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Design of Ergo Friendly Sickle for Population of Bastar Tribal of Chhattisgarh

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Abstract: ***In India, a large amount of tribals concentrated in Bastar region of Chhattisgarh. The livelihood of tribal are mainly depended on forest produces followed by Badi cultivation. To perform the shredding of trees and harvesting of crop like paddy and wheat etc women prefer traditional sickles. It was learnt that traditional tools including sickles are injury prone and uncomfortable during crop harvesting. To provide the better comfort and safety, the design of 12 different local sickles with 12 selected subjects were investigated during harvesting of paddy and wheat crop. It observed that the blade geometry contributes significantly to measured physiological parameter therefore the blade geometry is optimized. The anthropometric data of selected subject were collected and incorporated in design of the sickle and handle, particularly. The handle length was designed considering 95th percentile value of hand breadth cross the thumb i.e. 12.6 cm and handle diameter 5th percentile value of inside grip diameter i.e. 3.2 cm. Physiological assessment with sickle stated that the average heart rate was 114 bpm whereas energy expenditure rate found to be 9.40 kJ/min with 0.6198 l/min oxygen consumption rate. The performance of the newly designed sickles covers 20.5 m^2 /h which is more than the traditional sickle. It also reduced the cost of harvesting and reduction in farm labours by 47% and 20% respectively. It is concluded that the new design of sickle is suitable for the Bastar tribals and reduced injury and drudgery.***

Keywords: Ergonomics, Bastar, Tribals, Harvesting, Sickle

1. Introduction

Chhattisgarh is tribal dominated area where farm women play a vital rolein agricultural activities.According to Census 2011 tribal population of Chhattisgarh region is 7.8 million out of which 5.0 millions are engaged in agricultural.As far as the statistics of male and female engaged in agricultural work is concerned in Bastar female are involved more in farming activities. Census revealed that about 1.72 million of female population out of 2.87 million engaged in agriculture. Bastar population has low socio- economic status with limited power availability. It was studied by Chandrakar *et al.* (2013) that the power availability of this region is 0.44kW/ha which is far less than nation average i.e. 1.6 kW/ha. Although mechanization has reached in many parts of the country but still farming operations in Bastar are traditional one. This is due to lack of knowledge, low financial status, etc. Numerous handmade or traditional made tools are being used like sickle, farsha, tangia, etc as it is simple and easy to construct. For harvesting farm women prefers sickle which is called '*Heera*' in their local language. It is the curved blade attached with the wooden handle. This sickle many be used in other operations like weeding and small earth works. Beside this farm women perform harvesting by sickle during which injuries may occur. It has been reported by Yadav *et al.* (2010) that involvement of women was highly observed in harvesting (84%) and interculture operations (86%). Also it was reported that the maximum participation of women for rice crop (78.18%), followed by wheat (12.76%), pea (3.22%) and blackgram (2.41%) was observed. To perform this operation women go through various postures like sitting, squatting, stooping (Fig.1), sitting cum bending, standing cum bending, standing erect etc. This may cause ill effects like musculoskeletal disorders and occupational health risk. It has been reported by Mohan and Patel (1992) that maximum injuries occurred while working with hand tools like spade (24%), followed by sickles(23%). This not only causes physical disability but also economic hardship to the family. In order to reduce the postural discomfort and hazards, an ergonomic evaluation of occupational and farm activities needs to be conducted. It is unfortunate that the role of Bastar farm women have not been focused till today.

Figure 1: Stooped working posture

To improve the conditions of work and to reduce the fatigue during the work in the agriculture field, this is crucial to find the relationships between the ergonomics and various machine parameters. This analysis will be done by examining the different works earlier done by the scientists.Kumar *et al.*, (2008) suggested an ergonomic intervention in form of finger guard made of Teflon cloth to save upper limb injuries.To assess the suitability of the commercial sickle with local, Singh (2012) compared the Naveen, Vaibhav and local sickles during harvesting of paddy crop with 12 farm women at CIAE, Bhopal. The average heart rate during harvesting operation of sickles were 103 bpm, 107 bpm and 106 bpm respectively. The workload was under acceptable limit for day-long work with normal rest pause for studied sickles. It was reported by Pandey *et al.*, (2013) that Naveen sickle increased the output

by 6.9 per cent over the *deshi* sickle. Also area harvested increase by 4.7 per cent over the *deshi* sickle. The working heart rate observed was minimum for Naveen sickle i.e. 104bpm. Singh *et al.*,(2014) revealed that the working efficiency increased by 19.5% on using serrated sickle and also saving 19 % in cardiac cost of workers per unit of output. Aware *et al.*, (2016) evaluated ergonomically the existing and modified sickles. It was found that the field capacity of improved Vaibhav sickle was 112 m^2/h that was 13.1% higher than existing Vaibhav sickle i.e. 99 m2/h.

2. Material and Method

For the analyses of the design of ergo friendly sickle for Bastar farm women we will observe the sickle used by the farm women. For that subjects were selected from Kumhrawand, Palligaon, Tandpal, Negiguda, Lamker and Tahkpalvillage where the subjects are the representative of the tribals residing in Bastar region. From these villages 12 subjects were selected with sound health status. Subsequently, problems related with sickles preferred by them were studied and analyzed. For ergonomical analyses physiological responses such as heart rate, oxygen consumption rate and energy expenditure rate were measured with specific instruments and analyzed. Also the qualitative parameters were also analyzed.

