Indian Journal of Agricultural Sciences **88** (3): 447–52, March 2018/Article

Ergonomic assessment of wheel hoe and design compliance for women farm worker

JAYA SINHA[1], J K SINGH[2] and ADARSH KUMAR[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: 28 July 2017 ; Accepted:16 November 2017

ABSTRACT

Weeding is carried out by women farm workers with hand tools and most of these tools are operated in squatting or bending posture. These tools are essentially designed for male farm workers. One of the common hand tool used for weeding is wheel hoe. Therefore, ergonomic assessments of an existing wheel hoe and design modification were done to make it compatible for women workers. The wheel hoe was ergonomically evaluated for physiological and postural parameters. Mismatches were observed between required energy and sustainable energy output and between tool dimensions and anthropometric measurements of female operators. Based on the ergonomic evaluation the hoe was modified with two blade sizes and three handle widths .The modified wheel hoes were re-evaluated. Working with an existing wheel hoe was categorized as "heavy work" with "higher" overall discomfort. Heart rate, oxygen consumption and energy expenditure were lowest for modified weeder (10%-440mm) and the work classification improved to "moderate category". The resting period with the modified hoe reduced from 33.4 min to 20.7 min for one hour work cycle. With change in handle dimensions shoulder, elbow and wrist deviation were close to the natural range of motion. The body part discomfort score and overall discomfort score also reduced from 31 and 2.5 respectively to 18 and 1.5 for modified weeder (10%-440mm). Women workers found the modified hoe with 10% blade dimension and handle width 440mm, very comfortable to use. Modifications in the existing wheel hoe according to anthropometric parameters of female workers reduced energy consumption, body deviations and rest pause between work cycles and thus enhanced work output.

Key words: India, Manual weeder, Physiological parameters, Women farm workers

Traditionally, weeding is a manual operation performed with hand tools which require high energy, resulting in fatigue and low productivity. The manual weeder is operated in a standing posture in a pull, push or a pull- push mode. Manual weeding is a labour intensive farm activity, which accounts for 25% of the total labour requirement of crop cultivation (Nag and Datt 1979). This work is strenuous, physiologically demanding and requires adoption of odd posture leading to fatigue. It is reported that manual weeding is predominantly carried out by women farm workers (86%) (Singh *et al.* 2007). Ergonomic design intervention can improve overall occupational well-being and work tool design can reduce the ergonomic risk factors and improve productivity (Chakrabarti and Bhattachheriya 2012). Risk factors such as weight of the tool, improper design of handle and sharp edges result in pain in the upper extremities, anxiety and injury (Vyas *et al.* 2016). Women workers on Indian farms perform tedious and backbreaking tasks. Each one is involved in various agricultural and allied activities and some of these activities are found to have adverse health risks. The available agricultural tools are not women friendly as they are not designed on the basis of anthropometry or physiology of women. There is a communication gap between designers and women workers as their specific requirements regarding the design of agricultural tools are not properly conveyed to the designer (Shirahatti *et al.* 2009). To increase the productivity per unit area of small land holding and mitigate the drudgery of women farm workers, it is essential to have ergonomically designed agricultural tools and implements for women workers. The present study was undertaken to make design changes in the existing wheel hoe to make it compatible for women farm workers.

MATERIALS AND METHODS

Thirty five women farm workers were selected for the study. Their major anthropometric dimensions in standing posture were measured with an anthropometer along with measurement of hand dimensions. It was observed that physiological and postural parameters depend on the parameters such as height and age of operators. Therefore, to avoid such error the subjects of similar age group and anthropometry were selected for the study (Singh *et al*. 2012). So, based on height, six healthy workers in the age

[1]Research Scholar (e mail: sinha.jaya70@gmail.com), [2]Principal Scientist (e mail: jksingh_engg@iari.res.in), [3]Principal Scientist (e mail: adarsh_iari@rediffmail.com), Division of Agricultural Engineering.

