Ergonomical evaluation of hand operated maize dehusker-sheller with farm women

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Abstract: Hand operated maize dehusker-sheller was ergonomically evaluated with tenfarm women to assess the physiological workload and its performancein standing and sitting postures. Two workers are required during its operation, i.e., one for hand cranking and another for feeding the cob. One by one cob (without removing its outer layer/sheath) was fed in hopper at an interval of about 4 s. Farm women operated the equipment at their rhythmic speed in both postures. The average heart rate of subject was 144 and 142 beats min^{-1}in standing and sitting postures, respectively. The overall discomfort rating (ODR) and Body Parts Discomfort Score (BPDS) clearly indicated that the standing posture could be better option for operation of this equipment. This was found to reduce the physiological cost by 38.95% and 21.62% in dehusking & shelling the maize cob with hand, and dehusking by hand & shelling by octagonal maize sheller respectively.

Keywords: hand cranking, maize threshing, maize, physiological workload, heart rate, women

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1 Introduction

Dehusking of maize cob after plucking from maize stalk is performed by human beings with hand (called dehusking) and grain removal from cob (called shelling) is alsodone traditionally.Hand and power operated maize sheller and maize threshers are commercially available but these equipment are not suitable for removing the grain from un-dehusked maize cobs. Thus, dehusking of cob is done manually. This activity is mostly performed by farm women. Traditionally, taking out grain from maize cobs are done either with use of fingers & hand, sickle, beating with sticks etc. Except beating with stick, farm women used to perform these activities. No hand operated maize dehusker-sheller was available for dehusking-shelling the un-dehusked maize cob (Singh, 2010). It is reported that farm women were not accustomed with cycling in the country (Singh, 2005;Anon, 2005), hence, a hand operated maize dehusker-shellerwas developed using ergonomic consideration (Singh et al., 2012) to provide options before small and hill farmers. The developed equipment needs to be evaluated ergonomically with farm women as they are involved in the process of dehusking-shelling of maize cobs.

Physiological cost of operation is influenced by the health of operators, nutrition, basal metabolic rate and energy expended while working that can be indirectly measured by measuring oxygen consumption and heart rate. In general, person’s subjective experience of a particular workload or rate of work is more closely related to heart rate than to oxygen consumption during the performance of work (Christensen, 1962). Pheasant (1991) have also concluded that the heart rate is a better index of the overall physiological demand of work than energy expenditure and it has the additional advantage of being very much easier to measure in the field. Keeping this advantage, heart rate of subject was measured for assessment of physiological workload in the present

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study.Heart rate bears a linear relationship with the intensity of physical exercise and oxygen consumption especially if the steady state is reached (Le Blanc, 1957; Suggs and Splinter, 1961). Therefore, several research workers (Dhesi and Firebaugh, 1973; Monod and Zerib, 1985; Kumar and Parvathi, 1998; McNeill and Westby, 1999; Balasankri et al., 2003; Singh et al., 2006; Singh and Gite, 2007; Yadav et al., 2007; Singh, 2009) have used heart rate for assessment of physiological workload of the workers. In the present study, the hand operated maize dehusker-sheller was ergonomically evaluated with farm women to assess the physiological workload by measuring heart rate of subject, over all discomfort and body part discomfort in addition to the performance of equipment during hand cranking.

2 Materials and methods

2.1 Maizedehusker-sheller

The axial-flow maize dehusker-sheller consisted of threshing cylinder (beater attached with solid lugs), arch shaped two louverers (one at entry and another for exit), main shaft, bottom sieve with equally spaced 8 mm square mild steel bars, top and bottom cylinder cover, husk outlet, trapezium shaped hopper, grain outlet and frame, chain-sprocket system for power transmission etc. The concave clearance was 35 mm. The diameter of cylinder was 380 mm. The handle height from ground during its downward position was 600 mm as per the metacarpal-III height of subject. The crank length was 260 mm. The speed was stepped up to 5.23 times to achieve peripheral speed of about 5 to 5.5 ms^{-1}.

2.2 Protocols for heart rate measurement

The subjects chosen for the study were farm women who involved in various farm activities. The subjects were physically fit for performing the activities. Following points were considered for developing the protocol to conduct this experiment with the subjects.

- Subject having age of 25 to 45 years was taken for the study.
- Resting heart rate of anysubject did not exceed 100 beatsmin-1.
- Subject was given training of using the machine with complete operational techniques involved in it.
- The subjects selected were representative of User’s population (5thto 95th percentile of stature and body weight) as reported by Agarwal et al. (2007).
- All the subjects were informed about the heart rate monitor to be used on them for avoiding any misleading information.

