Physiological workload of farm women while evaluating sickles for paddy harvesting

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Abstract: Naveen, Vaibhav and local sickles were evaluated for harvesting paddy crop with 12 farm women (subjects) at CIAE, Bhopal. The data of improved and local sickles were compared. As per the anthropometric data of Madhya Pradesh farm workers, the effective handle length excluding ferrule and diameter of sickle's should not be less than 125 and 24 mm, respectively. Mean heart rate during work in operation of these sickles were 103 beats/min, 107 beats/min and 106 beats/min, respectively. The workload was under acceptable limit for day-long work with normal rest pause for studied sickles. The output of Naveen, Vaibhav and local sickles was 47.3, 60.7 and 65.4 m^2/h, respectively. Output with local and Vaibhav sickles was significantly higher than Naveen sickle. Low output with Naveen sickle might be due to less concavity, i.e. 30 mm. Thus, improved sickle having similar shape of blade to local having concavity could be manufactured and popularized among farm workers. The potential demand of improved sickle is more than 2.27 million in the country.

Keywords: improved sickles, women workers, heart rate, paddy harvesting, India

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1 Introduction

The sickle is one of humanity's oldest tools. Still widely used, it hasn't changed in design very much since ancient times - a (usually) curved blade with a handle that was used to cut, or reap, grain. Sickle with two types of cutting edge, i.e., plain and serrated having narrow serration with depth of about 1 mm are being used at farm by the farmers in the country. Of these, use of plain sickle is more because serrated sickle is mostly preferred for wheat harvesting. It is known that serrated sickle involves frictional force while plain sickle involves shearing force. Further, this type of serrated sickle has been improved by different research organizations and industry with better serration so that it could be used for harvesting more crops. Presently harvesting of paddy, wheat, soybean, gram etc are also being performed by mechanical harvester and combines. Nag, Sebastian and Malvankar (1980) reported that wheat and paddy harvesting demanded about 8% of the total human-h involved in their production. Singh and Singh (1978) found that a sickle with a serrated surface gives better performance than a plain one with shearing force at the cutting edge. An improved (Gujrat Agricultural University) sickle was developed by Varshney, Petal and Suthar (1984). Output of this sickle was 90 m^2/h for harvesting wheat crop. Nag et al. (1988) have analysed with reference to design features of nine different types of sickles and they indicated that blade geometry contributes significantly to human performance. They suggested modifications in design of improved sickle. Gite and Agarwal (2000) concluded that improved sickle with serrated edge reduced drudgery of farm women by about

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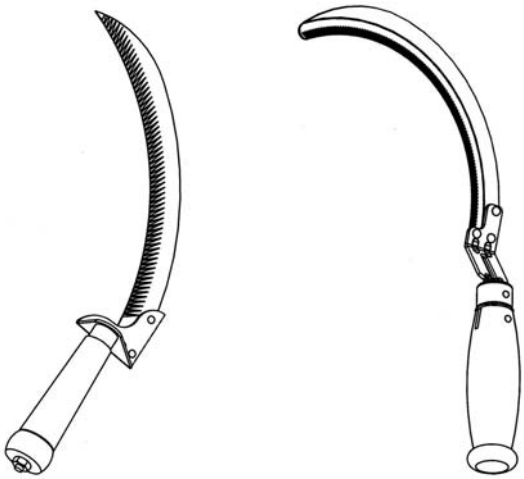
16.5% as compared to local sickle for harvesting wheat crop. The average heart rate of women workers of Coimbatore region of the Country was 120 beats per min while harvesting paddy crop with local sickle (Karunanithi and Tajuddin, 2003). Less work is being reported on physiological workload of farm women in harvesting paddy crop with improved and local sickles. There is need to evaluate improved and local sickles in harvesting paddy crop to assess physiological workload on farm women.

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 study as known that 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, Manian and Kathirvel, 2003; Singh, Gite and Agarwal, 2006; Singh and Gite, 2007; Yadav et al. 2007; Singh, 2009) have used heart rate for assessment of physiological workload of the workers. The present paper analysed the physiological workload of farm women in harvesting paddy crop and also suggests some modifications in design of handle based on anthropometrical data.