Table 1 Anthropometric dimensions of women farm workers (N=35)

Dimensions(mm)	Mean	SD	5^{th} % centile	95^{th} % centile	Subject					
					A	B	C	D	E	F
Stature	1545	11.8	1457	1574	1555	1540	1537	1554	1536	1552
Weight(kg)	49.8	8.4	35.9	63.6	52	52	62	55	56	64
Standing eye height	1435	3.1	1364	1466	1450	1420	1422	1454	1438	1452
Acromial height	1241	2.9	1192	1291	1260	1240	1250	1272	1256	1258
Elbow height	956	2.2	920	993	960	951	974	979	968	959
Knee height	433	1 .1	415	452	445	430	440	443	438	445
Illiocrystale height	825	2.1	818	976	827	821	825	824	814	827
Bideltoid breadth (elbow to elbow width)	371	1.0	318	423	360	355	368	365	354	372
Inside grip diameter	54	3.0	49	59	52	47	55	53	49	58
Middle finger palm diameter	23	2.0	20	26	20	28	24	20	22	25
Palm breadth without thumb	73	6.0	63	83	71	68	82	74	66	83
Palm breadth with thumb	93	7.0	81	105	94	85	92	86	77	96
Length	155	4.5	147	162	176	160	154	166	152	178
Palm thickness	33	2.0	30	36	30	30	32	33	31	33
Maximum aerobic capacity (l/min)					2.37	2.51	1.77	2.62	2.67	2.05

group of 25-35 were selected. It was ensured that subjects were free from musculoskeletal problems, physically fit, not suffering from any illness and were willing to participate in the experiments. Limited number of subjects and the particular age group was also a limitation of the study because of operational constraints. The mean values of anthropometric body and hand dimensions of 35 female workers (along with six selected subjects) are given in (Table 1).

Calibrations of subjects were done according to Naughton protocol (Naughton *et al.* 1963).The maximum heart rate of each subject was determined for age based criterion (HR_{max} = 220 – age). The subjects were sufficiently rested before starting the experiment to achieve a resting heart rate. The experiment was carried out for an hour continuously and then the subject took a rest to achieve a normal heart rate.

The experiments were conducted in the farm machinery laboratory of the Division of Agricultural Engineering, IARI. The experiments were conducted at room temperature 25° – 29 ° C with humidity of 50-60%. The corresponding values of oxygen consumption (VO_2) of the subjects for all experiments were determined from the linear relationship of HR and oxygen consumption calibration chart. The energy expenditure during the experiments was computed by multiplying the oxygen consumption values with the calorific value of oxygen (20.88 kJ/l).

Measurement of work rest cycle

If a particular activity requires higher than the sustainable limit of energy expenditure, there must be a rest pause to compensate for excess energy demand. Formula for estimating the total amount of rest required (Murrell 1965) for any given work activity depending on its average energy cost was used (equation 2.1). The value of "S" was taken as 30% of energy consumption of VO_2 max.

$$R = T (K-S)/ (K-6.3) \quad ....2.1$$

where, R= rest required in min, T=Total working cycle, min, K=Average kJ per min of work, S=kJ per min adopted as standard.

Neutral position places minimal stress on the body parts and it is achieved when the muscles are at their resting length and the joint is naturally aligned. When a joint is not in neutral position, its muscles and tendons are either in contraction or expansion. The human body has a natural range of motion (ROM). By considering ROM, tools can be designed to operate within the optimal ranges to reduce fatigue and muscle disorders. There are four different zones that a worker might encounter while sitting or standing (Chaffin *et al.* 1999). Zone 0 (Green Zone) Preferred zone for most movements, puts minimal stress on muscles and joints. Zone 1 (Yellow Zone) Preferred zone for smaller joint movements, puts sustainable stresses on muscles and joints. Zone 2 (Red Zone) More extreme position of limbs, puts greater strain on muscles and joints. Zone 3 (Beyond Red Zone) Most extreme positions of limbs, should be avoided if possible, especially with heavy lifting or repetitive tasks.

The postural assessment and deviation of workers were done while they were operating the wheel hoe on the farm. The measurement of lumbar deviation during weeding operation was recorded with a lumbar motion monitor. The trunk motion included the deviation, velocities and acceleration of the trunk in its three planes of motion- lateral plane (side bending), sagittal plane (forward bending) and the medial plane. Colour markers were placed on the joints of the hand and elbow of the operator to distinct critical points of movements for all the operations. Deviation in the arms and hands were measured with still snap obtained from the clippings of recorded videos. The photographs obtained were used to measure different angles to assess deviations in the arm and wrist with a help of software image measurement.