The ambient condition (dry bulb temperature and relative humidity) during the experiment was recorded.

The heart rate was measured with the help of polar heart rate monitor. Steps followed for heart rate measurement is given below:

- Before fixing the monitor and the transmitter to the subject, both were wiped-off with the white spirit using cotton to remove dust and the sweat of the previous subject.
- After that transmitter of the heart rate monitor was fixed on the subject’s chest with logo in the centre and receiver (wrist watch) was tied on subject’s right or preferable hand.
- Recording interval for heart rate was chosen for 60s to avoid numerous reading.
- Before recording the heart rate, subject was asked for 15 minutes (min)brisk walking followed by 30 min restto ensure normal resting heart rate, then the recording button was switched ON.
- The time of start of rest was recorded in the data sheet. At the same moment stopwatch was also kept ON.
- Rest of 10 min was given to each participating subject. During this resting period, subject was not allowed to talk, eating tobacco or changing the location to avoid any erratic reading.
- When rest period (10 min) was over in the stopwatch, subject’s heart rate was noted in the data sheet and she was asked to stand-up for performing the task.
- The duration of time of operation was recorded when real work started.
- The stopwatch was made again ON.
- Attention was paid during experiment about her queries/ difficulties if any such as personal need like need of drinking water etc. The demand was

rectified at that time. If it was not fulfilled, the trial was stopped and repeated.

- After completion of satisfactory work, the stopwatch was put OFF.
- The subject was allowed to rest in the same place, where she was during rest period, until the recovery heart rate equals to resting heart rate.
- After that the recording button of the wrist monitor was put OFF.
- The recorded data in the receiver of the monitor were downloaded daily in the computer through S-series infrared interface after completion of the work.
- Data for resting, working and recovery heart rate were segregated from total recorded data.
- The heart rate data from 6th min onwards of work of each worker was considered for calculating the average heart rate.
- The work pulse value was calculated by subtracting the mean heart rate of subject during work with their mean heart rate during rest.

2.3 Calibration of subjects

The subjects were calibrated on a mechanical hand cranking experimental setup at graded load for four hand cranking speed (35, 45, 55 and 65 rmin^{-1}). The graded load in sitting posture was No load, 0.5, 0.96, 1.46 and 1.96 kg while in standing posture was No load, 0.96, 1.46, 1.96 and 2.46 kg. The crank length was 245 mm in sitting and 260 mm in standing posture. The height of hand cranking setup and chair was adjusted using simple screw jack as per the subject stature and anthropometric dimensions. On-line torque transducer was attached in between cranking and pulley shaft. The physiological response of subjects was observed measuring heart rate. The energy expenditure rate at graded load was estimated using Singh et al. (2008) equation from heart rate.

2.4 Experimental details

The experiment was conducted at CIAE campus, Bhopal in year 2009-10. JM-216 variety of maize was used for the experiment. The maize dehusker-shellerwas operated by the farm women in standing and sitting posturesas shown in Figure 1.

Figure 1 Farm woman operating the maize dehusker-sheller in standing and sitting postures

The chair height was adjusted as per the convenience of the subject in operating the machine. The observations on dehusking-shelling efficiency, grain recovery and grain breakage was noted during feeding one by one cob in the machine. Fifteen kg un-dehuskedmaize cobs were taken for dehusking-shelling with the machine for each subject. Average number of un-dehusked cob per subject was counted. Feeding of another cob after 1st cob was based on the slow grain flow from its grain outlet. The hand cranking speed was noted with tachometer. The time involved in feeding the entire cob for each subject was noted and the exact feed rate was calculated. The weight of grain from all sources (grain outlet, husked cob outlet, cylinder), un-dehusked cob at husk outlet and in cylinder, dehusked cob at husk outlet and in cylinder, and un-shelled cob at husk outlet and in cylinder was measured using electric balance and platform scale. A set up for measuring the torque required in operating the machine was fabricated. The torque required in operation (idle and load) of the machine was measured using on-line torque transducer with recorder. Using FAO Agricultural Services Bulletin (Anon., 1994), the moisture content, maize grain/spent cob ratio, weight of cob and grain, damages of grains, size of un-dehusked cobs, dehusking efficiency, shelling efficiency, increase in percentage of damage of grain and output capacity was calculated.

