawn:

- Sowing is the basic agricultural process which gives good yield and revenue if done scientifically. Manual sowing not only affects the overall sowing process but also has greater influence on the operator's musculoskeletal systems. The study conducted on the farmers involving in manual maize seed sowing reveals the factor.
- It is the need of this time to address the issue to enhance the agricultural yield with higher working comforts thereby improving the productivity.
- DHM and VE using modern CAD system is a best tool to address the problems associated with work related injuries in agricultural scenario. The tool helps in integrating the human factors in design process to identify the complex agricultural problems early in the product design.
- Simulation using DHM and VE software evaluates the problems and gives enough ideas to the designers in improving the man-machine-environment situations. The DHM and VE tools presented in this study is an effective platform for designers in farm machinery development processes. It is assessed using DHM and VE that the current manual sowing posture is harmful for the farmers and may lead to MSDs in near future. The new improved seed sowing equipment thus designed ergonomically has good impact on their usability and comfort in operation.

Application of Research: Agricultural ergonomics, Farm machinery design

Research Category: Ergonomics in workplace, Agricultural Engineering

Abbreviations:
MSDs: Musculoskeletal Disorders
DHM: Digital Human Model
VE: Virtual Ergonomics
GDP: Gross Domestic Product
FMCG: Fast Moving Consumer Goods
RULA: Rapid Upper Limb Assessment
CAD: Computer Aided Design

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References

[1] Mahendra Dev S. (2011) *Small Farmers in India: Challenges and Opportunities,* Paper presented at Emerging Economies Research Dialogue" Beijing , China.
[2] Tanvi Deshpande (2017) *State of agriculture in India,* PRS Legislative Research (PRS).
[3] Yadav R., Tewari V.K. and Prasad. N. (1997) *Applied Ergonomics,* 28(1), 69-71.
[4] Freivalds A. and Kim Y.J. (1990) *Applied Ergonomics*, 21(1), 39-42.
[5] Thaneswer Patel and Sanjog J. (2013) *Advanced Engineering Forum*, 10, 16-21,
[6] Kyle Dooley W. (2012) *Ergonomics and the Development of Agricultural Vehicles,* ASABE Distinguished Lecture Series No. 36.
[7] Paul Windrum, Koen Frenken and Lawrence Green (2017) *Industrial and Corporate Change*, 26(6),953–971.
[8] Meyers J.M., Miles J.A., Faucett J., Janowitz I., Tejeda T.G., Duraj V. et al., (2000) *"High risk tasks for musculoskeletal disorders in agricultural field work"*, Paper Presented at the IEA 2000/HFES 2000 Congress, San Diego, CA.
[9] Meyers J.M., Miles J.A., Faucett J., Janowitz I., Tejeda T.G. and Kabashima J.N. (1997) *Ind. Hyg. Assoc. J.,* 58(2), 121-126.
[10] Meyers J.M., Miles J.A., Faucett J., Janowitz I., Tejeda T.G., Weber E. et al., (2001)*J. Agromed,* 8 (1), 37-52.
[11] Dul J. and Neumann W.P. (2009) *Applied Ergonomics,* 40, 745-752.

[12] Fadi A. Fathallah (2010) *Applied Ergonomics,* 41(2010), 738-743.
[13] *Saroj* Gupta and Gyanpur S.R.N. (2012) *Journal of Agricultural Technology,* 8(3), 1089-1098.
[14] Srinivas R.K. and Sivaramane N. (2013) *Assessment of the maize situation, outlook and investment opportunities in India*, Country Report 2013– Regional Assessment Asia (MAIZE-CRP), National Academy of Agricultural Research Management, *Hyderabad, India.*
[15] Helander M.G. (1999) *International Journal of Industrial Ergonomics*, 25(1), 97-101.
[16] Faraway J. and Reed M.P. (2007) *Technometrics*, 49(3), 277-290.
[17] Lynn McAtamney and Nigel Corlett E. (1993) *Applied Ergonomics,* 24(2), 91-99.