2 Materials and methods

Improved sickles of two organizations were taken for the present study (Figure 1). Naveen sickle was taken from Central Institute of Agricultural Engineering (CIAE), Bhopal and Vaibhav sickle from Dr. Bala Sahab Konkan Krishi Vidyaptteh (BSKKV), Dapoli. The performance of improved sickles was compared with local sickle for harvesting paddy crop. The hardness of these sickles was got tested at Field Testing Station, Bhopal to compare with Bureau of Indian Standards (BIS). The specifications of studied sickles were noted and compared with BIS (1967). Nag et al. (1988) also suggested some specifications of sickle while studying ergonomics in sickle operation. The detail of specifications of sickles is given in Table 1 and dimensions are shown in Figure 2.



Naveen Vaibhav

Figure 1 Naveen and Vaibhav improved sickles used in the study

Table 1 Dimensions of studied sickles as against standards

Particulars	Dimensions of Sickles, mm				
	BIS (1967)	Nag et al. (1988)	Studied Sickles		
			Naveen	Vaibhav	Local
Base plate for blade of sickle, (*A*)	12±2		55	24	9
Maximum width of blade, (*B*)	28±3		23	23	40
Blade thickness, (*C*)	4±0.5		1.5	1.5	4
Cutting surface, (*D*)			252	228	225
Outer length of blade, (*E*)			285	275	340
Concavity of blade, (*F*)	59	50	30	52	52
Sickle length, (*G*)		330	364	344	350
Maximum handle length, (*H*)	125		122	135	123
Effective handle length, (*h*)		110	109	122	115
Maximum handle dia, (*I*)		33	37	33.5	33.5
Length of ferrule, (*J*)	> 20		15	18	
Size of sickle, (*L*)	224±3		238	195	191
Pitch	1.5	2	2	2	

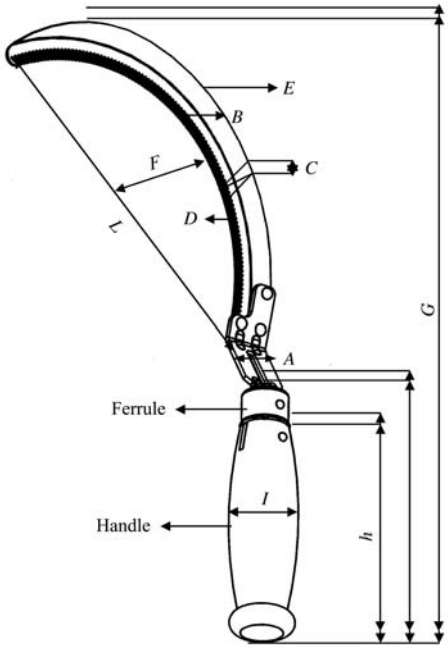


Figure 2 Dimensions for sickle used in study

The experiment was conducted with 12 farm women (subjects) for harvesting *Kanti* variety paddy at CIAE farm to assess the physiological cost of subjects while operating sickles (improved and local). All the subjects were trained in operation of the improved sickle before start of the actual experiment. The subjects were physically fit for participating in the experiment. Before starting the experiment, age, stature, weight of each subject were recorded. Each subject operated the sickle for 30 min. Ambient and crop conditions were also measured. Body mass index (BMI) was calculated by dividing square of height (m) to body weight (kg) of subjects. Based on body weight of subjects, aerobic capacity was estimated using Singh et al. (2008) general equation.