2.5 Instruments used

The heart rate monitor, Polar Electro Oy, Finland (model S 810™) consisted of transmitter and receiver was used to record ventricular beats per minute of the subject during rest, work and recovery. To measure the ambient condition during the experiment, dry and wet bulb temperature was measured with manually operated dry-wet bulb hygrometer. After pouring clean water, the hygrometer was rotated for a minute so that mercury columns remained steady and reading of wet and dry bulb was noted from respective columns. Torque transducer manufactured by EELEEL make, England was used for measuring torque. Stop watch of Racer make was used for measuring time during experiment. Digital photo/contact tachometer was used for measuring shaft speed of dehusker-sheller. Two electric weighing balances were used during study. A balance of 1 kg capacity with 0.1 g least count was used for measuring sample of grain. While another electric and battery operated balance of 15 kg with least count of 1 g was used for measurement of shelled grain, dehusked cob etc. Electric and battery operated platform scale was used for measuring the body weight of subjects and un-dehusked cob. The capacity of this scale was 150 kg and least count was 10 g. A compression load cell of 20 kg with least count of 0.01 kg manufactured by Nova Tech, London was also used for measuring the force at different positions of handle. Grip strength dynamometer of Takei Scientific Instruments Company Limited, Japan was used to measure the left and right grip force of subjects for assessing subject potentialities. HTC make SL-1350 sound level meter was used to measure the sound level of subject at their ear level during operation of the maize dehusker-sheller.

2.6 Formula used for the oxygen consumption and rest pause

The oxygen consumption of subject at their measured heart rate was estimated based on general equation given by Singh et al. (2008).

$$Y = 0.0114X - 0.68 \tag{1}$$

where, Y = oxygen consumption, L min^{-1}; X = heart rate, beats min^{-1}.

The oxygen consumption (L min^{-1}) was converted in kJ taking calorific value of oxygen as 20.93 kJ L^{-1}. The rest pause to the subject was also calculated using following formula, as given by Pheasant (1991):

$$\frac{r}{t} = \frac{E - A}{E - B} \tag{2}$$

where, r = resting time, min; T = total working time/ day, min; E = energy expenditure during working task, kcal min^{-1}; A = average level of energy expenditure considered acceptable, kcal min^{-1}; B = energy expenditure during rest, kcal min^{-1}.

Average level of energy expenditure acceptable for day-long work was considered on the basis of 40% of aerobic capacity as suggested by Nag and Chatterjee (1981), which comes to 0.64 L min^{-1} (3.2 kcal min^{-1}) based on Singh et al. (2008). Average level of energy expenditure during rest was taken to 1.35 kcal/min (0.27 L min^{-1}) based on the laboratory experiment conducted for Madhya Pradesh farm women (Singh, 2005). To measure localized discomfort, Corlett and Bishop (1976) technique was used by dividing the subject's body into 27 regions and the subject was asked to indicate the regions which are intolerable pain/discomfort, moderate pain/discomfort and just noticeable pain/discomfort. A ten point Visual Analogue Discomfort (VAD) rating scale (0 = no discomfort, 10 extreme discomfort) was used for assessment of overall discomfort rating (Legg and Mahanty, 1985), which is an adaptation of Corlett and Bishop (1976) technique.

2.7 Statistical analysis

The experiment was designed as Randomised Block Design (RBD)to reduce the effect of field parameters on the dependent variables, within the replications. Each replication (subject) for all the experiments was considered as separate block. The data of all dependent variables were analyzed by using SPSS and WINDOSTAT statistical software. The coefficient of variations were observed for heart rate, hand cranking speed and dehusking-shelling efficiency. Paired t-test was used to test the significance at 5% level between ODR and BPDS.

