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Ergonomic Evaluation of Women Farm Workers during Shelling Operation of Maize of Udaipur District

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A B S T R A C T

Women play a major and crucial role in doing the agricultural operations. The women workers in Udaipur district mostly uses their hands for removing maize kernels from maize cobs by drying them for 2-4 weeks. This study was conducted in 2019-20 at instructional Farm, CTAE, Udaipur with women farm workers during the shelling operation by traditional method, along with technically and ergonomically designed Pedal operated maize de-husker sheller. The main objective of the study was to reduce the drudgery of the female farm workers and to recommend the proper method for doing shelling operations of maize cobs. Use of proper method not only reduces the drudgery but also improves the operating efficiency along with the comfort, besides improving the productivity of the women farm workers in doing the operation. In view of this, an effort has been made to assess the physical and physiological parameters of women farm workers who are following traditional method along with the improved method for doing shelling operation of maize cobs. The whole study was conducted on ten female farm workers identified from the population of workers in the age group of 18 to 45 years. During the experiment, physiological workload i.e., heart rate, oxygen consumption rate, energy expenditure rate and physical workload i.e., overall discomfort rate, rate of perceived exertion and Musculo-skeletal problems were measured. Pedal operated maize de-husker sheller when compared to traditional shelling method was more women friendly following all the ergonomic considerations for reducing the drudgery of the women farm workers by 16.96%. It also increased the productivity (kg/h) during the shelling operation by using Pedal operated maize de-husker sheller by 5.41 times the traditional shelling operation.

Introduction

Agriculture, with its allied sectors, is the largest source of livelihoods in India. Seventy percent of its rural households still depend totally on agriculture for their livelihood, with 82 percent of farmers being small and marginal (FAO, India). Agriculture in India

constitutes 14% percent of GDP, 44 percent of employment and is the backbone of the rural economy. India is one of the major contributors to the agricultural sector and is claimed to be looking towards tremendous growth.

Agriculture is generally considered as the most drudgery prone industry which displays high physical workload. It is also noticed that there is very little history of application of ergonomics in design of agricultural equipment. Hence, there is a need for exploiting the available resources and technologies at appropriate and maximum level with changing agricultural scenario and global competition to boost the productivity by introducing best Ergonomical practices in agricultural region. It is reported that the foundation reasons of many product complaints and failure are often related back to an ergonomic mismatch. A descent understanding of ergonomics and human interaction may be a necessity for the merchandise to become successful within the market. The purpose of ergonomics is to enable a tool/implement to function better by improving the interactions between the human and the tool/implement.

Agarwal and Satapathy (2006) carried out an experiment on 2 male and 2 female farm workers of Meghalaya for Ergonomical performance evaluation of two different types of maize shellers. The reduction of workload for female and male workers for plastic covered maize sheller was 36.68 percent and 33.17 percent as compared to metallic maize sheller. Correspondingly, the Heart rate(HR) and Oxygen consumption rate (OCR) reduced by 17.39 and 31.7 percent for male and 23.1 and 20.0 percent for female farm workers. Three women friendly drudgery reducing tools were selected to assess their acceptability namely, Improved sickle, Tubular Maize Sheller and Groundnut Decorticator (Standing Type). It was found in the study that all three tools i.e. groundnut decorticator, maize Sheller and sickle were perceived highly acceptable by high majority (91.67, 85.00 and 86.67 percent) of farm women respectively (Santosh and Surbhi (2018)).

In Udaipur, most of the female farm workers having mostly small land holdings use the traditional method for the shelling operation. The commonly used method is drying the maize cobs for 2-4 weeks and after attaining the required moisture content, the kernels are removed from the cobs by the pressing with hands against the maize cobs for removing the kernels, also beating operation is also carried out for separating kernels from cobs. Majority of the farm women performs this operation by continuous sitting postures for longer times. Though, this method is very demanding of labour and full of drudgery. It is very clear that the poor posture during the shelling operation can increase the discomfort for both the healthy workers as well as less fit individuals. It requires large amount of human power to perform the shelling operation traditionally.

It is also been observed from the field survey that there is more amount of human power with least amount of ergonomics that was involved in the design of tools/implements and also in the environment in which they work. Ergonomically designed tools and working environment provides promising and encouraging results by enhancing the operating efficiency by reducing the drudgery, besides providing working comforts and thereby improving the productivity of workers with better safety and health. Hence, there is an urgent need to consider these issues in improving the relationship between the female farm farmers with the tool/implement developed and their working environment. Therefore, the study was conducted to access the ergonomic evaluation between the

traditional method and the ergonomically designed Pedal operated maize de-husker sheller and the reduction of drudgery for female farm workers during shelling operation by using the traditional method along with the ergonomically designed Pedal operated maize de-husker sheller. The percentage reduction of drudgery and increase in productivity (kg/h) over the traditional method can also be identified.