Details of the experiment

Independent parameters		
Harvesting		
Local sickle	12	L_1, L_2, L_3, L_4, L_5,L_6, L_7, L_8, L_9, L_{10}, L_{11}, L_{12}
Improved sickle	02	I_1, I_2
Commercial sickle	05	C_1, C_2, C_3, C_4, C_5
Subjects	12	S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}
Crop	02	Paddy, Wheat

Dependent parameters:
Ergonomical Parameters: Heart rate (HR), Oxygen Consumption Rate(OCR), Energy Expenditure Rate(EER), Body Part Discomfort Score(BPDS), Overall Discomfort Rate (ODR)
Field Performance: Effective field capacity, Man-h and labour requirment

2.1 Selection of operation

There is wide gap between the agricultural technologies among Bastar region. They still go through the tedious methods of harvesting i.e. by sickle which are manufactured by local blacksmith. Therefore to study the quantitative and qualitative performance of the tools, 12 traditional sickles were selected from the local market. Along with the 2 improved sickles and 5 commercially available sickles were selected to compare the optimization of the tools design. The study was done for harvesting of paddy and wheat. Further, geometry of the sickle (Fig.2) were studied and compared with Bureau of Indian Standards. Table 1 represents the specifications of sickle.

Table 1: Specifications of Sickle

S. No	Particulars of sickle in accordance with IS 4358 (1996)	Notation	Definition
1.	Base plate	A	width of base of the sickle blade where blade and handle is attached
2.	Blade width	B	Maximum width of cutting blade of the sickle
3.	Blade thickness	C	Width of blade from cutting surface to other surface of the sickle
4.	Cutting surface (CS)	D	Total length of the toothed edge of the curved blade. Surface may be plain or with marrow serration.
5.	Outer length of blade	E	The other surface of the sickle
6.	Concavity of blade	F	The state of cutting surface of being concave
7.	Sickle length	G	Total length of the sickle from top of outer surface of sickle to the handle bottom
8.	Maximum handle length	H	Part of holding in of the sickle
9.	Maximum handle diameter	I	For better power grip of the tool
10.	Length of ferrule	J	Protective metallic bush at the junction of blade and handle to keep the tang tight in the handle.
11.	Chord length (CL)	L	Length of the inner surface of the sickle from tip of the blade to the end blade
12.	Pitch	-	The distance between the teeth
13.	Radius of curvature	-	It is the radius of circle that fits normal section of the curve.

Source: Singh (2012)

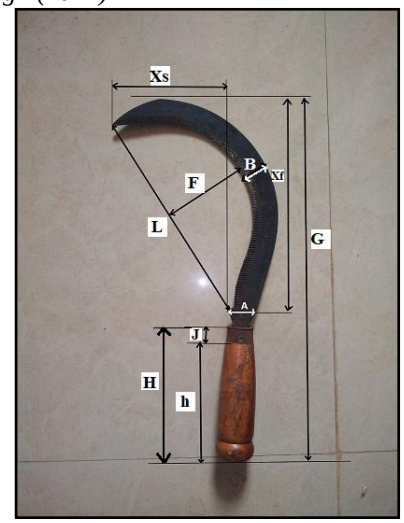

Figure 2: Dimensions of sickle

Figure 3: Pictorial representation of local sickles

Figure 4: Pictorial representation of improved and commercial sickles

2.2 Selection of subjects

To conduct the experiments, subjects (women) were selected from the age group of 20-45 years under self-farming category based on their origin. It was ensured that the selected subjects must be true representatives of their respective tribes. Total 12 farm women were selected randomly and their distributions among ethnic groups were based on the population in the village. Farm women were screened for normal health with general medical investigations like blood pressure and pulse rate etc. It assured that nobody is handicapped, dwarf, giant and musculoskeletal injury. All measured anthropometric dimensions (Table 2) were statistically analyzed for the value of maximum, minimum, mean, percentile value and coefficient of variance.

Table 2: Selected anthropometric dimensions of tribal women (N= 12).

Parameters	Mean	Min	max	SD	CV(%)	SE	5^{th}	95^{th}
Weight , kg	46.5	34	76	7.29	15.67	0.73	34.5	58.5
Stature	152.3	140	187	8.06	5.29	0.81	139.0	165.5
Hand thickness at metacarpal-III	3.8	2.3	6.8	0.96	25.48	0.07	2.2	5.3
First phalynx digit -III length	5.9	3.5	6.8	0.48	8.03	0.05	5.2	6.7
Palm length	9.2	2.5	11	1.02	11.01	0.10	7.6	10.9
Grip diameter (inside)	3.7	2.4	5	0.56	14.97	0.06	2.8	4.6
Grip diameter(outside)	5.7	3.5	7.5	0.75	13.02	0.07	4.5	7.0
Middle finger palm grip diameter	3.3	2.1	6.7	0.86	26.37	0.06	1.9	4.7
Grip span	8.1	4	12.5	1.43	17.70	0.14	5.7	10.5
Maximum grip length	11.4	2.8	17.5	2.32	20.31	0.17	7.6	15.2

2.3 Physiological parameters

Experiments were started at 07:30 am and subjects were asked to report at field. Pre-checks for health conditions have been done and after satisfactorily report from medical personal, women were allowed to perform harvesting operation. The environmental conditions like dry bulb and wet bulb temperature along with relative humidity were taken. Before starting the experiments, subjects were asked to take rest for 15 minutes so that resting heart rate could be measured. Experiments were performed for 30 minutes and after that subjects are allowed to take rest until HR reduced to initial heart rate or near about. The experiments were replicated thrice and average working heart rate was calculated. Further, oxygen consumption rate (OCR) determined with the help of formula given by (Singh et al., 2008).