3 Results and discussion

The average moisture content was 11.7 ± 1.16% (d.b). The maize grain/spent cob ratio was 0.758. Ten farm women (subjects) were involved in each experiment. The average age, height and weight of subject while operating the machine in standing posture were 33.1 ± 5.61 yrs, 1.514 ± 0.056 m and 43.3 ± 3.9 kg respectively. Correspondingly, the average age, height and weight of subject during sitting mode of operation of machine were 33.1 ± 5.61 yrs, 1.52 ± 0.052 m and 43.6 ± 4.14 kg. Only one subject was left handedin both mode of operation. The average body mass index (BMI) during standing and sitting mode of operation of the machine was 18.88 ± 1.4 and 18.86 ± 1.33 kgm^{-2} respectively. Except three subjects, the BMI of rest subjects were in normal range (18.5 to 24.9 kgm^{-2}) Anon. (2010). The dry bulb temperature and relative humidity in standing and sitting mode of operations were 24.25 ± 1.27℃ & 41.7 ± 7.72% and 22.85 ± 3.2℃ & 38.95 ± 14.6% respectively. The grip force exerted by the subject with their right hand was 237.0 ± 40.8 N while it was 188.5 ± 34.9 N with left hand. The force required to move the handle from its bottom and back side positions was observed to be 25.51 N which was well below to acceptable limit [30% of the grip force of subject (56 N)]. The torque required while operating the machine with load (feed rate of 100 kgh^{-1}) and no load at cylinder shaft speed of 280 r min^{-1} was 3.03 ± 1.01 Nm and 1.48 ± 0.51 Nm respectively. The torque required to just initiate the hand cranking was 2.5 Nm. The sound level during operation of this machine at ear's level of subject was 80 to 86 db (A).

3.1 Calibration of subject

All the subjects were calibrated on hand cranking frictional setup at graded load and varied cranking speeds. All the subjects performed similarly in laboratory i.e., heart rate increased with load and speed.

3.2 Physiological workload and rest pause

The physiological workload while operating the maize dehusker-sheller in standing and sitting postures by the subject was assessed based on their heart rate response. The average heart rate of subject was 144 beats min^{-1} at hand cranking speed of 56 r min^{-1} and standard deviation in heart rate of subject was 13 beats min^{-1} while operating maize dehusker-sheller in standing posture. The average heart rate of subject while operating maize dehusker-sheller in sitting posture was 142 beats min^{-1} at hand cranking speed of 54 r min^{-1}. The variation in heart rate of subject might be due to hand cranking speed, subject's physiological difference and load. The BMI of participated farm women in the experiment clearly indicated that most of farm women only touched the border line of range that might be one of the reasons of physiological difference. The physiological difference was also observed by many research workers (Kathirvel and Ananthakrishan, 2000; Balasankri et al., 2003; Shrimali, 2005; Singh et al., 2006; Singh and Gite, 2007; Yadav et al., 2007; Singh, 2009) during various agricultural operations. The variation in hand cranking speed was due to individual subject's rhythm for hand cranking. As the torque requirement during operation was 3.03 Nm, subjects successfully operated the machine with right or left hand during rhythm. The increase in heart rate with increase in hand cranking speed at graded load indicates the more muscle exercise by the subject during increase in the hand cranking speed which affected the circulatory changes with the supply of oxygen to the muscles and dissipation of heat produced that further affect the heart rate as reported by Le Blanc, (1957).

As per the criteria given by Varghese et al. (1994), the operation of hand operated maize dehusker-sheller by the subject was assessed for very heavy workload in both the postures. Heavy physiological workload suggested providing the rest pause to the subject. The rest pause to the subject was calculated using Pheasant (1991) equation. Average level of energy expenditure acceptable for day-long work was considered on the basis of 40% of aerobic capacity as suggested by Nag and

Chatterjee (1981), which comes to 0.64 L min^{-1} (3.2 kcal min^{-1}) based on Singh (2008). Average level of energy expenditure during rest was taken to 1.35 kcal min^{-1} (0.27 L min^{-1}) based on the laboratory experiment conducted for Madhya Pradesh farm women by Singh (2005). Using this equation, the rest pause was calculated for the operation period of 30 min which came to about 14 min. Heavy category of physiological workload suggested providing the rest pause to the subject. Thus for a period of 1 h operation of the machine, other subject who engaged for feeding the cob, could be shifted for operation and vice-versa. This way planning could be made during day-long work with machine.

3.3 Reduction in physiological cost with machine

The hand operated maize dehusker-sheller was found to reduce the physiological cost by 38.95% and 21.62% in dehusking& shelling the maize cob with hand, and dehusking by hand & shelling with tubular maize sheller respectively (Table 1).