Justification of the Research Study

Research studies investigating the Ergonomical studies on agriculture workers particularly about rural women workers in agriculture activities are scarce. In terms of research very few studies pertaining to ergonomics in agriculture activity i.e., during shelling operation in maize have been carried out in India, in particular, Udaipur district.

The objectives of the study were:

Assessment of physiological parameters, heart rate and oxygen consumption rate and Energy expenditure rate during shelling operation in maize with traditional and ergonomically designed Pedal operated maize de-husker sheller.

Assessment of overall discomfort rating (ODR) before and after the operation.

Assessment of Rating of perceived exertion after the operation.

Assessment of Musculo-skeletal problems after the operation.

Materials and Methods

Physiological and physical workload was calculated during the shelling operation of maize cobs which was performed in the month of October, 2020 at CTAE Instructional farm, Udaipur. The study was conducted on ten female farm workers selected from the representative population of workers between 5^{th} and 95^{th} percentile of the anthropometric criteria. During the study period all the operations were performed by these ten female farm workers only. Selected subjects had agriculture as their main source of livelihood.

All the subjects selected did not have the habits of chewing tobacco and taking any type of liquor. Subjects were between 18-45 years of age. Subjects were free from any chronological disease, physical disorder and were medically fit.

The operation was performed in maize crop of variety Pratap Makka 5 (PM 5), having moisture content 11-13% wet basis. The experiment was conducted in the morning, between 9 AM to 1 PM and in evening from 2 PM to 5 PM. The uniform time of 6h for all the operations was given in doing the operation. All the female farm workers were allowed to take rest for 15 minutes before performing the task and asked to perform the operation continuously for 30 minutes and then allowed to take rest for 15 minutes. The same procedure was followed for ergonomically designed Pedal operated maize de-husker sheller by following proper work-rest cycle.

For assessment of effect of physiological and physical work load on the performance of female farm workers, two different methods (traditional method and by using ergonomically designed Pedal operated maize de-husker sheller) in maize crop during shelling operation were taken as independent parameters.

Six dependent parameters includes three physiological workloads namely heart rate (HR), oxygen consumption rate (OCR) and energy expenditure rate (EER) and three physical workloads namely, Overall discomfort rate (ODR), Rate of perceived

exertion and Musculo-skeletal disorders were selected for this study.

Instrumentation

During the experiment, the measuring tape and weighing scale were used to measure the physical characteristics like height and weight.

Stopwatch was used for recording the time. Instrumentation used to conduct the experiments for measurement of physiological and physical workload is described below.

Physiological workload

Cortex Biophysik MetaMax® 3X portable CPX system

The MetaMax® 3X is a portable cardiopulmonary exercise system (CPX system) for pulmonary gas exchange measurements under real conditions as shown in Fig.1. As a truly portable system, MetaMax® 3X is battery operated. It is used as a self-contained measurement device, carried by the patient/test subject throughout the entire test. The MetaMax® 3X system could be used in both laboratory as well as in field conditions. Heart rate (HR) and oxygen consumption rate (OCR) were measured by using MetaMax® 3X is a portable cardiopulmonary exercise system (CPX system). Heart rate (resting HR, working HR) and oxygen consumption rate were measured by using K4b^{2}make by Cosmed (Italy). Based on the heart rate, the energy expenditure rate (EER) was calculated by using the following formula givenby (Varghese *et al.*,1994)

Energy expenditure rate (EER) (kJ/s) = 0.159 x Average heart rate (beats/min) – 8.72,

Increase in Heat rate, ΔHR (beats/min) = Average working heart rate – average resting heart rate

Output (m^2/h) = area covered x duration / average time

Cardiac cost of worker per unit of output (beats/ m^2 area covered) = ΔHR x duration / output.

Physical workload

Overall Discomfort Rating (ODR)

Overall discomfort rating (ODR) had been defined by using a 10-point psycho-physical rating scale developed by Borg (1990).

A scale of 70 cm length was fabricated having 0 to 10 digits marks on it equidistantly as shown below in Fig.2.

A movable pointer was provided to indicate the rating. The subject was asked to report her discomfort level on the scale before start of work. she was again asked to report the discomfort level at the end of work. The difference in the score of before and after the work was the real discomfort score.

Rating of perceived exertion

Rating of Perceived Exertion was measured at 5-point scale developed by Varghese *et al.*, (1994) very light –1,light-2, moderately heavy-3, heavy-4,very heavy-5

Musculo-skeletal problems

Incidences of Musculo-skeletal problems during the activity were identified with the help of body map (Corlett and Bishop, 1976) as shown in Fig.3, which indicates different body parts (Figure) viz; upper body parts (eye, neck, shoulder joint, upper arm, elbows, wrist/hands) and lower body parts (lower arm, low back, upper leg/ thigh, knees, calf muscles, ankles, feet). The scorecard showing the value from 0-6

0-no pain, 1-very mild, 2-mild, 3-moderate, 4-moderately heavy, 5- severe, 6- very severe was used to quantify the stress on the muscles.