Aerobic capacity of farm women = 33.18 mL kg^{-1} min^{-1} (1)

Figure 3 Farm woman while harvesting paddy with Vaibhav sickle

Polar Heart Rate Monitor, Polar Electro OY, Finland (model S 810 i) was used for recording heart rate of subjects during the course of study. The polar monitor consisted of a chest strap and a wristwatch type receiver. Before measuring the heart rate of the workers, they were given warming up exercise of brisk walking for 15 min followed by a rest of 30 min. After that the heart rate monitor was fixed on the worker. Data for resting and working were taken for the period of 10 min and 30 min, respectively. The recorded data in the receiver of the monitor were downloaded daily in the computer through interface after completion of the work. The heart rate data from 6^{th} min onwards of work of each subject was considered for calculating the heart rate during rest and work period as it is considered that the worker heart rate get stable after 3-5 min (Astrand and Rodahl, 1977). The heart rate data for resting and working (6^{th} - 30^{th} min) were averaged to get the mean value of heart rate for workers. After completion of work, heart rate of subjects was also noted for 10 min to assess whether heart rate comes to rest level or not. The work pulse value was calculated by subtracting the mean heart rate during work with the mean heart rate of worker during rest. Each day the experiment was conducted from 10 am to 2 pm. The subject operated the entire sickle in squatting posture (Figure 3). The subjects were asked for their opinion about the operation of the improved sickle. The data of area covered, working heart rate and work pulse were statistically analysed using single factor experiment with repeated measures. The oxygen consumption of subject on their measured heart rate was estimated based on general equation as given by Singh et al. (2008).

$$Y = 0.0114X - 0.68 \quad (2)$$

where, Y = oxygen consumption, l/min; X = heart rate.

The energy expenditure was calculated using 1 l oxygen equivalent to 20.93 kJ.

3 Results and discussion

3.1 Description of sickles

The weight of Naveen, Vaibhav and local sickles was 247, 194 and 299 g, respectively. Except the Vaibhav sickle, weight of Naveen and local was 1.1 & 1.23 times and 1.33 & 1.49 times higher than BIS (1967) and Nag et

al. (1988) recommendations, respectively. The higher weight might create biomechanical stress in operating these sickles. Upon examination of effective handle length (excluding furrel) of studied sickles, it was observed that this was less in Naveen sickle (Table 1), though it is as per the Nag et al. (1988). But normally subjects hold sickle diagonally for cutting the crops due to their crop holding positions and some space is needed due to continuous working of sickle with hand. Thus the 95th percentile value of hand breadth across thumb was assessed based on anthropometric information of farm women which was 96 mm. This dimension is measured at the level of distal end of the 1st metacarpal of thumb (Figure 4). When subject holds diagonally then it would be about 20% more. The sickle is also used by men worker, hence, 30% over this dimension would be 125 mm. Thus it could be suggested that the dimension for effective hand length should not be less than 125 mm.

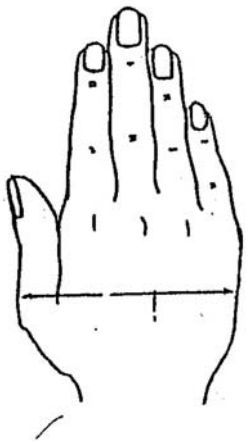
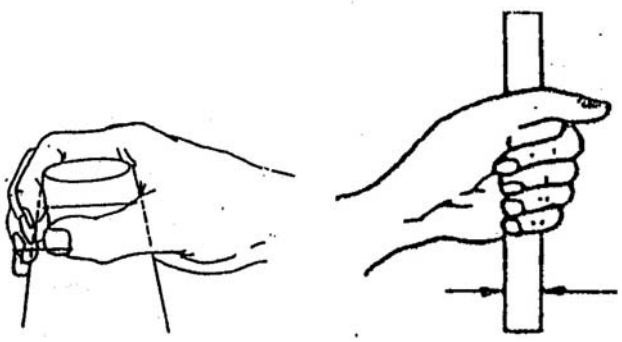


Figure 4. Measurement of hand breadth across thumb.

