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Mohammad Muzammil
Abid Ali Khan
Faisal Hasan *Editors*

Ergonomics for Improved Productivity

Proceedings of HWWE 2017 Volume 2

Springer

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Editors
Mohammad Muzammil
Department of Mechanical Engineering
Aligarh Muslim University
Aligarh, Uttar Pradesh, India

Abid Ali Khan
Department of Mechanical Engineering
Aligarh Muslim University
Aligarh, Uttar Pradesh, India

Faisal Hasan
Department of Mechanical Engineering
Aligarh Muslim University
Aligarh, Uttar Pradesh, India

ISSN 2509-5986 ISSN 2509-5994 (electronic)
Design Science and Innovation
ISBN 978-981-16-2228-1 ISBN 978-981-16-2229-8 (eBook)
https://doi.org/10.1007/978-981-16-2229-8

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Ergonomic and human factors engineering has a vital role to play in today's world of fierce competition. People are looking for new ways to improve productivity. Human-centred technology and the use of humans as a scarce resource are necessities of the moment. Researchers in the past have shown that the human–machine working environment as a whole, if given proper and due consideration, can lead to the operation of the system in an efficient manner. The work done in the area so far should be compiled/reviewed to standardize procedures, so that professionals and engineers can use the significant but scattered knowledge available in the literature. Not only will this help people improve results, but it will also recognize the need to make it an essential part of the work culture. Although the knowledge and use of such practices are somewhat satisfactory in industrially developed nations, the picture is quite bleak in developing and underdeveloped countries. Cost-effective ergonomic solutions based on their physiological and anthropometric consideration are the need of the moment for subsequent countries. These can greatly help you catch up with your developed counterparts.

The papers contained in this proceedings were presented at the 15th International Ergonomics Conference on Ergonomics for Improved Productivity held at Aligarh Muslim University, Aligarh, India, December 8–10, 2017, under the aegis of the Indian Society of Ergonomics. The aim of the conference was to provide a key international forum for academicians, researchers and industrial partners to exchange ideas in the field of ergonomics/human factors engineering. The outcome was the introduction of new and better ways to improve productivity by creating a better work environment that leads to a satisfying and sustainable way of life. The proceedings consists of two volumes that contain several modules of prominent research areas of ergonomics. The conference was well attended with the participation of researchers/practitioners from around the world. As there was a wide variety of people who contributed to these procedures, we are confident that they will prove to be a valuable collection on the topic of ergonomics for improved productivity and humanizing work and work environment.

Aligarh, India

Mohammad Muzammil
Abid Ali Khan
Faisal Hasan

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Editors and Contributors

About the Editors

Dr. Mohammad Muzammil is a Professor in the Department of Mechanical Engineering and also in-charge of the Ergonomics Research Division. He has B.Sc. Engineering (Mechanical) and M.Sc. Engineering (Industrial and Production Engineering) from Aligarh Muslim University, India. He has self-supplicated his Ph.D. in Ergonomics. He has more than thirty years of teaching and research experience to his credit in the area of Industrial Engineering, Operations Management, Economics and Management and Ergonomics. His research interest is hand tool design, human response to vibration and noise, noise control engineering, human–computer interaction and human cognitive performance. He has published around papers in journals of international and national repute and presented papers at several conferences.

Dr. Abid Ali Khan is a Professor in the Department of Mechanical Engineering and is also associated with the Centre for Interdisciplinary Biomedical and Human Factors Engineering in the Faculty of Engineering and Technology. He has B.Sc. Engineering (Mechanical) and M.Sc. Engineering (Industrial and Production Engineering) from AMU, Aligarh. He received his Ph.D. from the University of Limerick, Ireland. He teaches Ergonomics, Experimental Methods and Analysis, Design of Experiments and Research Methodology. His research interest is occupational ergonomics, human response to vibration, work-related musculoskeletal disorder and EMG. He has published more than 90 papers in various international and national journals and conferences. He is involved in the R&D activities related to the various areas, viz. whole body and hand-arm vibration exposure, ergonomic evaluation of new designs and EMG-based prosthetics.