- ***Measuring of heart rate***

To measure the heart rate of subjects, commercial heart rate monitor is used. The HR monitor is available with chest strap for taking heart rate of the selected subject. Monitor receives the signal from chest strap and indicates the heart rate in beats per minute (bpm). Further, ΔHR could be calculated;

$$\Delta HR = HR_{work} - HR_{rest} \quad \text{… eq. (2.1)}$$

Where;

ΔHR = increase in Heart rate, bpm

HR_{work} = working Heart Rate, bpm

HR_{rest} = Resting Heart Rate, bpm

- ***Determination of oxygen consumption rate***

The oxygen consumption rate is the amount of oxygen inhaled by the women per unit time and computed from the heart rate of the subject. It represents an individual capacity to utilize oxygen. It states that a point is reached where increase in work rate is no longer accompanied by increase in oxygen uptake and the individual is assumed to have reached her maximum level of oxygen uptake and is given by the following equation (Singh *et al.*, 2008).

$$OCR = 0.0114 \times HR - 0.68 \quad \text{…eq. (2.2)}$$

Where;

OCR= oxygen consumption rate (l/min)

HR= heart rate (bpm)

- ***Predication of energy expenditure rate-***

Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical activities such as breathing, blood circulation, food digestion and body movement. The energy expenditure rate (EER) could be determined directly by multiplying the OCR with the calorific value of oxygen as 20.93 kJ/l (Nag *et al.*, 1980). The energy expenditure (KJ/min) could also be estimated using formula proposed by Varghese *et al*. (1994) as follows;

$$EER = 0.159 \times AHR - 8.72 \quad \text{… eq. (2.3)}$$

Where,

EER = Energy Expenditure Rate (kJ/min)

AHR = Average Heart Rate (bpm)

- ***Predication of Overall Discomfort Rating***

The overall discomfort rating during harvesting and threshing operation experienced by the selected Bastar farm women estimated by the point on the psychophysical rating scale i.e. the 0 to 10-point rating scale which shows that 0 is no comfort to 10 as extreme discomfort. A scale of 70 cm length having 0 to 10 digits marked equidistantly as shown Fig.5.

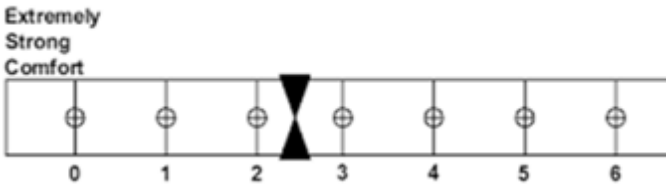

Figure 5: Visual analogue discomfort scale for evaluation of overall body discomfort (Borg, 1982)

- ***Determination of Body Part Discomfort Score***

For the localization of different Body part discomfort score the body diagram as shown in Fig.6 divided in to 27 numbers of regions, on the basis of Corlett and Bishop Technique, the body diagram chart used during the experiments. For the same the subject was asked to mention all body parts with discomfort, starting with the worst and the second worst and so on until all parts were mentioned

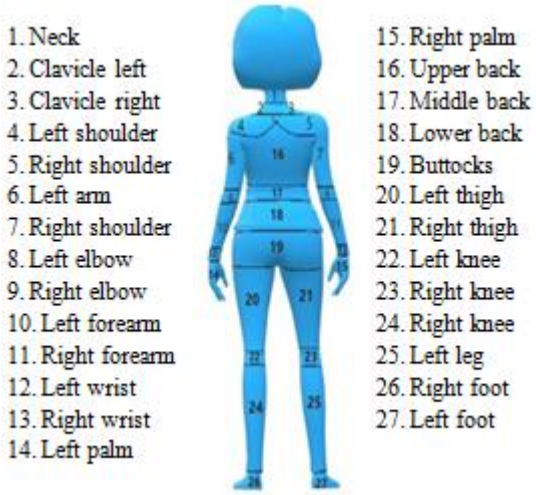

Figure 6: Body map showing different region used in study for knowing BPDS (Corlett and Bishop, 1978)

3. Results

It is observed that harvesting is mainly performed by Bastar farm womenlittle late after sunrise. They have opinion that due to moisture of overnight dew, it creates slip during harvesting and hence causes hand injuries Fig.7. It is also observed that the sickles preferred were designed by local black smith with no such ergonomically fit design. It was also observed that the sickle used were of different geometrical considerations. Further it is observed that serration at cutting edges were not uniform due to local techniques. Also the after long hours of operation the serration may get blunt.Farm women experience callus in their hand marked with red in Fig.7due to stiffness of the handle. It was also observed that the sickle blade was loosely attached with the ferrule which hinders during harvesting. Therefore, for further study 12 traditional sickle (L1-L12) of local design were collected from local smith, 5 commercial sickles (C1-C5) and 2 improved sickles(I1-I2) were opted for comparative study.

Figure 7: Hand injuries while harvesting

3.1 Study of sickle characteristics

The characteristics of the sickle such as concavity, weight, blade geometry etc are given in Table 3. It was observed that none of the local sickle made out the standard criteria as per BIS recommendation whereas improved sickle is a bit change with traditional one in terms of base width (A) particularly which provide proper gripping of the tool. It was learnt that little finger is much prone to rubbing in low clearance cutting.

Table 3(A): Specifications of traditional studied sickles

Particulars	BIS (1967)	Traditional sickle					
		L1	L2	L3	L4	L5	L6
Base Plate (A)	12±2	10*	8	9	7	8	14*
Blade width (B)	28±3	15	23	28	22	21	17
Blade thickness (C)	4±0.5	4	2	2	2	1.5	4
Cutting surface (CS) (D)		336	338	330	340	310	315
Outer length of blade (E)		353	354	345	352	325	330
Concavity of blade (F)	59	73	76	56	51	69	64
Sickle length (G)		332	322	365	326	312	341
Maximum handle length (H)	125	105	93	103	105	91	113
Effective length (h)		105	93	103	105	91	113
Maximum handle diameter(I)		25	35	30	25	30	29
Length of ferrule (F)	>20	-	-	-	-	-	-
Chord length (CL) (L)	224±3	220	221	260	220	206	230