The handle diameter of Naveen sickle was observed to be on higher side than even Nag et al. (1988) specifications (Table 1). Thus, the diameter of handle for sickle was also assessed based on related anthropometric data of farm women. Diameter of Naveen, Vaibhav and local sickle was 37 mm, 33.5 mm and 33.5 mm, respectively. For harvesting cereal crops including grasses it is observed that the middle finger palm grip diameter of subjects might be considered in place of inside grip diameter as considered by Nag et al. (1988) because stroke of sickle per min during paddy harvesting was about 37 to 43. The measurement of both positions is shown in Figure 5. Keeping the above points in view, 5th percentile value of the middle finger palm grip diameter was considered which, was 21 mm. Since the sickle would be used by both men and women workers, hence, the diameter of handle should be about 15% more than this. Thus, the handle diameter should not be less than 24 mm and it should also be not more than the Nag et al. (1988) specifications.



Grip diameter (inside) Middle finger palm grip diameter

Figure 5 Anthropometric measurement of grip and middle finger palm grip diameter

The hardness of Naveen, Vaibhav and local sickles was found to be 402 HV, 336 HV and 310 HV, respectively. The hardness of all the studied sickles was less than BIS (1967) specifications for sickles (with plain blade: 400-620 HV & for serrated blade: 500-800 HV). This suggests for improvement in hardness of sickle blade to increase its life.

3.2 Subject's detail

The mean (±SD) age, stature and weight of subjects were 38.3 (±6) years, 152.3 (±4.4) cm and 49.9 (±7.5) kg, respectively. Average BMI (±SD) was found to be 22.32 (±3.2) kg/m^2. According to international classification (Anon., 2009) of adult as under weight, over weight and obesity based on Body Mass Index (BMI), one subject was underweight, two subjects were overweight and rest nine subjects were in normal BMI range (18.5 to 24.99). Average estimated aerobic capacity of subjects was 1.702 l. min^{-1}. The participated subjects were having experience of more than 10 years in agriculture. Except two subjects, rest was right handed.

3.3 Working environment

The mean (±SD) value of globe bulb temperature, dry bulb temperature and relative humidity, during the experiment was 39.5 (±3.6)℃, 28.3 (±1.5)℃ and 36.6

(±5)%, respectively. The range of wind speed during experiment was 0.5 (±0.4) m/s to 1.9 (±0.9) m/s. The average soil moisture content at the time of harvesting was 20.16% (d.b.). The average (±SD) number of tillers/plant (hill), plant to plant spacing, row to row distance and plant height were 4.2 (±1.9), 18.9 (±8.9) cm, 21.2 (±5.9) cm and 61.6 (±6.3) cm, respectively. The moisture content of crop during harvesting was 91.74% (w.b).

3.4 Performance of sickles

The average number of hills/cut by the subject was 1 to 2. Normally subjects used to hold the 5-7 cut plants in hand thereafter they kept in the field. Number of strokes (operation of handle) per min was 36.7, 37.8 and 42.8 while harvesting paddy crop with Naveen, Vaibhav and local sickles, respectively. Correspondingly, average output per h with these sickles was 47.3, 60.7 and 65.4 m^2. Higher output obtained with local sickles as compared to improved one was only due to their habits of using this sickle since long-time. Using single factor experiment with repeated measures, it was observed that there was no significant difference in output data of paddy harvesting obtained with Naveen, Vaibhav and local sickles. Further analysis indicated that output with local and Vaibhav sickles was significantly higher than Naveen sickle at 1% significance level. Low output with Naveen sickle might be due to less concavity, i.e. 30 mm. Thus, it suggests that concavity (curvature of sickle blade w.r.t. handle) played an important role from workers point of view as they are well acquainted with use of local sickle having high curvature than improved sickle. Hence suggested concavity by Nag et al. (1988) might be considered in developing improved sickle.

3.5 Physiological workload

The heart rate of subjects for entire sickle was almost similar except with local sickle during end of harvesting which increased whereas with rest of sickles it was as per trend (Figure 6). The average heart rate of subject while operating Naveen, Vaibhav and local sickles was 103, 107 and 106 beats/min, respectively.