Dr. Faisal Hasan obtained his Ph.D. in the area of Reconfigurable Manufacturing System from Indian Institute of Technology Roorkee. He joined as a faculty member in the Department of Mechanical Engineering, AMU, in 2003. His teaching and research interests include manufacturing systems, human factors and operations management. He has published more than 75 papers in journals of national and international repute. He has also attended and presented papers at various international and national conferences.

Contributors

Ashad Ahmad Department of Mechanical Engineering, ZHCET, A.M.U, Aligarh, Uttar Pradesh, India

Saleem Ahmed Department of Design and Automation, School of Mechanical Engineering (SMEC), VIT University, Vellore, Tamil Nadu, India

Mohd Zubair Akhtar Zakir Husain College of Engineering and Technology, AMU, Aligarh, India

Kashif Ali Zakir Husain College of Engineering and Technology, AMU, Aligarh, India

Abid Ali Khan Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Mohd Anas Department of Mechanical Engineering, Integral University, Lucknow, India

Abdul Ahad Ansari Mechanical Engineering Department, ZHCET, AMU, Aligarh, UP, India

Akhter Husain Ansari Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Mubashshir Ahmad Ansari Mechanical Engineering Department, AMU, Aligarh, India

Sarif Anwar Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, UP, India

Syed Nasir Asghar Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, UP, India

Masood Ashraf Ergonomics Research Division, Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

V. V. Aware Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

Poorni Bagra Department of Resource Management, SNDT Women's University, Juhu, Mumbai, India

Venkatesh Balasubramanian Indian Institute of Technology Madras, Chennai, Tamil Nadu, India;
RBG Lab, Department of Engineering Design, IIT Madras, Chennai, India

Priyanka Basant Department of Resource Management, SNDT Women's University, Mumbai, India

Debkumar Chakrabarti Indian Institute of Technology Guwahati, Guwahati, Assam, India;
Department of Design, Indian Institute of Technology Guwahati, Guwahati, India

Manjit Kaur Chauhan Department of Resource Management, SNDT Women's University, Juhu, Mumbai, India

S. Darius Gnanaraj Department of Design and Automation, School of Mechanical Engineering (SMEC), VIT University, Vellore, Tamil Nadu, India

A. K. Dash AICRP On UAE, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha, India

Md. Dilshad Alam Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Abdul Faheem Department of Mechanical Engineering, ZHCET, Aligarh Muslim University, Aligarh, UP, India

Md Faizan Mechanical Engineering Department, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Mohammad Faizan Department of Mechanical Engineering, ZHCET, A.M.U, Aligarh, Uttar Pradesh, India

Mohd Shah Faizan Mechanical Engineering Department, AMU, Aligarh, India

Hasan Faraz Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Ayesha Farooq Department of Business Administration, FMSR, Aligarh Muslim University, Aligarh, India

Mohd. Farooq Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, India

Omar Farooq Department of Electronics Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Parveen Farooquie Department of Mechanical Engineering, ZH College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Adnan Hafiz Department of Mechanical Engineering, ZHCET, A.M.U, Aligarh, Uttar Pradesh, India

Faisal Hasan Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Falah Hasan Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

S. S. Hebbal Industrial and Production Engineering Department, P.D.A. College of Engineering, Gulbarga, India

Nabeel Hidayat Department of Mechanical Engineering, ZHCET, A.M.U, Aligarh, Uttar Pradesh, India

Taliv Hussain Department of Mechanical Engineering, ZHCET, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Mohd Mohsin Ikram Department of Petroleum Studies, Aligarh Muslim University, Aligarh, India

Rauf Iqbal NITIE, Mumbai, India

Abhinandan Jain Department of Electronics Engineering, Aligarh Muslim University, Aligarh, India

Harshita Jain Department of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Mohammad Talha Javed Aligarh Muslim University, Aligarh, India

Sougata Karmakar Department of Design, Indian Institute of Technology Guwahati, Guwahati, India

Johny Khajuria Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Abid Ali Khan Ergonomics Research Division, Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Afreen Khan Department of Computer Science, Aligarh Muslim University, Aligarh, India

Imtiaz Ali Khan Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Junaid Khan Aligarh Muslim University, Aligarh, India

Obaidullah Khawar Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, UP, India