*All dimensions in mm

Table 3(B): Specifications of traditional studied sickles

Particulars	BIS (1967)	Traditional sickle					
		L7	L8	L9	L10	L11	L12
Base Plate (A)	12±2	12	15*	13*	8	12*	9
Blade width (B)	28±3	18	16	17	16	15	16.5
Blade thickness (C)	4±0.5	3	3.5	3.7	3.9	3	3.8
Cutting surface(CS) (D)		345	335	336	342	260	276
Outer length of blade (E)		358	405	352	355	300	300.6
Concavity of blade (F)	59	71	80	72	63	71	65
Sickle length (G)		356	360	360	336	351	349
Maximum handle length (H)	125	124	117	121	104	115	112
Effective length(h)		106	102	121	-	-	-
Maximum handle diameter (I)		23	29	30	28	27	29
Length of ferrule(F)	>20	14	15	-	-	-	-
Chord length (CL) (L)	224±3	214	235	232	225	235	228

*All dimensions in mm

Further, seven selected commercial sickle were investigated for their design. It was seen that commercial one are

following the standard norm some variations were available but not much deviating from norms (Table 4). It was observed that the ferrule is present in every sickle which is not available in traditional sickles.

Table 4: Specifications of commercial sickle

Particular	BIS (1967)	Types of sickles						
		I1	I2	C1	C2	C3	C4	C5
Base Plate (A)	12±2	56	23	13	15	16	13	13
Blade width (B)	28±3	23	23	24	34	35	23	24
Blade thickness (C)	4±0.5	1.5	2	1.5	4.5	1.4	2	2
Cutting surface(CS) (D)		252	277.3	273	235	157	240	252
Outer length of blade (E)		323	340	353	300	181	267	355
Concavity of blade (F)	59	51	52.5	65	25	45	52	53
Sickle length (G)		375	380	335	390	268	274	367
Maximum handle length (H)	125	126	130	118	165	115	110	125
Effective length (h)		110	116	104	76	100	95	115
Maximum handle diameter (I)		32	32	33	22	20	29	30
Length of ferrule (F)	>20	15	15	14	60	15	13	9
Chord length (CL) (L)	224±3	225	232	206	220	114	165	235

3.2 Evaluation of design criteria of sickles

The weight of sickles affects the muscles of wrist which may be affected if heavier sickle is used for longer hours of harvesting crop. According to Nag *et al.*,(1988) the weight of sickle should be around 200g. The weight of the sickle C_5 is maximum that is 335g followed by C_1 304g. The weights of traditional sickles are observed to be in the range of 185-212 g as shown in Table 8.

Pitch defines as the number of teeth present in per unit length cutting of crop become possible due to action of hand which apply shear force. Improper and non uniform serration creates difficulty in cutting the crop stems such practice push farm women to exert higher hand pressure which creates callus in hands. This makes user feel stress and difficulties. It is observed that all sickles except C_3 and C_5 are serrated. The radius of curvature helps to hold a greater number of plants while harvesting the crop as more number of plants can be wrapped. It was observed that the traditional sickles are having abrupt curvature due to less radius of curvature and commercialized sickles I_1, C_2 and C_5 are with gentle curvature that allows smooth movement of the sickle due to more radius of curvature as shown in Table 8.

Further, it was observed that the CS-CL ratio which is the ratio of length of cutting surface to the length of the hand movement sickle C5 indicates more hand movement as compared to other sickle whereas cutting surface is identified in all sickle. However, the CS-CL ratio observed to be higher for traditional sickle L7, L4, L1 and L2 as shown in Table 8.This shows that the cutting surface is more. If the cutting length is more the area of cuts will be less i.e. stroke and hence, lesser forward movement. Hence it was learnt that the CS-CL ratio was used for optimizing the other dimensions of the sickle as Aware *et al.*,(2016).

Table 8: Evaluation of design criteria of sickles

Type of sickle		Weight(g)	Pitch	Radius of curvature	CS-CL ratio	Xs/CS	Xf/CS
BIS (1967)			1.5				
Traditional sickle	L_1	188	2	135.4	1.53	0.4	0.70
	L_2	190	2	142.5	1.53	0.35	0.68
	L_3	193	1.5	122.5	1.27	0.33	0.64
	L_4	200	1	133.4	1.54	0.38	0.71
	L_5	212	1	125.2	1.50	0.34	0.72
	L_6	196	2	138.4	1.37	0.42	0.62
	L_7	185	1.5	128.5	1.61	0.36	0.67
	L_8	189	1.5	137.2	1.42	0.41	0.69
	L_9	198	1	145.7	1.45	0.37	0.70
	L_{10}	197	1.5	126.5	1.52	0.34	0.60
	L_{11}	195	1.5	136.4	1.11	0.35	0.62
	L_{12}	194	2	127.2	1.21	0.38	0.64
Improved sickle							
	I_1	183	2	214.8	1.12	0.35	0.83
	I_2	217	1.5	137.9	1.19	0.43	0.7
	C_1	304	1.5	79	1.33	0.3	0.62
	C_2	280	1.5	178	1.07	0.44	0.76
	C_3	105	Plain	62.3	1.38	0.388	0.636
	C_4	162	Plain	75.8	1.45	0.26	0.54
	C_5	335	1.5	146.1	1.07	0.56	0.73

3.3 Field Performance oftraditional sickles

Different sickles were tested with two major crop of Bastar region i.e. paddy and wheat. To perform the operation, farm women were ask to operate their traditional sickle for paddy crop harvesting. It was observed that farm women harvest an average area about 45.8 m^2/h the effective field capacity (EFC) was found to be 0.0045 ha/h. Further, it was estimated that about 221 man-h could be required to harvest the 1ha field. Based on the experimental trait it was calculated that 20-33 farm women could be require to harvest paddy of 1 ha/hourTable 9 shows the above mentioned data. Such machine parameter gives the estimation about INR 6364/- as cost of harvesting operations.