Results and Discussion

To evaluate the shelling operation through ergonomic point of view, ten female farm workers were selected in the age group of 25 to 45 years were selected at random and average age of the respondents engaged in maize shelling operation was counted as 32.50 years measuring body height of 156.50 cm and weight as 46.50 kg, respectively (Table 1).

Physiological work load during shelling operation of maize was determined on the basis of various parameters like average heart rate during work and rest, energy expenditure and physiological cost of work while performing the activity.

Specifications of studied pedal operated maize de-husker sheller

The specifications of the studied pedal operated maize de-husker sheller is indicated in Table 2.Fig.4. indicates shelling operation by Pedal-operated maize de-husker sheller used in the study.

Physiological cost of the female farm workers during weeding operation in maize crop

Field experiments were carried out to assess the physiological cost of the subjects in terms of heart rate (HR), oxygen consumption rate (OCR) and Energy expenditure rate (EER) during shelling operation in maize crop, both manually and with pedal operated maize-de-husker sheller. The level of variation between manual shelling and pedal operated maize-de-husker shelling on increase in heart rate (HR) and oxygen consumption rate (OCR) were evaluated statistically. The increase in heart rate (HR) is expressed as difference in working heart rate and resting heart rate. The increase in oxygen consumption rate (OCR) is expressed as difference in working oxygen consumption rate and resting oxygen consumption rate.

The operation was performed in maize crop of variety Pratap Makka 5 (PM 5), having moisture content 11-13% wet basis. The experiment was conducted in the morning, between 9 AM to 1 PM and in evening from 2 PM to 5 PM. The uniform time of 6h for all the operations was given in doing the operation. All the female farm workers were allowed to take rest for 15 minutes before performing the task and asked to perform the operation continuously for 30 minutes and then allowed to take rest for 15 minutes.

Heart rate response of the subjects during shelling operation

The mean of resting heart rate, working heart rate and recovery heart rate of traditional shelling method was observed as 81.72±1.69, 93.82±2.26 and 85.53±1.87 beats/min respectively. The mean increase in heart rate was observed as 12.1±2.02 beats/min.

According to classification suggested by Sen *et al.*,(1969), working HR for manual shelling operation could be rated in “light” category of workload.

The mean of resting heart rate, working heart rate and recovery heart rate by using pedal operated maize de-husker sheller was observed as 84.25±2.13, 138.04±3.5 and 104.89±1.62 beats/min respectively. The mean increase in heart rate was observed as 53.81±3.39 beats/min. According to classification suggested by Sen *et al.*,(1969), working OCR for manual shelling operation could be rated in “heavy” category of workload.

The mean Working heart rate and ΔHR of traditional shelling and by using pedal operated de-husker sheller, shown in Fig.5, was observed as 12.1 and 53.81 beats/min respectively. Mean ΔHR value for pedal operated de-husker sheller was slightly higher when compared to traditional shelling method.

Physiological cost/Cardiac cost of the selected subjects during shelling operation

The increase in Physiological cost/ Cardiac cost of the work in beats/kg of production during shelling operation during manual shelling operation and by using pedal operated maize de-husker sheller was 88.30±7.15 and 73.32±2.14 beats/kg. The productivity (kg/h) by pedal operated maize de-husker sheller was more when compared to traditional shelling method.

Oxygen consumption rate of the subjects during shelling operation

The Resting OCR for manual shelling operation was 0.157±0.02 l/min and working OCR was 0.373±0.03 l/min. The mean OCR was 0.216±0.02 l/min respectively. According to classification suggested by Sen *et al.*,(1969), working OCR for manual shelling operation could be rated in "light" category of workload.

The Resting OCR for pedal operated maize de-husker sheller was 0.232±0.03 l/min and working OCR was 0.962±0.05 l/min. The mean OCR was 0.730±0.05 l/min respectively. According to classification suggested by Sen *et al.*,(1969), working OCR for pedal operated maize de-husker sheller could be rated in "moderately heavy" category of workload. The mean working OCR and ΔOCR during shelling operation by manual shelling and pedal operated maize de-husker sheller is given graphically in Fig.6.

It can be seen that mean working OCR and ΔOCR during shelling operation is higher in case of pedal operated maize de-husker sheller.

Energy Expenditure Rate (EER) of the subjects during shelling operation

The Energy expenditure rate (EER) for female subjects during manual shelling was calculated from oxygen consumption rate (OCR).

Since OCR is a better parameter than heart rate, the energy expenditure rate was estimated by multiplying the working OCR with the calorific value of oxygen as 20.88 kJ/l (Nag and Dutt, 1980).

The mean EER for traditional shelling method for ten female subjects was 7.78±0.55 kJ/min. According to classification suggested by Sen *et al.*,(1969), Energy expenditure rate for manual shelling operation could be rated in "light" category of workload.

The mean EER for pedal operated maize de-husker sheller for ten female subjects was 20.01±1.10 kJ/min. According to classification suggested by Sen *et al.*,(1969), Energy expenditure rate for pedal operated maize de-husker sheller could be rated in "moderately heavy" category of workload.