Praveen Kumar Department of Industrial and Production Engineering, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, India

Vikash Kumar Shiv Nadar University, Noida, Uttar Pradesh, India

Gowtham Mahalingam Amity University, Noida, Uttar Pradesh, India

M. Manzoor Hussain Mechanical Engineering Department, JNTUH College of Engineering, Hyderabad, India

Sadaf Meraj Aligarh Muslim University, Aligarh, India

Tauheed Mian Mechanical Engineering Department, AMU, Aligarh, India

Sarthak Mittal Shiv Nadar University, Noida, Uttar Pradesh, India

A. K. Mohapatra AICRP On UAE, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha, India

Salman Mohd Khan Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Qasim Murtaza Department of Mechanical Engineering, Delhi Technological University, Delhi, India;
Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Sameen Mustafa Mechanical Engineering Department, Zakir Hussain College of Engineering and Technology, AMU, Aligarh, UP, India

M. Muzammil Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, UP, India

Mohammad Muzammil Ergonomics Research Division, Department of Mechanical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Priyadarshini Natarajan Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

Ali Nawaz Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Mohammad Faisal Noor Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, UP, India

Nooruzzaman Mechanical Engineering Department, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Parvej Department of Mechanical Engineering, AMU, Aligarh, India

Mohd Parvez Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Prachi Patel Department of Resource Management, SNDT Women's University, Juhu, Mumbai, India

S. V. Pathak Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

A. K. Pundir NITIE, Mumbai, India

S. M. Qutubuddin Industrial and Production Engineering Department, P.D.A. College of Engineering, Gulbarga, India

Abdul Rahman Department of Mathematics, Aligarh Muslim University, Aligarh, India

Subhana Rais Department of Home Science, A.M.U, Aligarh, Uttar Pradesh, India

Sufian Raja Department of Mechanical Engineering, Aligarh Muslim University, Uttar Pradesh, Aligarh, India

Raghunathan Rajesh Department of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

Hemu Rathore Department of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Md. Tauseef Raza Mechanical Engineering Department, ZHCET, AMU, Aligarh, UP, India

Fazal-Ur Rehman Department of Anatomy, Aligarh Muslim University, Aligarh, UP, India

S. J. A. Rizvi Department of Petroleum Studies, Aligarh Muslim University, Aligarh, India

Bhaskar Saha Central Institute of Technology, Kokrajhar, Assam, India

Samsher Delhi Technological University, Delhi, India

Cesar Sanin The University of Newcastle, NSW, Australia

Abhas Raj Saxena Department of Mechanical Engineering, ZH College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Apurbalal Senapati Central Institute of Technology, Kokrajhar, Assam, India

Syed Imran Shafiq Aligarh Muslim University, Aligarh, India

P. U. Shahare Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

Hitesh Sharma Department of Design, Indian Institute of Technology Guwahati, Guwahati, India

Meeta Sharma Amity University, Noida, Uttar Pradesh, India

Rajat Sharma Department of Mechanical Engineering, ZH College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

N. A. Shirsat Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

Aditya Shringi Department of Design and Automation, School of Mechanical Engineering (SMEC), VIT University, Vellore, Tamil Nadu, India

Anoop Kumar Shukla Amity University Uttar Pradesh, Noida, India

Mohd Abdul Moid Siddiqui Faculty of Management, Asian Business School, Noida, India

Suhail Ahmad Siddiqui Mechanical Engineering Department, ZHCET, AMU, Aligarh, UP, India

Amandeep Singh School of Mechanical and Civil Engineering, MIT Academy of Engineering, Pune, Maharashtra, India

Arjan Singh Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Harwinder Singh Department of Mechanical Engineering, Guru Nanak Dev Engineering College (GNDEC), Ludhiana, Punjab, India

L. P. Singh Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Lakhwinder Pal Singh Department of Industrial and Production Engineering, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, India

Onkar Singh Harcourt Butler Technical University, Kanpur, India

Reenu Singh NITIE, Mumbai, India

Sarbjit Singh Department of Industrial and Production Engineering, Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Suman Singh Department of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Sathish Kumar Sivasankaran RBG Lab, Department of Engineering Design, IIT Madras, Chennai, India