To measure body part discomfort score (BPDS), Corlett and Bishop Technique was used (Corlett and Bishop 1976). In this technique the subject's body was divided into 27 regions and the subject was asked to indicate the discomfort after every 15 min of work. All the body parts were numbered and in each experiment their numbers were changed to avoid any bias in reporting. The subject was asked to mention all the body parts with discomfort, starting with the most uncomfortable and so on until all the uncomfortable body parts had been mentioned. The number of different groups of body parts, which were identified from extreme discomfort to no discomfort, represented the number of intensity levels of discomfort experienced by the worker.

For the assessment of overall discomfort rating a 5-point psychophysical rating scale; 0-No discomfort, 1-Very little discomfort, 2-Mild discomfort, 3-Great discomfort, 4-Extreme discomfort was used, which is an adoption of Corlett and Bishop Technique. At the end of each experiment, the subject was asked to indicate their overall discomfort rating on this scale. The overall discomfort ratings given by each of the six subjects were added and averaged to get the mean rating.

A wheel hoe is a common weeding tool used for weeding and intercultural in row crops. It has a long handle operated by push and pull action. It has a wheel assembly, a set of replaceable soil tools and a handle assembly. The long handle made of 25 mm diameter conduit pipe has a U-shaped handle fixed at the end. The inclination of handle was 25^0 from horizontal. Both the ends of the handle had plastic grip. All the soil working components of the tool were made from medium carbon steel and hardened to 40-45 hot rolled coil. The cutting blade was of V-shaped, sharpened at the edges. The working depth of the tool can be adjusted through the plate with multiple holes provided in the frame and welded to the tool assembly. The ground wheel was made up of two circular rings with a mild steel rod.

The weeding efficiency of the weeder was evaluated in the carrot field having row to row spacing of 20 cm in the experimental farm of Division of Agricultural Engineering, IARI. Weeding was performed when height of weeds were about 3-5 cm. For the weeding efficiency, a wooden frame of 1 × 1 m was thrown in the field randomly and the number of weeds was counted. The weeding efficiency of the weeder was calculated (Remesan *et al*. 2007). To determine the working speed with a hoe during operation, the time for covering 10 m between two planting rows was recorded. Three measurements were recorded in each plot. Effective field capacity (C_e) and man – hour per ha were calculated.

Based on the ergonomic evaluation and performance of an existing wheel hoe, modifications were done to suit the female farm worker. The mismatches were observed between required energy, sustainable energy output and anthropometric dimensions of female operators. Following modifications were incorporated in the wheel hoe. Blade dimensions were reduced by 5% and 10% to reduce the application of push-pull force. 2. Handle width was reduced to 400, 440 and 480 mm from 540 mm based on anthropometric dimension of elbow to elbow width (Bideltoid breadth) of female worker with a permissible allowance of shoulder abduction. 3. A quick height adjustment system according to operator height.

RESULTS AND DISCUSSION

Heart rate, oxygen consumption and energy expenditure

The selected subjects were first calibrated. The relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects, which were in close agreement with the results reported by researchers (Rodalh 1989, Bridger *et al*. 1995). This relationship differed from one individual to another (Kroemer *et al.* 2000) due to differences in subject's age and anthropometric dimensions.

It was observed that the heart rate value of the subject during the experiment increased steeply in the beginning and stabilizes after six min of operation. The mean value of working heart rate and corresponding oxygen consumption values are given in Table 2 . The mean value of heart rate during operation of existing wheel hoe was in the range of 103 to 125 beats/min, quite close to the values reported in previous studies (Gangopadhyay *et al*. (2010). Energy

Table 2 Physiological performance and postural parameters of subjects for the existing and modified tools

Modified wheel hoe (% blade reduction- handle width) (mm)	Heart rate (beats/min)	Oxygen consumption (l/min)	Energy expenditure (kJ/min)	Work category	Weeding efficiency (%)	Field capacity (m^2/h)	Time required (man hour/ha)	Avg. twisting velocity (deg/sec)	Maximum sagittal flexion (deg)	Maximum lateral velocity (deg/sec)
Existing	115	1.03	21.50	Heavy	84.37	145.00	68.26	3.43	13.66	35.09
5%- 400	108	0.87	18.16	Heavy	82.97	123.30	79.67	3.65	13.76	34.29
10%-400	108	0.86	17.95	Moderate	84.03	140.00	74.19	3.18	13.32	33.84
5%-440	103	0.79	16.49	Moderate	88.86	156.00	63.81	3.52	12.9	34.22
10%-440	104	0.78	16.28	Moderate	90.59	185.00	54.22	3.65	12.89	35.06
5%- 480	107	0.88	18.37	Heavy	85.98	146.67	68.12	3.35	13.33	34.22
10%-480	103	0.77	16.07	Moderate	88.88	151.67	67.19	3.37	12.97	33.10