Table 1 Comparative analysis for dehusking-shelling with hand operated maize dehusker-sheller and other methods

Method of dehusking-shelling	Average values
Output in dehusking and shelling cob by hand, kg cob/h	10.72
Work pulse, beatsmin^{-1}	17
Total physiological cost/kg cob, beats	95
Output in dehusking by hand and shelling by tubular maize sheller, kg cobh^{-1}	14.56
Work pulse, beatsmin^{-1}	18
Total physiological cost/kg cob, beats	74
Feed rate of un-dehusked maize cob with hand operated maize dehusker-sheller, kg cobh^{-1}	83.59
Work pulse during hand cranking, beatsmin^{-1}	62
Work pulse during cob feeding, beatsmin^{-1}	19
Total physiological cost, beats/kg cob	58
Reduction in physiological cost with hand operated maize dehusker-sheller as compared to dehusking and shelling, %	
By hand	38.95
By hand and tubular maize sheller	21.62

3.4 Overall discomfort score

i) Sitting posture

Just after operation of maize dehusker-sheller in sitting posture, discomfort level rated by the subject varied from 6 to 7.5 (average 6.75) and the coefficient of variation in discomfort rating was 10.1% (Table 2). The discomfort rating (score) varied from 2.5 to 3.5 (average 3.0) after 30 min duration of operation and coefficient of variation in the rating was 11%. Using paired t-test, the discomfort rating obtained with the subject just after work in this posture and after 30 min of work was compared and found that the discomfort rating obtained after 30 min of work was significantly lower at 1% level.

Table 2 Overall discomfort rating (score) as perceived by subjects while operating the maize dehusker-sheller

Subject	Discomfort score out of 10			
	Sitting posture		Standing posture	
	Just after work	After 30 min	Just after work	After 30 min
S1	6	3	5.5	2
S2	6.5	3	6	2.5
S3	6	2.5	5	3
S4	6.5	3	7	3
S5	6.5	3	6	3
S6	7.5	3.5	6.5	3
S7	7.5	2.5	6.5	3
S8	7.5	3	5.5	2
S9	6	3	6	2.5
S10	7.5	3.5	7	3.5
Mean	6.75	3.00	6.15	2.75
S.D	0.68	0.33	0.71	0.49
C.V	10.07	11.00	11.54	17.82

ii) Standing posture

The discomfort rating experienced by the subject just after operation of the maize dehusker-sheller in this posture varied from 5.5 to 7 (average 6.15 out of 10 point scale) and coefficient of variation in discomfort rating was 11.54% (Table 2). Subject-wise discomfort rating varied from 2 to 3.5 (average 2.75) after 30 min of work and coefficient of variation was 17.82%. The discomfort rating obtained after 30 min of work was significantly lower at 1% level as compared to that one obtained just after the work. The standing posture was observed better than sitting as 40% subject felt more pressure either on shoulder or wrist or legs and foot in sitting mode than standing.

3.5 Body parts discomfort score in standing and sitting postures

Based on subject's feeling about the discomfort in different regions of their body while operating the maize dehusker-sheller, the body part discomfort score (BPDS) varied from 3 to 8 (average 5.2 out of 10.5) in standing mode of hand cranking and coefficient of variation in BPDS was 28.85% (Table 3). In sitting posture, the body part discomfort score varied from 4 to 10 (average 7.4 out of 14.1) and coefficient of variation in BPDS was 21.62%. In both the posture, the variation in BPDS was due to the subject. The moderate level of discomfort experienced by the subject during hand cranking in standing posture was in upper arm followed by shoulder, wrist, elbow, lower arm and upper and lower back.During hand cranking in sitting posture, the moderate level of discomfort was in shoulder followed by upper arm and elbow; clavicle right, lower arm, right palm and wrist; and foot and legs during hand cranking in sitting posture. Effect of posture on hand cranking was statistically analyzed using paired t-test and BPDS was found significantly higher in sitting as compared to standing at 1% level. None of subjects reported for intolerable pain during hand cranking the maize dehusker-sheller in both the posture during operating time. This might be due to less operating time.

Table 3 Body part discomfort score as perceived by the subject while operating the maize dehusker-shellerin both postures

Subject	Standing posture		Sitting posture	
	BPDS Score	Rating	BPDS Score	Rating
S1	6	0.50	6	0.50
S2	4	0.44	6	0.50
S3	6	0.50	6	0.50
S4	6	0.50	8	0.53
S5	4	0.44	8	0.53
S6	8	0.53	10	0.56
S7	4	0.44	8	0.53
S8	6	0.50	8	0.53
S9	5	0.56	9	0.50
S10	3	0.50	5	0.56
Mean	5.2	0.49	7.4	0.52
SD	1.5	0.04	1.6	0.02
C.V, %	28.85	7.68	21.62	4.33