S. K. Swain AICRP On UAE, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha, India

Edward Szczerbicki Gdansk University of Technology, Gdansk, Poland

Vaibhav Tiwari Department of Electronics Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Mohd Kamil Vakil Department of Civil Engineering, Z. H. College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Ayush Varshney Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, UP, India

Mehul Varshney Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Nishant Varshney Department of Electronics Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Mohd Wajid Department of Electronics Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

Md. Zeeshanuddin Mechanical Engineering Department, ZHCET, AMU, Aligarh, UP, India

Mohammad Zunaid Delhi Technological University, Delhi, India

Chapter 1
Assessment of Human Cost of Work of Tribal Women Farmers in Harvesting of Maize with the Use of Improved Sickles

Harshita Jain, Suman Singh, and Hemu Rathore

1 Introduction

India is among the top ten countries in the world with respect to production of cereals. Among the cereal crops, India stands on 6th position with respect to production of maize (FAO STAT 2013). It is third most important cereal in the country after wheat and rice. Women constitute almost half of the work force engaged in agriculture. The rural women participate in a broad range of agricultural activities such as production, processing, preservation and utilization of food. They play a key role in the entire food system starting from the selection of seeds, sowing, manuring, drying, stacking, storing and feeding the family from the harvested produce. Tribal women constitute half of the work force among tribals in India. Rural women play key roles in agriculture sector by working with full passion in production of crops right from the soil preparation till post-harvest activities (Ahmed and Hussain 2004). Tribal women are discriminated, though they make enormous contribution to the agriculture and allied sectors. They have very little access to the knowledge and skills of modern farm technologies and related resources. The data on participation and drudgery faced by tribal women in agriculture as per existing review are very limited. Hence, the present study was undertaken to establish a database on drudgery experienced therein tribal areas. The technology intervention gave exposure to tribal women for reducing drudgery in agriculture, particularly in maize harvesting operations. In the present investigation, the human cost of work in various parameters like biomechanical and physiological was done to compare the difference between traditional and improved methods of agriculture. The present study was conducted with the objective to assessed human cost of work of tribal women farmers in harvesting of maize with the use of improved sickles.

H. Jain (✉) · S. Singh · H. Rathore
Department of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

M. Muzammil et al. (eds.), *Ergonomics for Improved Productivity*,
Design Science and Innovation, https://doi.org/10.1007/978-981-16-2229-8_1

2 Methodology

The present investigation was carried out in the Kherwada Tehsil of Udaipur district of the Rajasthan state, which is one of the tribal districts of the state. In selecting the district, the main consideration was the agriculture as the main occupation of people living in such villages. In this area, male migration rate is also high. Human cost of the work was calculated for 30 purposively selected women farmers who were willing to participate in identified drudgery-prone activity, i.e., harvesting performed by tribal women.

Intervention with improved sickles was done on these 30 purposively selected subjects. The criteria of selection of these 30 subjects was on the basis of willingness of subjects, and normal range of BMI, blood pressure, and heart rate. The subjects having normal BMI, blood pressure, and heart rate and not suffering from any chronic disease were selected for investigation for getting reliable results. An experimental-cum-exploratory research design was used for this study as the study was concerned to find out the psycho-physiological cost of work in harvesting of maize.

3 Assessment of Health Condition of Selected Samples

3.1 Body Mass Index

Knowledge of respondents and limitations from physical point of view will help to determine their work–demand fitness compatibility. The height and weight of a person are also indicative of one's fitness. For calculating the BMI, weight and height of the women farmers were taken. The height of the subjects was measured using an anthropometric rod and weight by bathroom weighing scale. BMI was studied as per the classification given by Garrow (1984). It was measured by Quetelet's Index. The formula for calculation of BMI is:

$$\text{BMI(kg/sq.m) by Quetelet's Index} = \frac{\text{Weight(kg)}}{\text{Height(m}^2\text{)}}$$

S. No.	BMI class	Presumptive diagnosis
1	<16.0	CED* Grade III (Severe)
2	16.0–17.0	CED Grade II (Moderate)
3	17.0–18.5	CED Grade I (Mild)
4	17.0–18.5	Low weight normal
5	20.0–25.0	Normal
6	25.0–30.0	Obese Grade I
7	>30.0	Obese Grade II

*Chronic energy deficiency

3.2 Blood Pressure

Blood pressure is directly proportional to the amount of work done. The normal range of blood pressure ranges from 80 to 120 mmHg. It tends to increase with the amount of work done, thus increase physiological cost of work. Respondents' blood pressure was measured by sphygmomanometer.

