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Design Requirements of farm tools for women based on ergonomic principles

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Abstract : Most of the farming operations in India are being done by small farmers with women contributing upto 60 per cent of labour. The tools used being basically meant for male workers are very heavy for women resulting higher workload and increased discomfort to them. Higher energy demand and increased drudgery created by the tools develop stresses, which affects the safety and health of the women. This paper examines a few of farm tools used by women and, based on ergonomic aspects, quantifies the inadequacies of such tools with respect to energy expenditure and their body (anthropometric) dimensions. This would greatly help the researchers to appropriately design simple and labour effective gadgets considering ergonomic requirements. Such designs of tools would not only minimize drudgery of the women but also increase productivity at reduced expenditure levels.

Keywords: Farm tools, Discomfort, Drudgery, Energy expenditure, Anthropometric dimensions.

Introduction

"In order to awaken the people it is the women who have to be awakened. When she is on move, the family moves, the village moves, the nation moves" - These words of Pandit Jawaharlal Nehru is the central theme in the socio-economic paradigm of the country as it is an accepted fact that when women are in the main stream of progress, any economic and social development can be meaningful.

Agriculture is the mainstay of Indian economy as over 70 percent of India's population depends on agriculture and allied occupations for their livelihood. The rural women constitute almost 60 per cent of farm work force and play a significant role in Indian agriculture. Women undertake various types of farm operations like weeding, transplanting, harvesting with sickle, bundling and transportation by overhead, threshing by beating or treading, winnowing and rural food processing. These farm works carried out by women are tedious and time consuming which demands more energy and induces discomfort, fatigue and finally disorders in the back of the subjects. Though many of the tasks performed by males are getting mechanized, the women continue to toil in labour intensive jobs and also in considerable amount of drudgery. The operations performed by women could be studied with reference to the tools used, analysed and improved to reduce uncomfortable bending postures, energy expenditure and discomfort of the operator. In addition, new farm tools should be ergonomically designed and developed to increase the comfort and operating efficiency of the farm women.

Design based on ergonomic principles

The performance of any farm machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration. Recently, use of ergonomic principles has given considerable attention in agricultural machineries. But relatively little or no attention has been given to small scale farming tools and equipment.

The farmers have been continuously using the tools and equipment, which have been developed by trial and error method adopted by the local blacksmiths who understand their farmer community. In this process, however, the women farm workers have suffered the most as the

Table 1. Selected anthropometric dimensions of male and female workers

Sl.No.	Segment / Parameter	Male	Female
1.	Weight, kg	62.5	55
2.	Height, cm	169.4	157.8
3.	Elbow height, cm	148.3	108.1
4.	Arm reach	87.4	75
5.	Forearm hand length	45.5	40.5
6.	Hand length	17.9	16.1
7.	Hand breadth	9.4	8.4
8.	Palm length	10	8.8

Table 2. Body dimensions expressed as proportions of stature

Sl.No.	Body dimension	Proportion of stature	
		Barkla (1961)	Gite and Yadav (1989)
1.	Eye height	0.936	0.932
2.	Acromion height	0.811	0.827
3.	Elbow height	0.608	0.633
4.	Sitting height	0.525	0.517
5.	Eye height (sitting)	0.477	0.456
6.	Acromion height (Sitting)	0.340	0.344
7.	Knee height (sitting)	0.315	0.314
8.	Frearm hand length	0.272	0.283
9.	Popliteal height	0.245	0.252

general aparthy towards women, has not merited attention to their particular tool requirements even by the blacksmiths. The women thus manage either with very primitive tools or reluctantly use tools meant for men and consequently give lower performance in addition to invoking long term health hazards.

Segment-link ratios

Segment-link ratios give a useful proportionality of body segment in relation to total height. Table 1 shows a sample measurement of anthropometric parameters of male and female workers related to hand tools. Significant differences in selected segments between male and female workers have been found in the data. This points to the need for a physical compatibility between the tool size and operator as determined by appropriate segment -links for male and female workers.

Table 2 shows body dimensions expressed as proportions of stature reported by Gite and Yadav (1989). Barkla (1961) has given the corresponding values of proportions for British population. According to Murrel (1975), there is a high probability that whatever the mean stature of a sample, any given body dimension of length will be very nearly a constant proportion of stature. Thus, if the stature is known, dimensions not available in the sample can be obtained by proportion. Barkla (1961) used this method for the design of seats. From table 2 it can be seen that there is considerable variation in the proportion values between Gite and Yadav (1989) and those of Barkla (1961). This variation could be due to the differences in body build up of Indian and British people.

Segment-link ratio and tool geometry

Hand tools may be short or long handled. Manually operated equipment may have push, pull or push-pull mode of operation. A typical hand tool/equipment consists of the functional part, handle and a connecting part. The design of the handle depends on the mode of operation, amount of effort required, anthropometric data of the working population, hand material etc. Linking of tool geometry to a relevant segment-link ratio was essential* for the safe operation of any tool. For instance to draw a compromise between the need for using long handled manual tillage tool for energy reduction (Nwuba and Kaul ,1985), a parameter of Q.60H was used to designate the handle length, taking care of the 95th percentile value of the user population for men (Wagami,1983) and 0.59H for women(Abdulkarium,1986) where H was the height of the user. Similarly the basis for the diameter of the tool handle was that it should not be more than the diameter of the circle which hand length will make when making an approximate circumference of such a circle as it grips the handle. The tool handle diameter was thus calculated taking the length of hand as 0.11H. According to Parikh (1980), the diameter of the handle should be such that while an operator grips the handle, his longest finger should not touch the palm.