Table 9: Field Performance of during harvesting with traditional sickles

Type of sickle	Area covered(m^2/h)		EFC(ha/h)		Man -h required/ha		Labour req/h		Cost of harvesting INR per ha	
	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat
L_1	48.5	42.5	0.00485	0.00425	206.2	235.3	26	29	5927.8	6764.7
L_2	45.7	41.2	0.00457	0.00412	218.8	242.7	27	30	6291.0	6978.2
L_3	53.8	55.5	0.00538	0.00555	185.9	180.2	23	23	5343.9	5180.2
L_4	38.4	32.7	0.00384	0.00327	260.4	305.8	33	38	7487.0	8792.0
L_5	42.5	43.2	0.00425	0.00432	235.0	231.5	29	29	6756.8	6655.1
L_6	41.4	46.5	0.00414	0.00465	241.1	215.1	30	27	6931.1	6182.8
L_7	39.2	40.1	0.00392	0.00401	255.1	249.4	32	31	7334.2	7169.6
L_8	42.2	42.1	0.00422	0.00421	237.0	237.5	30	30	6812.8	6829.0
L_9	50.6	48.6	0.00506	0.00486	197.6	205.8	25	26	5681.8	5915.6
L_{10}	44.2	46.2	0.00442	0.00462	226.2	216.5	28	27	6504.5	6222.9
L_{11}	45.8	42.1	0.00458	0.00421	218.3	237.5	27	30	6277.3	6829.0
L_{12}	57.2	58.4	0.00572	0.00584	174.8	171.2	22	21	5026.2	4922.9
Mean	45.8	44.9	0.00458	0.00449	221.3	227.3	27.6	28.4	6364.5	6536.8

For harvesting wheat mean area covered for harvesting is 44.9m^2/hour the effective field capacity was found to be 0.0044 ha/h. It was calculated that about 227 man-h are required to complete 1ha harvesting. The farm women required to harvest the wheat crop of 1 ha per hour are 21-38. The cost for harvesting wheat crop is about INR 6500/-. It was observed that the about 2 % less area can be covered while harvesting wheat with traditional sickles as shown in Table 9. This hence increases the cost of harvesting of wheat with traditional sickles by 2.1 %. It was also learnt that the area covered for harvesting is higher in case of sickle L12 i.e. 57.2 m^2 and 58.4 m^2 for paddy and wheat harvesting respectively as shown in Table 9. Hence, for the refinement of sickle design parameters of L12 are considered.

3.4 Field Performance of improved and commercial sickles

After the assessment of traditional sickles the farm women were given enough training for harvesting with improved and commercial sickles. Table 10 shows the performance assessment on harvesting paddy and wheat crop. It was observed that the average area covered on harvesting paddy is 58.3 m^2 which is 27.5 % more than the traditional sickle. Also for harvesting wheat is 57.9 m^2 area is covered which is about 30% more than the traditional one. It was observed that the area covered by the I_2 is more followed by C_3 and I_1sickles. By harvesting with the traditional sickle average area covered is around 44.9 m^2/h which is 48.7% lower than the I2sickle. This interpreted that the performance of I2 sickle will be greater along with the effective field capacity hence the man hour required for harvesting is 123.1 h. It was found in the current study that maximum man-h requirement per ha and number of labour per ha was needed were more in case of Traditional sickle (L1-L12) i.e. 305.8 and 38 but minimum man-h requirement per ha and number of labour per ha in case of I2 is 123.2 and 15 respectively.

Table 10: Performance while harvesting paddy and wheat withImproved and commercial sickles

Type of sickle	Area covered(m^2/h)		EFC(ha/h)		Man -h required/ha		Labour req/h		Cost of harvesting INR per ha	
	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat
I_1	64.3	63.4	0.00643	0.00634	155.5	157.7	19	20	4471.2	4534.7
I_2	81.2	83.1	0.00812	0.00831	123.2	120.3	15	15	3540.6	3459.7
C_1	50.3	48.5	0.00503	0.00485	198.8	206.2	25	26	5715.7	5927.8
C_2	53.6	52.5	0.00536	0.00524	186.6	190.8	23	24	5363.8	5486.6
C_3	65.4	64.2	0.00654	0.00642	152.9	155.8	19	19	4396.0	4478.2
C_4	49.8	51.4	0.00498	0.00514	200.8	194.6	25	24	5773.1	5593.4
C_5	43.5	42.5	0.00435	0.00425	229.9	235.3	29	29	6609.2	6764.7
Mean	58.3	57.9	0.00583	0.00579	178.2	180.1	22.2	22.5	5124.2	5177.8

3.6 (a) Assessment of HR during harvesting

The resting heart rate was measured prior to the harvesting operation and average of the resting HR is calculated. It was observed while harvesting paddy with the traditional sickle that the average working HR is maximum by using L7 traditional sickle i.e. 143.33 bpm followed by L10and L3 sickle i.e. 130.9, 130.2 bpm. The minimum HR is observed with L4sickle i.e. 113.8 bpm depicted in Table 11. The lower HR values were observed as the farm women are habitual in using their sickles.

Prior to the harvesting with the commercial and improved sickle farm women were trained. The average working HR is maximum by using C4 and C5 sickle i.e. 140.5 and 130.8 bpm. The minimum HR is observed with I2sickle i.e. 112.0 bpm. The minimum average HR is observed by improved sickle I2 i.e. 112.0 bpm which is 28.5 %, 26 %, 17.3 %, 17.3 % lesser than the L7, C4, L10, C5 respectively. It was analyzed that comparatively lower HR value was observed in improved sickle rather than commercial and traditional sickle. It was interpreted that the working with improved sickle provides ease of work to the worker. Commercial sickles are designed according to different working purpose such as weeding, cutting hard stems and horticulture activities. But improved sickle are designed according to the anthropometric data and selectively for harvesting purpose.