4 Assessment of Human Cost of Work in Maize Production System

4.1 Physiological Variables

In physiological variables, the energy expenditure and physiological cost of work were calculated and results drawn. The calculation of average heart rate was one to calculate energy expenditure as well as physiological cost of work.

4.2 Calculation of Energy Expenditure

Energy expenditure of each activity carried out by worker was estimated from the heart rate responses using the formula given by Varghese et al. (1994):

$$\text{Energy Expenditure}(\text{kJ}/\min) = 0.159 \times \text{Average Working Heart Rate}\left(\text{bmin}^{-1}\right) - 8.72$$

4.2.1 Physiological Workload Index

The workload was determined as per the workload classification developed by Varghese et al. (1994).

Physiological workload index

Scores	Physiological workload	Energy expenditure (kJ/min)
1	Very light	Upto 5
2	Light	5.1–7.5
3	Moderately heavy	7.6–10.0
4	Heavy	10.1–12.5
5	Very heavy	12.6–15.0
6	Extremely heavy	>15

5 Measurement of Heart Rate for Calculation of Physiological Cost of Work

Instrument—Heart Rate Monitor

Circulatory stress was evaluated from the cardiac cost of work and cardiac cost of recovery. The cardiac cost of recovery is the total number of heart beats above the resting level occurring between the end of the work and return to the resting state (Saha 1999). The following formulae was used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW) (Singh et al. 2007).

After preparing the subject for the experiment, the subject was asked to sit in shade in a relaxed position for 10 min. This was followed by taking resting heart rate for 5 min. The women were asked to perform the activity. During performance of activity, working heart rate was taken for 20 min. Immediately after the termination of the activity, the subjects were given rest and recovery heart rate was recorded for 5 min duration. Heart rate (HR) for every minute was recorded.

5.1 *Calculation of Physiological Cost of Work*

Heart rate data were used to calculate

$$\text{Physiological Cost of Work} = \frac{\text{Total Cardiac Cost of Work(TCCW)}}{\text{Total time of activities}}$$

TCCW = Cardiac Cost of Work (CCW) + Cardiac Cost of Recovery (CCR).
CCW = Average Heart Rate (AHR) × Duration.
AHR = Average Working Heart Rate − Average Resting Heart Rate.
CCR = (Average Recovery Heart Rate − Average Resting Heart Rate) × Duration.

5.2 *Biomechanical Variables*

Biomechanical variables were calculated by measuring angle of deviation from natural angle of body and rapid upper limb assessment (RULA), and the results were drawn.

5.2.1 Measuring the Angle of Deviation

It was done in order to know the type of posture used in performing the activities in terms of standing, sitting, squatting, bending, and various combinations of these activities. The angle of body deviation was mainly focused on angle of the backbone. More the angle of deviation from normal, more will be the stress on the backbone, hands, and other body parts; hence, more will be the fatigue.

For calculation of angle of deviation, the following steps were taken:

- The subjects were asked to keep natural body posture which they adopt while not doing any kind of activity in a particular body posture of either sitting or standing.
- The photographs were taken, and with the help of photographs in natural position, the angle of deviation was measured.
- For measuring the angle of deviation, the photographs were placed on an empty white wall with the use of projector, and with the help of goniometer, angle of deviation was measured.
- Similarly, the photographs were taken of the body parts involved in activity were elicited while performing the activity and the same procedure was followed.
- The deviation between natural posture and working posture was illustrated in the results.