3.6 Performance of maize dehusker-sheller

i) Standing posture

Subject-wise feed rates in terms of un-dehusked cobh^{-1} varied from 71 to 95 kg (average 83.59 kg) at hand cranking speed from 51 to 60 r min^{-1} (Table 4). The variation in the feed rates of un-dehusked cob might be due to the subject. The average output was found 60.33 kg h^{-1} and variation was from 48 to 72 kg h^{-1}. The variation in output might be due to grain:un-spent cob ratio. None of cob was observed without dehusking thus dehusking efficiency was 100% while shelling efficiency was 98.47% which varied from 97 to 99% with 0.73% coefficient of variation. The grain breakage varied from 0.16 to 1.46% (average 0.82%). It was observed that the grain breakage was high at hand cranking speed of 51 and 60 r min^{-1}. The correlation between hand cranking speed with feed rate and output was observed and found that the hand cranking speed had positive correlation with feed rate (0.873) and output (0.913) at 1% level.

Table 4 Feed rate, output, shelling efficiency and grain breakage while operating the maize dehusker-shellerin standing posture

Subject	Cranking speed /r min^{-1}	Feed rate /kg cobh^{-1}	Output /kg grainh^{-1}	Shelling efficiency/%	Grain breakage/%
S1	51	70.96	48.25	97.78	1.46
S2	52	72.00	50.40	97.22	0.88
S3	54	81.45	58.91	97.54	0.86
S4	55	76.06	54.10	99.12	0.32
S5	55	80.60	59.64	99.10	0.16
S6	56	76.81	56.33	98.32	0.49
S7	56	93.10	67.66	99.12	0.82
S8	58	95.07	69.40	98.72	0.91
S9	58	94.74	66.95	98.70	0.85
S10	60	95.07	71.62	99.09	1.45
Mean	56	83.59	60.33	98.47	0.82
S.D.	2.76	9.94	8.23	0.72	0.42

ii) Sitting posture

The hand cranking speed of subject varied from 50 to 58 r min^{-1} (average 54 r min^{-1}) (Table 5). Subject-wise feed rates varied from 62 to 99 kg (average 82.96 kg h^{-1}). The variation in feed rates might be due to the subject. The average output was 57.57 kg h^{-1} and variation was from 42 to 69 kg h^{-1}. Only one un-dehusked cob having weight of about 75 g was observed at kernel outlet with two subjects in this posture when cranking speed was 58 r min^{-1}, therefore, the dehusking efficiency was 99.5%. The shelling efficiency varied from 96 to 98% (average 97.16%). The coefficient of variation for shelling efficiency was 0.7%. The grain breakage varied from 0.20 to 1.78% with average of 0.75%. It was observed from the table that the grain breakage was high at hand cranking speed of 58 rpm. This might be due to high impulse force with respect to cob during dehusking-shelling at speed of 58 r min^{-1}. Positive correlation was obtained between hand cranking speed, output with cob and grain-wise (0.883 to 0.907) and shelling efficiency (0.842) at 1% level.

Table 5 Feed rate, output, shelling efficiency and grain breakage while operating the maize dehusker-shellerin sitting posture

Subject	Cranking speed /r min^{-1}	Feed rate /kg cobh^{-1}	Output /kg grainh^{-1}	Shelling efficiency/%	Grain breakage/%
S1	51	65.45	44.51	96.50	0.57
S2	52	61.64	41.92	96.25	0.62
S3	50	70.00	48.00	96.10	0.6
S4	54	79.06	54.03	97.06	0.68
S5	53	83.72	58.88	97.20	0.20
S6	55	89.70	64.29	97.91	0.40
S7	55	93.26	64.97	97.81	0.59
S8	57	94.57	63.36	97.32	0.74
S9	56	93.43	66.64	97.80	1.35
S10	58	98.72	69.10	97.70	1.78
Mean	54	82.96	57.57	97.16	0.75
S.D.	2.60	13.29	9.83	0.68	0.46

4 Conclusions

The ODR and BPDS clearly indicated that the standing posture could be better option for operation of the maize dehusker-sheller. The entire subjects easily operated the hand operated maize dehusker-sheller with either left or right hands. Since two workers are required for its operation (one for feeding and other for cranking), if they are swapped, the equipment can be operated for 1 hand thereafter a rest of about 15 min could be provided. Hand operated maize dehusker-sheller was found to reduce the physiological cost by 38.95% and 21.62% in dehusking- shelling the maize cob with hand, and shelling the maize cob with hand & octagonal maize sheller respectively.

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