The mean EER during shelling operation by manual shelling and pedal operated maize de-husker sheller is given graphically in Fig.7. It can be seen that mean EER during shelling operation is higher in case of pedal operated maize de-husker sheller.

Fig.1 Cortex Biophysik MetaMax® 3X portable CPX system

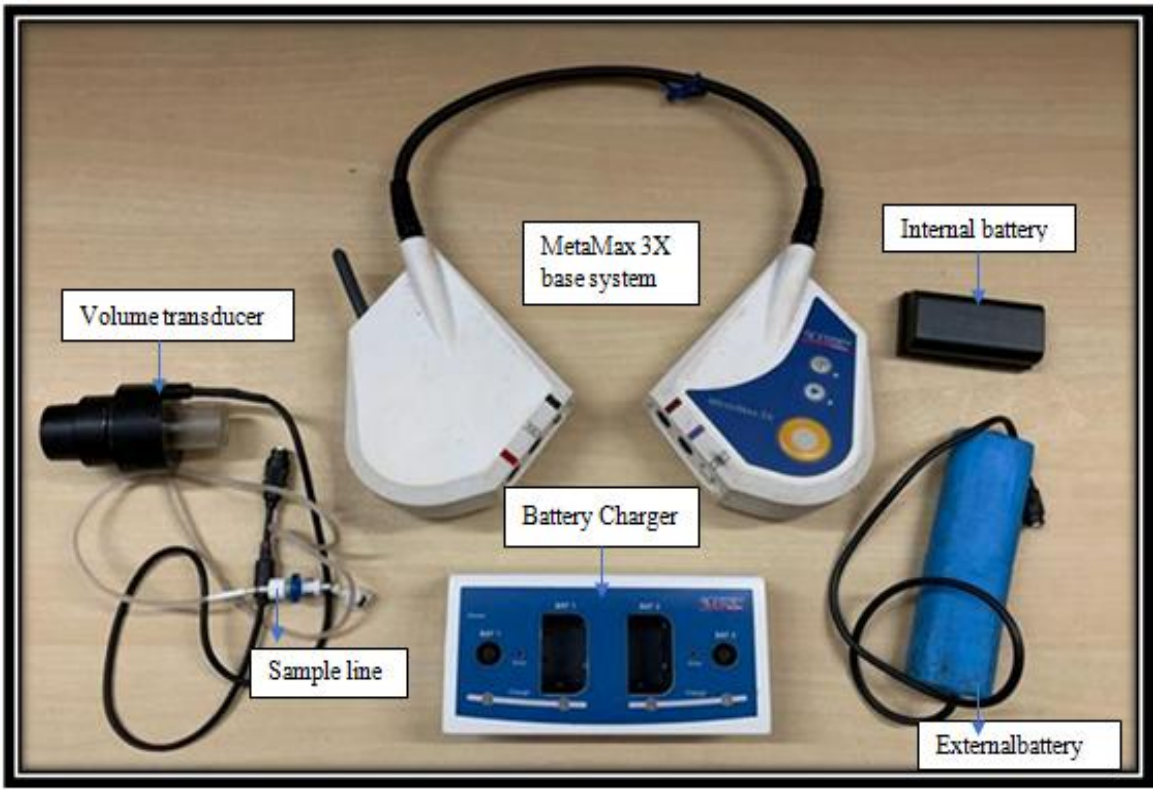


Table.1 Physical characteristics of selected female farm workers (N=10)

S.No	Physical characteristics of female farm workers	Mean±Standard deviation
1.	Age (years)	33.30±9.25
2.	Height (cm)	149±7.18
3.	Weight (Kg)	45.4±5.72
4.	Body mass index (BMI)	20.58±2.03

Table.2 Specification of Pedal operated maize de-husker sheller

S.No	Specifications	Observations
1.	Height of the pedal at its lowest position, mm	76
2.	Saddle height, mm	806
3.	Crank length, mm	180
4.	Diameter of drum, mm	170
5.	Diameter of Flywheel, mm	500
6.	Length of peg, mm	40

Table.3 Responses on Musculo-skeletal problems and Rating of perceived exertion (RPE) of the female farm workers during shelling operation

Type of operation	Musculo-skeletal problems	Rating of perceived exertion (RPE)
Pedal operated maize de-husker sheller.	left leg, right leg, left thigh, right thigh, buttocks, mid back and lower back	Heavy
Manual shelling	left palm and right palm, buttocks, mid back and lower back	Light

Table.4 Evaluation of performance data of different parameters of the farm women while performing shelling operation (N = 10)