5.2.2 Rapid Entire Body Assessment (REBA)

- REBA is a postural targeting method for estimating the risks of work-related entire body disorders by swift and methodical assessment of the postural risks of workers. REBA was developed by Hignett and Mc Atamney for assessing workers' postures for determining risk index of work-related musculoskeletal disorders (WRMSDs). Important tasks for each job are selected first. For each task, postural factors are assessed by assigning a score to each associated body region
- The Group A (trunk, neck and legs) postures and the Group B (upper arms, lower arms, and wrists) postures for left and right sides of the body was scored. For each region, there is a posture scoring scale plus adjustment notes for additional considerations. Then, we scored the load/force and coupling factors. Finally, the activity was scored, and the scores from Table A for the Group A posture scores and from Table B for the Group B posture scores were found. Score A is the sum of the Table A score and the load/force score. Score B is the

sum of the Table B score and the coupling score for each hand. Score A gives the row, and score B gives the column in Table C. Score C is read from Table C where this row and column coincides. The REBA score is the sum of the Score C and the activity score.

5.2.3 REBA Decision

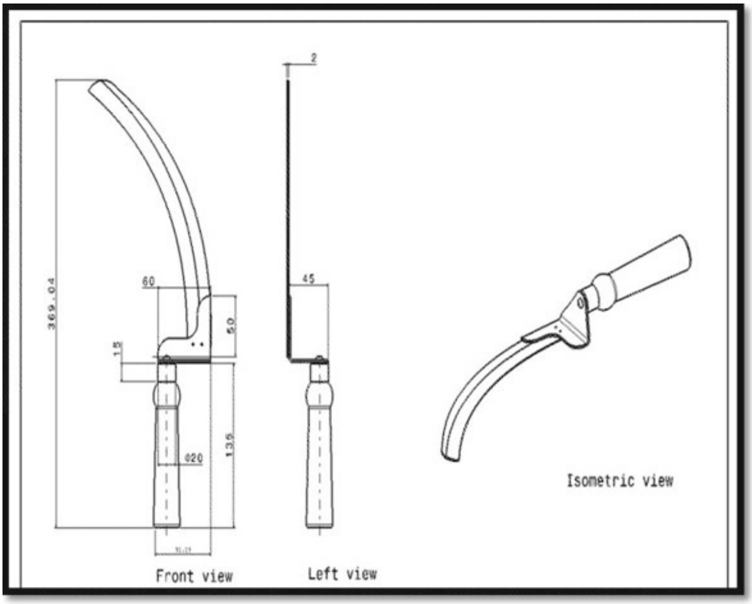
After the data for each region were collected and scored, tables on the form were then used to compile the risk factor variables, generating a single score that represents the level of MSD risk as outlined below:

- 1 Negligible risk, no action required
- 2–3 Low risk, change may be needed
- 4–7 Medium risk, further investigation, change soon
- 8–10 High risk, investigate and implement change
- 11+ Very high risk, implement change.

As seen, the score 1 represents the user to be at a negligible risk and does not require any corrective action to be taken. Scores ranging from 2 to 3 and 4 to 7 mean the user is at low and medium risk, respectively, and that further investigation is required to see if any changes are needed to be made. If the score is more than 8, it would mean the user is at high risk and needs to implement necessary changes instantly to correct the incorrect posture.

6 Information Regarding Improved Tools Used for Harvesting of Maize

- The harvesting of maize was very tedious activity because of the thickness of the stem. The women farmer used conventional sickle which was non serrated and heavy in weight. This sickle requires high amount of force to cut the stem.
- In the present study, two types of improved serrated sickles in which one was replacement of conventional sickle which is used for all crops and the other one named Laxmi sickle was specially designed for harvesting of maize crop by scientist of Dapoli.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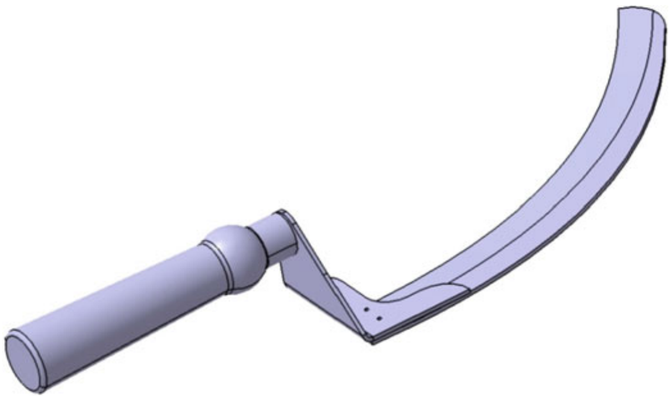