The heart rate of subject was the lowest with Naveen sickle as compared to the harvesting with local and Viabhav sickle. But the area covered was also lowest (Table 2). The mean work pulse (increase in heart rate during work over resting heart rate) value of the subjects was 19, 21 and 20 beats/min with Naveen, Vaibhav and local sickles, respectively. The variation in work pulse value of subjects in Naveen sickle operation was 12 to 28 beats/min whereas it was 15 to 27 beats/min with Vaibhav sickle and 12 beats/min to 29 beats/min with local sickle. Correspondingly estimated oxygen consumption in harvesting paddy crop with these sickles was 0.4942, 0.5398 and 0.5284 l/min. The energy expenditure per m^2 area harvested with these sickles was 219, 186 and 169 J. The workload of worker in operation of Naveen sickle was of light category while operation of Vaibhav and local sickles was of moderate category as per the classification of workload given by Varghese, Saha and Atreya (1994). The values of work pulse and heart rate during work was under acceptable limit for continuous work (Saha et al., 1979).

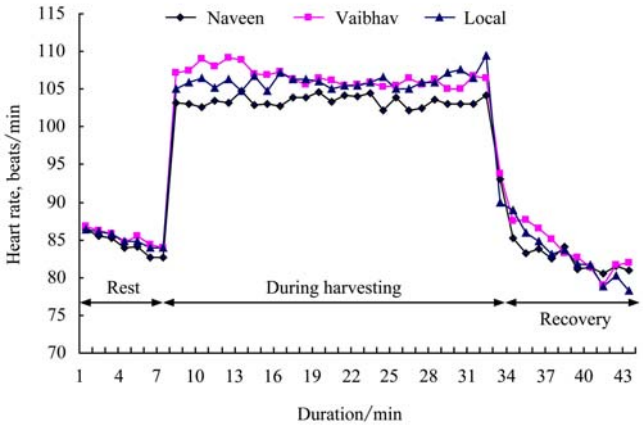


Figure 6 Average heart rate of subjects during rest, work & recovery period

Table 2 Performance data of various sickles used for paddy harvesting.

Particulars	Average values (± S.D) for different studied sickles		
	Naveen	Vaibhav	Local
Plant Angle, degree		3.4 to 10.8	
Number of Hills/cut	1.5±0.1	1.8±0.3	1.7±0.3
Number of Hills/round of cut	6.8±1.3	6.8±1.3	6.8±1.3
Strokes/min	36.7±6.1	37.8±6.0	42.8±7.9
Area Covered/$m^2 \cdot h^{-1}$	47.3±7.4	60.7±10.2	65.4±13.1
Working Heart Rate, beats/min	103±7	107± 10	106±10
Work Pulse, beats/min	19±6	21±4	20±5
Estimate Oxygen Consumption/$L \cdot min^{-1}$	0.4942	0.5398	0.5284
Estimated Energy Expenditure/m^2 area Covered/$J \cdot min^{-1}$	219	186	169

3.6 Demand of improved sickles

It is understood that the plain sickle working on principle of shearing force is used for impact cutting of thin bushes also in addition to harvesting of crops. As reported by Singh (2008) that level of mechanization in harvesting was 0.56% and 0.37% with reaper and combine, respectively. This clearly indicates the potentiality of improved sickle in the country. Research studies showed that the improved sickle with serrated edge could be successfully used for harvesting paddy, wheat, gram, soybean and other type of crops having thin crop stalk. Considering area under these crops and output of sickle for these crops, potential demand for improved sickles in the country would be more than 2.27 million. If 1% growth per year is assumed, then the future of this type of sickle could be thought.

4 Conclusions

Naveen, Vaibhav and local sickles were evaluated with 12 subjects to assess their physiological workload while harvesting paddy crop having crop moisture content of 91.74% (w.b.) in vertisol. The workload in operation of the entire sickle was under acceptable limit for day-long work with normal rest pause. The effective handle length excluding ferrule and diameter of sickle's should not be less than 125 and 24 mm, respectively. Low output was obtained with Naveen sickle might be due to less concavity, i.e. 30 mm. Thus, improved sickle having similar shape of blade to local having concavity of 50 mm could be manufactured and popularized among farm workers. The potential demand of improved sickle having serrated edge is more than 2.27 million in the country.

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