Particulars	Mean±Standard deviation	
Type of tool used	Manual shelling	Pedal operated maize de-husker sheller
Total time of operation per subject (hours)	1	1
Average working heart rate (beats/min)	93.82±2.26	138.04±3.5
Average resting heart rate (beats/min)	81.72±1.69	84.25±2.13
Average recovery heart rate (beats/min)	85.53±1.87	104.89±1.62
ΔHR (working HR - resting HR) (beats/min)	12.10±2.02	53.81±3.39
Productivity (kg/h)	8.18±0.8	44.26±3.18
Energy Expenditure Rate (kJ/min)	7.78±0.55	20.01±1.10
Oxygen consumption rate, Working OCR, l/min	0.373±0.03	0.962±0.05
Physiological cost of work (beats/kg)	88.30±7.15	73.32±2.14
Overall discomfort rating (ODR) at the starting of work	1.14	1.15
Overall discomfort rating (ODR) at the end of the work	2.2	7.95
Overall discomfort rating (ODR)(start-end)	1.06	6.80
Body part discomfort score (BPDS)	37.9	71.2
Rating of perceived exertion (RPE)	2.65	4.55
Reduction in drudgery (%)	-	16.96

Table.5 ANOVA for shelling operation in maize crop

Table.5a ANOVA for HR for manual shelling and pedal operated maize de-husker sheller

S.No.	SOURCE	DF	SS	MS	F_{cal}	CD	CV
1.	Between groups	1	9777.042	3259.014	1126.53153*	3.3954	6.22
2.	Within groups	18	156.22	8.67888889			
3.	Total	19	9933.262				

*P-Value significant at 0.01

Table.5b ANOVA for ΔHR for manual shelling and pedal operated maize de-husker sheller

S.No.	SOURCE	DF	SS	MS	F_{cal}	CD	CV
1.	Between groups	1	8698.6205	1232.8735	1117.04563*	6.285	5.49
2.	Within groups	18	140.169	7.78716667			
3.	Total	19	8838.7895				

*P-Value significant at 0.01

Table.5c ANOVA for EER for manual shelling and pedal operated maize de-husker sheller

S.No.	SOURCE	DF	SS	MS	F_{cal}	CD	CV
1.	Between groups	1	755.46632	251.82210	1032.96252*	3.51*	4.21
2.	Within groups	18	13.16446	0.73135889			
3.	Total	19	768.63078				

*P-Value significant at 0.01

Table.5d ANOVA for CARDIAC COST for manual shelling and pedal operated maize de-husker sheller

S.No.	SOURCE	DF	SS	MS	F_{cal}	CD	CV
1.	Between groups	1	1170.14402	390.04800	41.6982035*	4.26	4.28
2.	Within groups	18	505.1199	28.0622167			
3.	Total	19	1675.26392				

*P-Value significant at 0.01

Fig.2 ODR 10-Point Scale

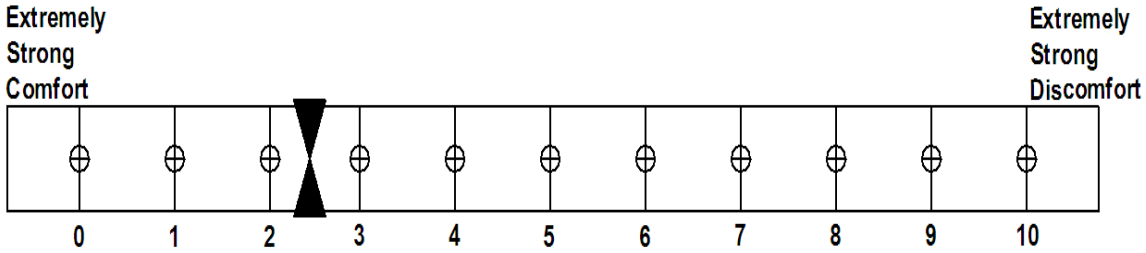


Fig.3 Body map (Corlett and Bishop, 1976)

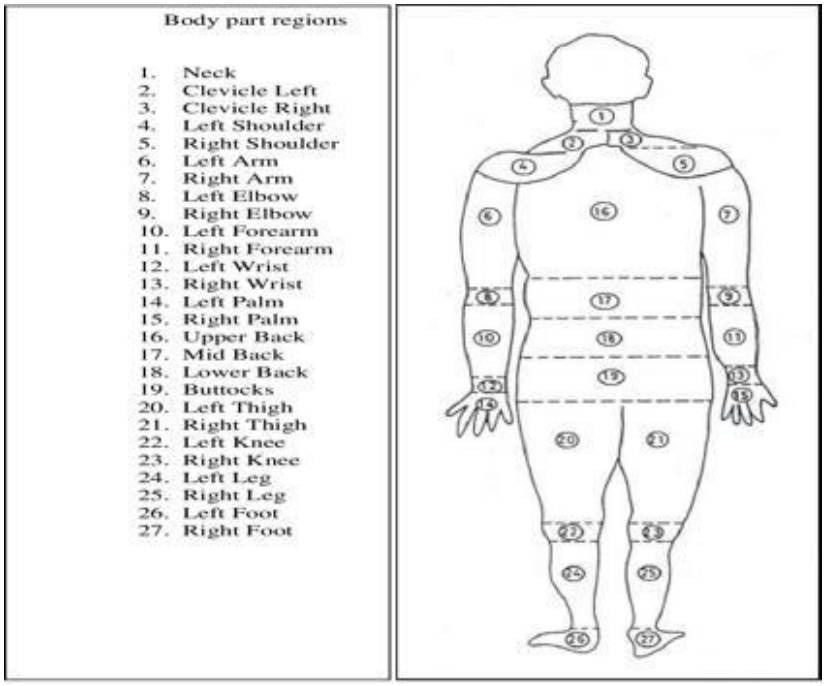


Fig.4 Shelling operationby Pedal-operated maize de-husker sheller used in the study