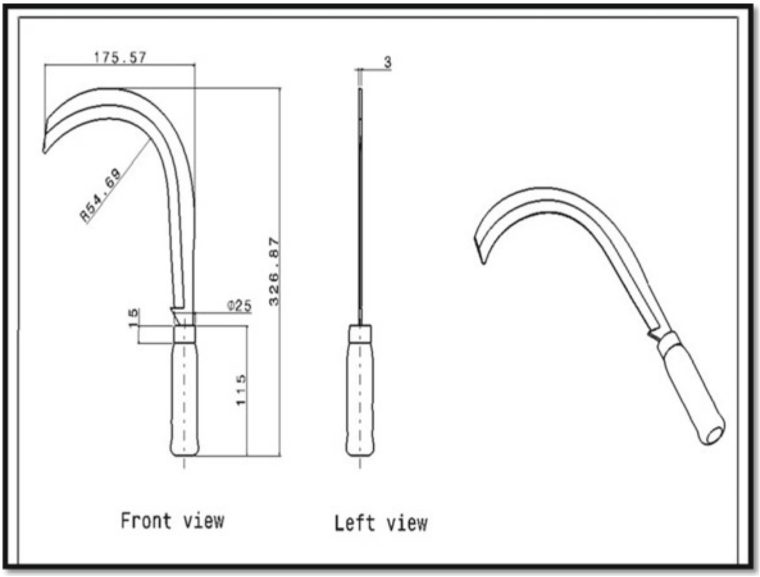

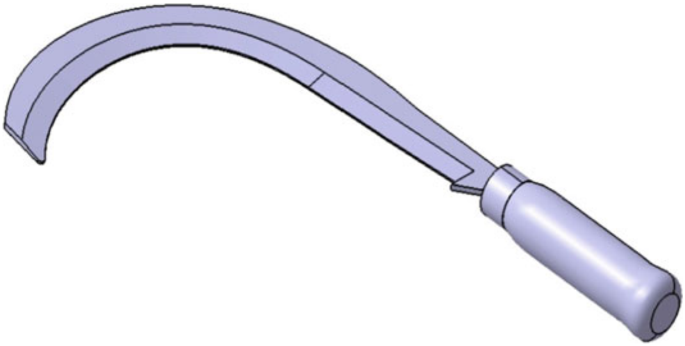

The data were collected personally by the investigator by using tools explained above for assessment of drudgery. Pre- and post-intervention data collection for human cost of work were also done and impact of improved technology was also assessed.

7 Results and Discussion

Maize harvesting activity was also one of the women-dominated activity and had lot of physiological load and was drudgery prone to women. Traditionally, harvesting is done by conventional sickle which was found very heavy in weight and causes injuries to women's hand, wrist, etc. It also requires lot of force to perform task as the maize stem is very thick. Due to application of force, women felt pain in wrist.

The two types of improved sickles with different designs and dimensions were introduced, and the data were collected on psycho-physiological cost of work with the use of conventional and improved sickles, and the variation in the results was evaluated. The results are presented below.

7.1 Physical Characteristics of Subjects

For the assessment of psycho-physiological cost of work, the data were collected from 10 purposively selected subjects who were willing to participate in exploratory research. The psycho-physiological cost of work was calculated for both conventional and improved methods, and impact was illustrated in results. Table 1 revealed the physical characteristics of the women subjects selected for experimental work. The mean age of subjects was 33.38 years, mean height 159 cm, and mean weight 56.5 kg.

7.2 Health Status of Subjects

To avoid any experimental error and to minimize the effect of poor health status on women's working capacity, total 30 subjects who belonged to age group of 25–35 years having normal height, weight, BMI, blood pressure, heart rate and no history of chronic illness were selected purposively for the experimental purpose (Table 2).

7.3 Physiological Variables

Physiological variable, energy expenditure, and physiological cost of work were measure and the data compared with the use of conventional sickle.