During harvesting wheat the physiological responses are while resting is measured prior to the harvesting operation and average of the resting HR is calculated. It was observed while harvesting wheat with the traditional sickle that the average working HR is maximum by using L7 traditional sickle i.e. 146.2 bpm followed by L10and L3 sickle i.e. 127, 127.5 bpm. The minimum HR is observed with L4sickle i.e. 116.5 bpm depicted in Table 11. During harvesting with improved and commercial sickles the average working HR is maximum by using C4 and C5 sickle i.e. 134.5and 132.3 bpm. The minimum HR is observed with I2sickle i.e. 114.5 bpm.

Table 11: Physiological parameters of selected subject during harvesting paddy and wheat crop

Type of sickle	Avg working HR (bpm)		Avg working OCR (l/min)		Avg working EER (kJ/min)	
	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat
L_1	124.7	134.2	0.7416	0.850	11.11	12.618
L_2	118.7	125.1	0.6732	0.746	10.15	11.171
L_3	130.2	127.5	0.8043	0.774	11.98	11.553
L_4	113.8	116.5	0.6173	0.648	9.37	9.8040
L_5	119.3	126.4	0.6800	0.761	10.25	11.378
L_6	120	124.5	0.6880	0.739	10.36	11.076
L_7	143.3	146.2	0.9536	0.987	14.06	14.526
L_8	121.4	123.4	0.7040	0.727	10.58	10.901
L_9	127.4	125.0	0.7724	0.745	11.54	11.155
L_{10}	130.9	127.0	0.8123	0.768	12.09	11.473
L_{11}	121.9	120.0	0.7097	0.688	10.66	10.360
L_{12}	128.5	124.5	0.7849	0.739	11.71	11.076
I_1	120.1	118.3	0.6687	0.669	10.09	10.090
I_2	112.0	114.5	0.6161	0.625	9.36	9.4860
C_1	117.0	120.0	0.6727	0.688	10.13	10.360
C_2	118.2	117.5	0.6671	0.660	10.07	9.9620
C_3	119.5	112.4	0.6823	0.601	10.28	9.1520
C_4	140.5	134.5	0.9217	0.853	13.62	12.666
C_5	130.8	132.3	0.8106	0.828	12.07	12.316

3.6 (b) Assessment of OCR during harvesting

The resting OCR was calculated through resting HR and the working OCR was also calculated through working HR. During harvesting paddy with traditional sicklesit was observed that working OCR was maximum for L7 i.e. 0.987 l/min followed by L1i.e. 0.8123l/min. It was observed while harvesting paddy with the traditional sickle that the average working OCR is maximum by using L7 traditional sickle i.e. 0.9536 l/min. followed by L10sickle i.e. 0.8123 l/min. The minimum OCR is observed with L4sickle i.e. 0.6173 l/min depicted in Table 11. The lower OCR values were observed as the farm women are habitual in using their sickles.

The average working OCR is maximum by using C4 and C5 sickle i.e. 0.9217 and 0.8106 l/min. The minimum OCR is observed with I2sickle i.e. 0.6161 l/min.While harvesting wheat the resting OCR was calculated through resting HR and the working OCR was also calculated through working HR. It was observed that working OCR is maximum for L7 i.e. 0.987l/min followed by L1 sickle i.e. 0.85l/min. The average working OCR is maximum by using C4 and C5 sickle i.e. 0.853 and 0.828 l/min. The minimum OCR is observed with I2sickle i.e. 0.625 l/min.

3.6 (c) Assessment of EER during harvesting

The result presents that need of higher amount of energy while C1 sickle was used but while I2 sickle was used comparatively lower amount of energy was needed with respect to other sickles. The energy expended while using the I2 was 9.357 kJ/min where as it was observed higher energy expenditure while using L7 it is 14.07 kJ/min. The workload was found lower in case of C3, followed by I2, L4.

On the harvesting operation of wheat crop the result represents that need of higher amount of energy while C1 sickle was used but while I2 sickle was used comparatively lower amount of energy was needed with respect to other sickles. The energy expended while using the C3 sickle was 9.152kJ/min where as it was observed higher energy expenditure while using L7 it is 14.52 kJ/min. The workload was found lower in case of C3, followed by I2, L4. The energy expenditure was observed lower in some traditional sickle as the farm women were habitual in using it.

3.6 (d) Body part discomfort score

The mean body discomfort score as per Corlett and Bishop scale (1975) on harvesting of paddy and wheat crop for all the selected subjects as shown in Fig.8.The body region that are affected due to harvesting red area shows the severity of the pain The harvesting for long time in bending posture creates the higher discomfort feelings to lower back i.e. 6.5 followed by the right and left thigh due to static posture for longer time there is strain in the thighs. Due to cutting of crop in pulling motion of hand in curved path subjects felt pain in right and left wrist i.e. 5.9 and 5.2 score respectively. Also the discomfort is in right and left hand i.e.6.2 and 5.8 respectively. Foot is also the pain area as whole body weight lies on the foot and working continuously for 8h harvesting may cause pain in foot. Continuous bending posture has resulted in higher discomfort feeling to the subject at lower back and continuous dynamic motion of the hand muscle for longer hours increased the level of discomfort of the subject.

Figure 8: Localization of the effective body region while harvesting operations

3.6 (e) Overall discomfort rate

The highest ODR observed after harvesting with different types of sickles was during harvesting with L7 sickle i.e. 7.89 followed by L10 (7.2) and L3 (7). The Fig.9 depicts that the ODR is minimum in I_2 as 5.1 followed by I_1 as 5.2. The discomfort is experienced by the subject due to imperfect design of the traditional sickle. This shows that the improved design of the sickle reduces the ODR of the subjects and hence provides reference for further modification in the traditional sickles.