Fig.5 Mean WHR and Delta HR during shelling operation

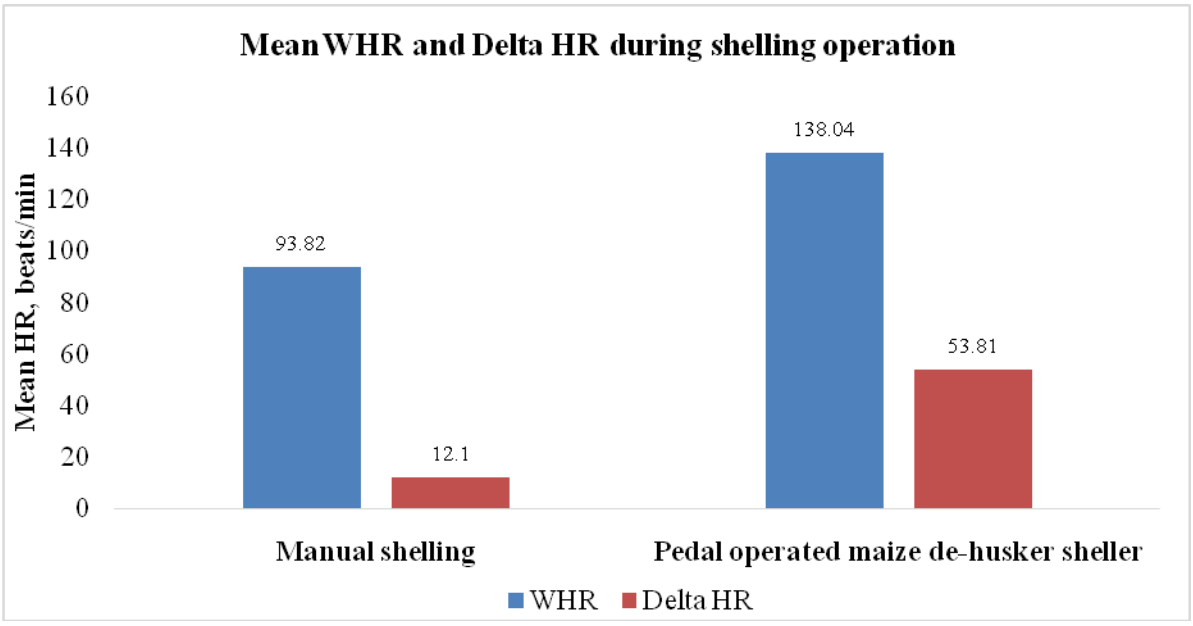


Fig.6 Mean working OCR and Delta OCR duringshelling operation

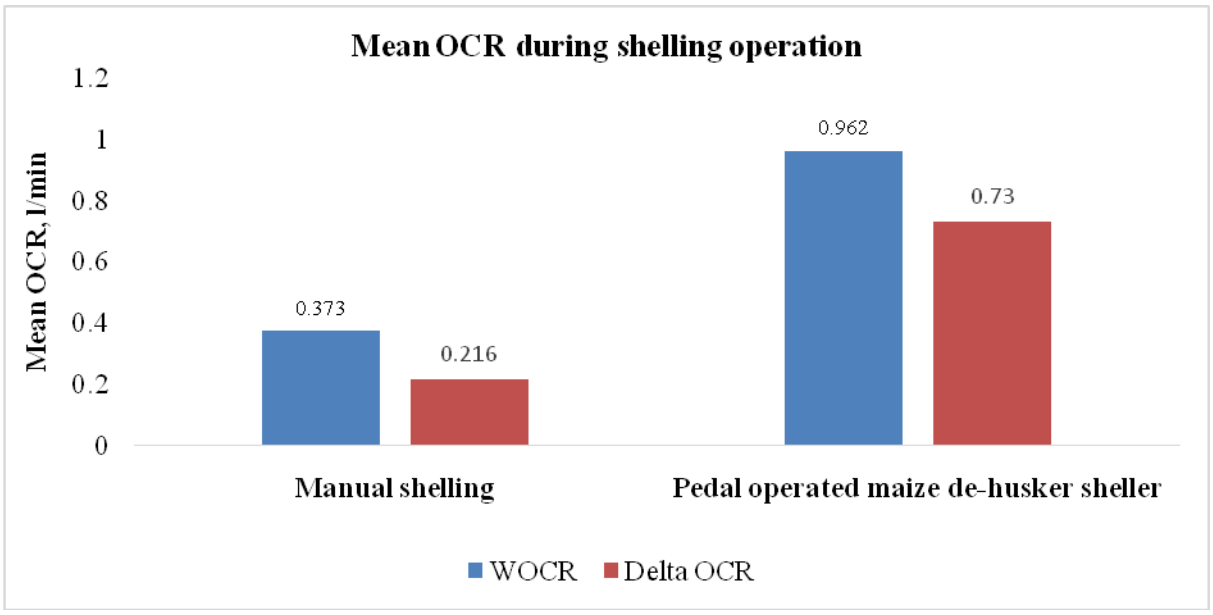


Fig.7 Mean EER during shelling operation in maize crop

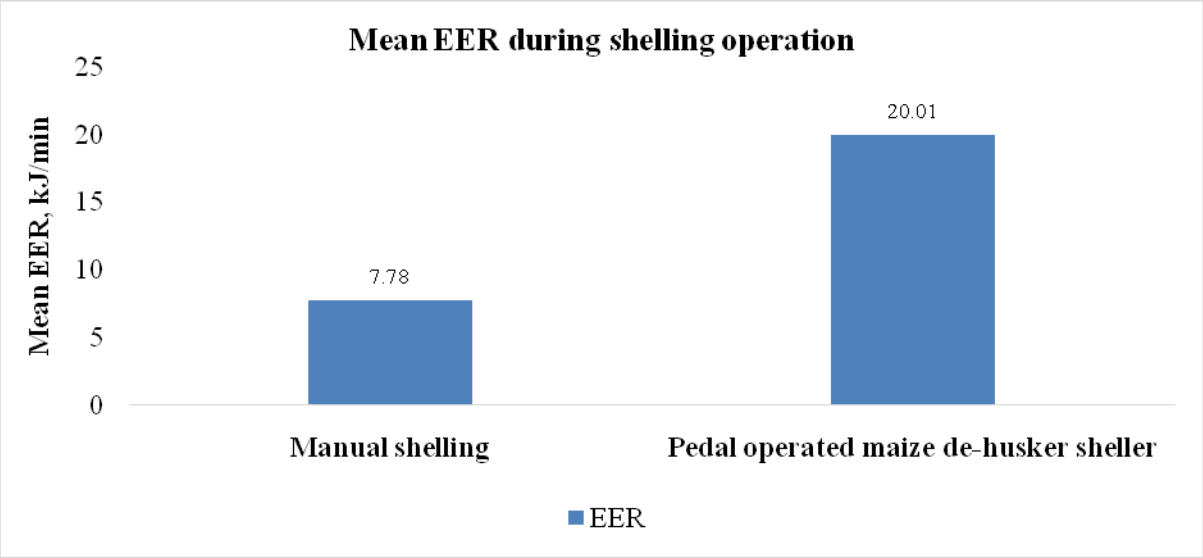
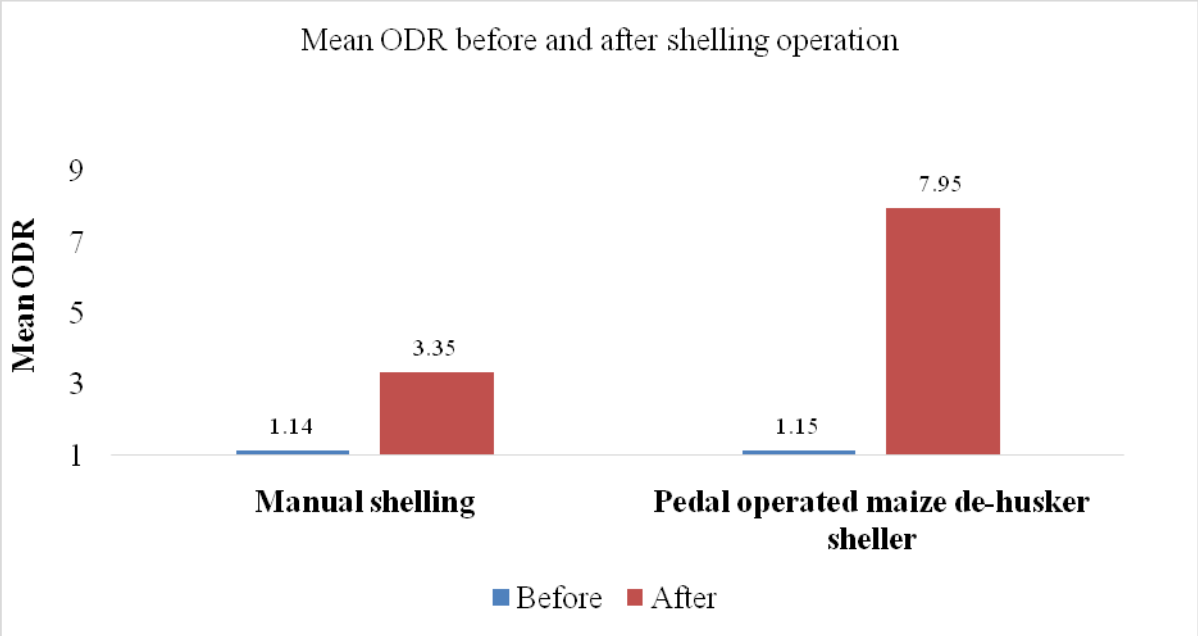


Fig.8 Mean overall discomfort rating of the female farm workers



Physical workload of the female farm workers during shelling operation in maize crop

Observations were taken during field experiments to assess the physical workload viz., overall discomfort rating (ODR), body part discomfort rate (BPDS) and rating of perceived exertion (RPE) experienced by the selected female farm workers as per the procedure given in (materials and methods) for maize shelling.