In the harvesting operation, conventional sickle was compared with two improved sickles. The summary of the data depicted the energy expenditure was 12 kJ/min which decreases when improved sickle I 10.22 kJ/min and improved sickle II 10.49 kJ/min were used. PCW was also high when conventional sickle

Table 1 Physical characteristics of selected women farmers

Physical characteristics	Mean	SD
Age (years)	33.8	±2.14
Height (cm)	159	±0.02
Weight (kg)	50.5	±5.81

$n = 30$

Table 2 Health status of selected women farmers

Variables of health status	Observed value (mean)	Recommended value	Category	References
Blood pressure (mmHg)				
Systolic	125 ± 5.35	120 mmHg	Normal	Guyton and Hall (2007)
Diastolic	73.8 ± 3.52	80 mmHg	Normal	Guyton and Hall (2007)
Heart rate (bmin^{-1})	87.3 ± 6.6	70–80 bmin^{-1}	Normal	Guyton and Hall (2007)
Body mass index (Kg/sq m)	19.24 ± 2.68	20–25 kg/sq m	Below normal	Garrow (1984)
Working years	13.8 ± 4.82	–	–	–

n = 30

(37.1) was used and decreased when Improved sickle I (33) and conventional sickle II (25.3) were used. *Hence, it can be concluded that both the Sickles I and II were found efficient compared to conventional sickle on the basis of physiological variables.* The data concluded that while working with improved sickles, the TCCW and PCW reduce. The data of both sickles were also compared, and it was found that sickle Laxmi was more effective in reduction of TCCW and PCW compared to improved Sickle I.

7.4 Output

The data presented in Table 3 depict that with the use of conventional sickle, the output was 150 m^2/h which was increased up to 16.66%, i.e., 175 m^2/h with the use of improved sickle I, whereas with the use of improved sickle II, output increased up to 26.66%, i.e., 190 m^2/h.

Thus, the human cost of work pertaining physiological variable was low while using improved technology as compared to conventional one.

8 Biomechanical Variables

Biomechanical variable, i.e., angle of deviation of body, was measured, and with the use of REBA worksheet, the body discomfort category was studied.

Table 3 Percentage change in heart rate, energy expenditure, output, TCCW, and PCW by use of improved sickles over conventional

Physiological parameters	Conventional sickle Mean/SD	Improved sickle I Mean/SD	Improved sickle II (Laxmi) Mean/SD	% change I	*t* value	% change II	*t* value
Average resting heart rate, $bmin^{-1}$	83.4/3.4	84.9/3.7	83.5/0.8	–		–	
Average working heart rate, $bmin^{-1}$	130.3/9.7	119.1/1.04	120.8/1.2	8.59	2.78	7.29	3.33
ΔAWHR over rest, $bmin^{-1}$	46.9	34.2	37.3	27.07	–	20.46	–
Average energy expenditure resting, $bmin^{-1}$	4.54/0.54	4.78/0.58	4.55/0.58	–	–	–	
Average energy expenditure working, $bmin^{-1}$	12/1.55	10.22/1.60	10.49/1.90	14.83	2.78	12.58	3.33
Output, m^2/h	150	175	190	16.66	–	26.66	–
Total cardiac cost of work (TCCW)	954/13.13	841/23.54	711/25.38	11.84	1.28^{NS}	25.47	3.88
Physiological cost of work (PCW)	31.8/0.44	28.0/0.78	23.7/0.85	11.94	1.28^{NS}	25.47	3.88

*significant at 1% level of significance
n = 30
NS = Non significant

8.1 Angle of Deviation of Body

8.2 Rapid Entire Body Assessment (REBA)

The data depicted in Table 4 depicted that the natural angle of the women subjects back in sitting position 90.7°, neck 180.6°, and wrist 180.7°. When conventional sickle was used, the angle of body was changed to 135.1°, 200.3°, and 236.8°, respectively, whereas with the use of improved Sickles I and II, the reduction in percent change in angle was clearly seen which revealed that the use of improved tools helped the women subjects in maintaining the natural posture of the body which ultimately reduced the chances of occupational health problems. Furthermore, Table 5 reveals that when the conventional sickle was used the REBA