Table 3. Energy requirement for 3 different tasks with men and women operators

Environment	Men		Women		Higher unit energy for women
	Output	Energy/Output (kJ)	Output	Energy/Output (kJ)	
		Task : Pounding (Output unit : Kg m^{-3})			
E_1	42.6	1.03	30.3	1.30	20.8
E_2	35.2	1.01	22.8	1.65	38.8
E_3	26.5	1.50	17.8	2.07	27.5
Average	34.8	1.18	23.6	1.67	
		Task : Weeding (Output unit: m^2)			
E_1	12.5	3.76	9.8	4.94	23.9
E_2	11.3	4.02	9.2	5.57	27.8
E_3	10.1	4.79	8.6	6.25	28.2
Average	11.3	4.19	9.2	5.59	
		Task : Ridging (Output unit : m^3)			
E_1	2.0	32.85	0.8	68.66	52.2
E_2	1.8	35.14	0.9	63.82	44.9
E_3	1.6	40.99	0.9	62.02	33.8
Average	1.8	36.33	0.9	64.83	

Fundamentals of handle design

The purpose of a handle is to facilitate the transmission of force from the musculoskeletal system of the user to the tool in the performance of the task or purpose for which she is using it. As a general rule we can say that to optimize force transmission is to optimize handle design (Stephen, 1996).

The following are some guidelines

i. Force is exerted most effectively when hand and handle interact in compression than shear. Hence it is better to exert a thrust perpendicular to the axis of a cylindrical handle than along the axis,

ii. All sharp edges or other surface features, which cause pressure hot spots when gripped, should be eliminated,

iii. Handles of circular cross-section will be most comfortable to grip since there will be no possibility of hot spots,

iv. Surface quality should neither be so smooth as to be slippery nor be so rough as to be abrasive.

Energy assessment

The physical work load to which the worker is exposed can be objectively assessed either by (a) direct measurement of the energy expenditure required to do the job, or (b) indirectly by recording the worker's heart rate during the performance of work. (Rodhal, 1989).

The direct measurement of oxygen uptake of the subjects while operating the tools is the most accurate method. The disadvantage with this approach is that the measured oxygen uptake only represents the energy expenditure for the time period during which the expired air sample is collected, which may not be representative for this operation in general for the entire work period. Also the equipment used for collection of the expired air (masks, air hoses etc.) may restrict or affect the worker and may even hamper the actual work operation.

The indirect assessment of the workload, on the basis of the continuously recorded heart rate, reveals on other hand, a general picture of the activity level during the whole day's work or the specific time periods of work. Moreover, by this method it is possible to relate the individual worker's reaction to different treatments as judged by the heart rate response (Rodhal, 1989). For these reasons, the indirect assessment of workload based on the recorded heart rate may be preferable in many cases.

Using heart rate as an index, energy levels were measured for selected tasks and existing tools and these were compared for men and women farmers (Abdulkarim, 1986). Table 3 gives values for 3 operations namely pounding, weeding and ridging for three work environments (Abdulkarim, 1986). Theses were studied as examples of some typical tasks done by women farmers. In pounding the difference between final density was used as a measure of output as the density of a sample is increased, with repeated pounding. For weeding and ridging, respectively, the area weeded and volume of soil dug up per unit time was used as output. The work environments covered a range of temperature and relative humidity like on an average E1 represented temperature of 20°C and 48 per cent RH, E2 was for temperature of 25°C and 85 per cent RH and E3 for 36°C and 63 per cent RH.

As is reflected, the unit energy expenditure by women is consistently higher than for men. Physiological studies have shown that for sustained work, energy demand should not exceed 4.5 $kJ\,min^{-1}$ and any excessive energy requirements, as was experienced in these studies, when sustained for long duration can be detrimental to health in the long run.

The possibility of reducing drudgery by introducing the concept of rest intervals at suitable periods appears also promising. Initial studies, using ridging as an operation, showed that by regulated rest pauses drudgery was reduced by about 16 and 8 per cent respectively for male and female workers and simultaneously gave an output increase of 48 per cent for male and 39 per cent for female operators over traditional schedule of work (Abdulkarim and Kaul, 1986).

Ramana (1999) studied the effect of basic design parameters, namely weight, angle of blade with handle girth of hand hoes on physiological response of female workers. He found that the operational strokes/min and area covered decreased as the weight of the hoe increased irrespective of the type of worker. The area covered by the female worker was decreased from 1.84 m^2 min^{-1} to 1.56 m^2 min^{-1} as the weight of the tool was increased from 0.55 kg to 0.85 kg. But the cardiovascular stress, was increased from 93 beats min^{-1} to 106 beats min^{-1} as the weight of tool increased from 0.55 to 0.85 kg. Oxygen consumption was increased from 0.905 1 min^{-1} to 1.21 min^{-1} for the above increase of weight. So the weight of the tool should be kept to minimum for increasing the operator's efficiency. More over he found that as the angle of the blade increased, the heart rate was lowered from 98 beats min^{-1} to 92 beats min^{-1}. At the same time more area was dug at lower blade angle. So the blade angle should be kept to be minimum to reduce the energy expenditure as well as to increase the operating efficiency of female workers. In addition by providing the bent angle (bent angle possess blade angle 30° at blade joining part and 60° at hand grip) weeding efficiency was higher and oxygen consumption was less. This is because the subject works without much bending i.e., more straight which inturn reduced the strain in the spinal muscle force and lumbosacral joint reaction.

Conclusion

The study points to the need for evolving farm equipment specific to women's level of energy and body dimensions, as is in the case of bicycles where we have a specific shape and size for women as distinct from the bicycles meant for men. Efforts are underway to apply similar concepts in developing and justifying distinctly different tool for women farm workers. A greater global interaction on this aspect will indeed accelerate developments.

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