Overall discomfort rating of the female farm workers during shelling operation

ODR experienced by the selected female farm workers before and after during manual shelling operation was taken. The mean ODR of the subjects before manual shelling operation was 1.14 and the mean ODR of the subjects after manual shelling operation was 3.35 respectively. The mean ODR of the subjects before using Pedal operated maize de-husker sheller was 1.15 and the mean ODR of the subjects after using Pedal operated maize de-husker sheller was 7.95 respectively. Almost both the methods before starting the shelling was same.

Maximum ODR was observed in by using Pedal operated maize de-husker sheller because of continuous pedalling operation. The ODR for manual shelling operation was less as the operation was carried out in sitting posture only. Graphical representation of ODR is presented in Fig. 8.

Body part discomfort score (BPDS) during weeding operation

Experiments were carried out in order to assess BPDS of female farm workers during shelling operation. The mean BPDS for manual shelling and with Pedal operated maize de-husker sheller was 37.9 and 71.2 respectively. The maximum mean BPDS for female farm workers was high in case of Pedal operated maize de-husker sheller. The majority of discomfort was observed at left leg, right leg, left thigh, right thigh, buttocks, mid back and lower back areas for almost all the subjects during shelling operation with Pedal operated maize de-husker sheller. This was mainly due to the pedalling operation continuously in sitting posture. The majority of discomfort was observed in the left palm and right palm due to removal of grains by holding the cob in hand.

Rating of perceived exertion (RPE) during shelling operation

Experiments were carried out in order to assess RPE of female farm workers during shelling operation. The mean RPE for manual shelling and with Pedal operated maize de-husker sheller was 2.65 and 4.55 respectively. The maximum mean RPE for female farm workers was high in case of Pedal operated maize de-husker sheller. Responses on Musculo-skeletal problems and Rating of perceived exertion (RPE) of the female farm workers during shelling operation is given in Table 3.

Performance evaluation of different parameters during shelling operation

Physiological workload during the shelling operation of maize crop was determined on the basis of various parameters like average heart rate during work and rest, oxygen consumption rate, energy expenditure rate, physiological cost of work while performing the activity and physical workload was determined on the basis of Overall discomfort rating (ODR) (before and after the operation), Rating of perceived exertion (RPE) and BPDS. Table 4 indicates the evaluation of performance data of different parameters of the farm women while performing shelling operation (N = 10).

The performance evaluation of data given in Table 4, clearly indicates that the pedal operated maize de-husker sheller saves nearly 16.96% of the cardiac cost of the worker per unit of output over manual shelling operation of maize cobs, which is nothing but reduction in drudgery by 16.96%. Productivity (kg/h) with pedal operated maize de-husker sheller was 5.41 times more over manual shelling operation.

Statistical analysis for shelling operation

Statistical analysis of data for manual shelling operation can be seen from ANOVA Table 5 that, the mean working heart rate of pedal operated maize de-husker sheller was significantly (P<0.01) higher than manual shelling operation in maize crop. The ΔHR of pedal operated maize de-husker sheller was significantly (P<0.01) higher than manual shelling operation in maize crop.

It can be seen from ANOVA Table 5 that, the mean EER of pedal operated maize de-husker sheller was significantly (P<0.01) higher than manual shelling operation in maize crop. Analysis of correlation data for pedal operated maize de-husker sheller showed that the cardiac cost is significant at (P<0.01) positively correlated with ΔHR (r(9)=0.93). It also showed that the cardiac cost is significant at (P<0.01) inversely correlated with productivity (r(9)=-0.94), which means that increase in cardiac cost may affect the productivity. Singh *et al.*, (2010) also reported positive relationship of cardiac cost with average HR during maize shelling with tubular maize sheller.

Pedal operated maize de-husker sheller when compared to traditional shelling method was more women friendly following all the ergonomic considerations for reducing the drudgery of the women farm workers by 16.96%. It also increased the productivity (kg/h) during the shelling operation by using Pedal operated maize de-husker sheller by 5.41 times the traditional shelling operation and also provides safety and reliability to the farm workers. This not only reduces the drudgery but also reduces the fatigue, tiredness, exertion when proper work-rest cycle.. Proper training regarding the operating of Pedal operated maize de-husker sheller is very important to avoid the Musculo-skeletal problems associated.

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