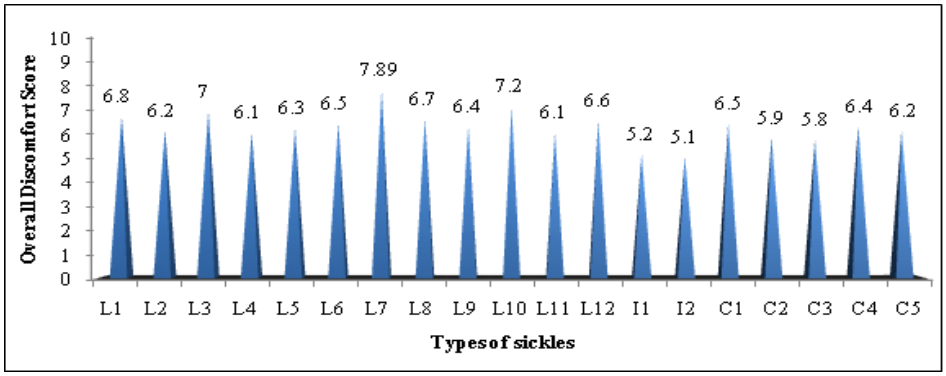

Figure 9: Overall discomfort score

3.7 Ergonomic Interventions for Drudgery Reduction

Subsequent physiological responses and the workload assessment of different sickle during harvesting of paddy and wheat, observed that the sickle are mismatch ergonomically in view of anthropometric data, muscular strength and aerobic capacity. Further proceeding to new design of tool, some selected ergonomic interventions are implicated with the existing tools for enhancing the suitability and performance of the sickle. Such intervention may reduce the drudgery and workload on farm women during crop harvesting.

3.7(a) Cushioning material

It was learnt that traditional sickle causes callus due to excessive hand pressure during crop harvesting so handle grip was suggested. For cushioning effect elastomer or rubber is used as suggested by Vidhu (2011). The sickle handle were covered by selected rubber grip and given to farm women performing the harvesting operation. They reported that handle provided better gripping because of non slippery movement. The cutting of crop was comparatively easier. The modifications to the handle of sickles L1-L12 were implicated. Earlier handle was cylindrical in shape which was turned into little tapered (2) shape. It allows proper gripping and uniform distribution of grip forces around the hand. The pressure distributionon gripping a cylindrical handle forms a closed system of forces in which portions of the digits and palm are used, in opposition to each other, to exert compressive forces on the handle. The physiological responses of each sickle were observed again. It was observed that the heart rate is about 120 bpm, OCR is 0.689 l/min and EER is 10.38 kJ/min. The subjective response after application of cushioning over the sickle handle it was known that the sickles L2, L4 and L11 are better according to farmers and L3, L5, L6 and L9 are good sickles and rest are average and not good as shown in Table 12. It was observed that the rubber covering is highly acceptable by the farm women.

Table 12: Subjective response for traditional sickle after ergonomical interventions

Sickles	Farmers Opinion	Heart Rate (bpm)	Sickles	Farmers Opinion	Heart Rate (bpm)
L_1	Not good	122.1	L_7	Not good	134.4
L_2	Better	119	L_8	Average	126.2
L_3	Good	128	L_9	Good	124.2
L_4	Better	120.2	L_{10}	Average	127.7
L_5	Good	125.1	L_{11}	Better	120.4
L_6	Good	124.5	L_{12}	Not good	126.5

3.7(b) Weight reduction of sickle

It was understood that the sickle weight is also significant in working efficiency of the farm women. The heavier sickles are incorporated for impact cutting which is not used for cereal crop cutting as given by Nag (1988). Therefore, the weight of sickle is reduced by implicating handle with plastic handle material and which hence reduces the weight and required material for the construction of the sickle. This improves the centre of mass of the sickle and requires less hand wrist movement for harvesting operation. As reported by Nag (1988) that weight of sickle should be around 200 g blade thickness was reduced to get the desired weight.

Aforesaid findings suggested that limited sickles werefound suitable for the farm women of Bastar. It was observed that mismatch with the anthropometric dimensions were major issue. Further, to meet out the anthropometric dimensions. Some selected ergonomic intervention, which were proven good were already implicated over existing sickle. It was found that L traditional sickle improvised a lot and farm women accepted it extensively.

In due course of investigation fabrication of new sickle was done. Local smith men were contacted and 15 sickles were asked to fabricate with following design criteria.

3.8 Handle length

For proper accommodation of the sickle handle in palm the design of the handle requires anthropometric dimension i.e. hand breadth across thumb and inside grip diameter

(Dewangan *et al.*, 2008). These two anthropometric dimension of 100 subject of Bastar farm women suggested that the 5th percentile value is about 7.3 cm and 2.8 cm and 95th percentile value is 10.5 cm and 4.6 cm. The mean values are 8.9 cm and 3.7 cm. Thus 95th percentile value of hand breadth across the thumb was considered for handle length decided to be 10.5 cm. It is also observed that the subject holds sickle diagonally therefore for designing the handle as Singh (2009) 20% more is recommended i.e. 126 mm. Also for effective gripping it should not be less than 126 mm. This would accommodate 90% of farm women. Similarly, 15 % more 5th percentile value of inside grip diameter of the subject was considered which is about32mm. The diameter should not be less than 32 mm and not more than specifications given by Nag *et al.* (1988). Tapered shape of the handle is designed as to get the desired gripping of the sickle according to inside hand diameter of the hand. The tapering is provided to get lesser diameter base plate and greater diameter towards the end of the sickle so that the center of mass is near to the line of action. This maintains the balance of the sickle while working. Hence this will reduce the wrist muscular ache and increases the working ability.

Optimization of the design parameters

From the design parameters of traditional sickle it is observed that the CS-CL ratio near to 1.3 will provide better hand movements and other parameters could be optimized as Aware *et al*. (2016).

- CS-CL ratio is kept more than 1 to restrict the hand movement and considered as 1.53 as the physiological responses observed are lesser for this sickle and taking chord length as 230 mm as this dimension is not highly variant cutting surface can be optimized as 350 mm.
- Considering Xs/CS ratio as 0.34, Xs found to be 111 mm. Further, considering Xf/CS ratio as 0.66, Xf will be 215.5 mm.
- Since material of blade cannot be preferred as steel and mild steel even it gives more longevity of the sickle because of more cost of sickle.
- Center of mass kept near to the handle so that impact of weight may not be in wrist.

Hence the modified sickles were made after all the above mentioned optimized design parameter. The pictorial representation is shown in Fig.10. In Table 13 represents the dimensions of the modified sickles.

Figure 10: View of introduced interventions in existing sickles

Table 13: Physical dimension of modified sickle

Particulars	Dimensions (mm)	Particulars	Dimensions (mm)
Base Width	21	Handle Diameter	32
Blade Width	23.5	Chord length	230
Blade thickness	3.5	Pitch	1.52
Cutting surface	350	CS-CL	1.53
Outer surface	390	Radius of Curvature	122.1
Concavity	67	Xs/CS	0.262
Length of sickle	301	Xf/CS	0.853
Handle length	126	Weight(g)	190

Physiological assessment of modified sickles

The physiological responses while harvesting paddy are observed for 12 subjects. It was observed that the minimum heart rate of subject S_{10} i.e. 107 bpm. The maximum heart rate 120.2 bpm is observed while harvesting by the subject S_5. The average value of heart rate is obtained by the subjects is 114 bpm. The increase in heart rate from resting position is found to be 37.52 bpm as represented in Table 14. It was discovered that the energy expenditure rate is 9.406 l/min which is 2.72 times of the resting energy expenditure rate. The oxygen consumed while harvesting is 0.6198 kJ/min. The working with modified sickle is rated as moderately heavy as per Varghese *et al.* (1994) while working with traditional sickles the physiological responses are categorized in heavy workload. Hence the modification in the sickles reduced the workload.

Table 14: Physiological parameters harvesting paddy and wheat with modified sickle

Subjects	Avg. Working HR(bpm)		Avg. Working OCR(l/min)		Avg. Working EER(kJ/min)	
	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat
S_1	118.5	119.5	0.6709	0.6823	10.121	10.280
S_2	114.2	117.2	0.6218	0.6560	9.4378	9.9148
S_3	109.5	114.5	0.5683	0.6253	8.6905	9.4855
S_4	110.0	113	0.5740	0.6082	8.7700	9.2470
S_5	120.2	124.2	0.6902	0.7358	10.391	11.027
S_6	111.0	113.5	0.5854	0.6139	8.9290	9.3265
S_7	116.5	118.4	0.6481	0.6697	9.8035	10.105
S_8	114.5	112.5	0.6253	0.6025	9.4855	9.1675
S_9	110.4	117.4	0.5785	0.6583	8.8336	9.9466
S_{10}	107.0	110	0.5398	0.5740	8.2930	8.7700
S_{11}	121.3	122.5	0.7028	0.7165	10.566	10.757
S_{12}	115.2	110.2	0.6332	0.5762	9.5968	8.8.017
Mean	114.0	116.08	0.6198	0.64	9.406	9.74

The physiological responses while harvesting wheat are observed for 12 subjects. It was observed that the minimum heart rate of subject S10 i.e. 110 bpm. The maximum heart rate 124.2 bpm is observed while harvesting by the subject S5. The average value of heart rate is obtained by the subjects is 116.08 bpm. The increase in heart rate from resting position is found to be 40.42 bpm. It is discovered that the energy expenditure rate is 9.74 l/min which is 2.9 times of the resting energy expenditure rate. The oxygen consumed while harvesting is 0.64 kJ/min as represented in Table 14. The working with modified sickle is rated as moderately heavy as per Varghese *et al.* (1994) while working with traditional sickles the physiological responses are categorized in heavy workload. Hence the modification in the sickles reduces the workload. It is also observed that physiological parameters for harvesting wheat are comparatively more than the harvesting paddy. It may be

due to the difference in moisture content. It is observed that the while harvesting paddy the moisture content is 22.5% and for wheat it is 17.4%. Since wheat can be harvested later stages of maturity level due to lesser shattering losses. But for harvesting paddy as soon as possible harvesting is done after attaining the maturity stage to avoid the shattering losses.

Field assessment of the modified sickle

The assessed field performance revealed that the modified sickles improved the effective field capacity. The area covered for harvesting paddy is 20.5 m^2/h more than the harvesting paddy with traditional sickles. For harvesting wheat it is 17.57 m^2/hmore. The harvested area is 66.3 m^2/h for paddy and for harvesting of wheat it is 62.5 m^2/h as shown in Table 15. About 65% reduction in cost of harvesting and lesser the farm women required for the harvesting operation. Hence the improvement of the performance of sickle was observed after implication if modification to the sickles.

Table 15: Field Performance by Modified sickles during harvesting

Particulars	Paddy	Wheat
Area covered(m^2/h)	66.3	62.5
Effective field capacity (ha/h)	0.00663	0.00625
Man -h required/ha	150.8	160
Labour req/h	18	20
Cost of harvesting Rs per ha	4140	4600

4. Conclusion

The ergo friendly design of sickle influenced the physiological responses as evidenced by the difference in heart rate and discomfort experienced by the subjects. During harvesting with traditional sickle it was the maximum heart rate attended was 143 bpm where as while harvesting with modified sickles maximum heart rate reached was 124 bpm. The area covered for harvesting has been increased by 30.3% with modified one. Due to cushioning in handle problem of callus in hand was not reported. This shows that the modified sickle is ergonomically fit for Bastar farm women.

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