Table 3 Deviation of body segments (degrees) with existing and modified wheel hoes

Body deviation(degrees)	Subjects	Wheel hoe handle width (mm)			
		540	400	440	480
Shoulder abduction	A	38-42	28-31	23-26	30-34
	B	39-41	29-30	23-25	31-36
	C	38-41	28-31	24-26	30-34
	D	39-42	28-32	23-25	31-33
	E	38-40	29-31	24-27	32-35
	F	30-41	30-32	25-28	30-34
Range of motion		2	1	1	1
Shoulder extension	A	25-28	10-15	0-2	15-18
	B	25-27	10-16	0-2	15-19
	C	26-28	11-17	0-3	14-17
	D	25-27	11-14	0-2	16-19
	E	26-29	10-15	1-3	15-17
	F	27-28	12-16	2-4	13-15
Range of motion		2	1	0	1
Elbow flexion	A	82-88	85-90	90-94	88-90
	B	82-87	85-89	92-95	87-90
	C	84-88	86-90	91-94	86-89
	D	83-87	85-89	90-95	87-90
	E	82-86	86-90	91-94	86-90
	F	85-89	85-88	90-94	85-87
Range of motion					
Ulnar deviation	A	42-50	20-28	12-16	30-38
	B	44-49	22-30	13-16	32-40
	C	42-48	22-32	12-17	33-41
	D	42-44	20-25	12-15	30-36
	E	43-47	20-24	13-14	33-37
	F	45-47	22-27	13-17	33-37
Range of motion		3	3	2	3
Wrist extension	A	22-27	18-21	17-20	20-25
	B	22-26	18-20	17-21	21-25
	C	21-25	19-23	16-19	20-24
	D	24-28	19-22	18-21	21-26
	E	23-26	17-19	16-20	22-25
	F	22-27	18-22	17-22	19-23
Range of motion		2	1	1	1
Back deviation	A	27-32	15- 20	4-8	20-25
	B	25-30	15-19	4-9	21-26
	C	26-31	17-22	5-10	21-27
	D	28-32	15-19	4-8	21-26
	E	26-29	16-21	5-10	22-24
	F	27-32	18-23	6-9	22-28
Range of motion		2	1	0	2

expenditure during operation was 18.3 to 22.9 kJ/min and based on energy expenditure the wheel hoe operation was categorized as "heavy work".

The critical component interacting with soil is blade whose cross-sectional area determines the force requirement based on the type of soil. An attempt was made to reduce the operational force requirement by reducing the width of cutting blade. The blade dimensions (width) were reduced by 5% and 10% of the existing blade. The reduced blade width decreased the area of contact with soil from 35.70 cm^2 to 34.02 cm^2 and 32.13 cm^2 for reduced 5% and 10% blade dimension respectively. This reduced the force requirement from 122.09 N to 116.34 and 109.88N resulting in reduced efforts. The work rest pause also reduced by 38.01%; resulting in longer work duration for one hour work cycle. It was observed that rest pause required for the existing weeder was 33.45 min for one hour work cycle, this duration reduced to 20.68 min for modified weeder (10%-480 mm).

After modification, it was observed that the heart rate of the subjects during the operation of the modified wheel hoe reduced by 11 beats/min as compared to the existing wheel hoe. Correspondingly, oxygen consumption also reduced, shifting the category of workload from "heavy" to "moderate". It was found that treatments (modifications) had a significant effect on energy expenditure while replications had no effect on energy expenditure (Table 4).There is a significant difference in the energy expenditure of the modified wheel hoe (5%-440mm) and (10%-440mm) compared to the existing wheel hoe. Heart rate was lowest for working with a wheel hoe (5%-440mm and 10%-480 mm), followed by (10%-440mm). It was observed that (5%-440mm), (10%-440mm), (10%-400mm) and (10%-480mm) had "moderate" category of work while (5%-400mm) and (5%-480mm) fall in "heavy" category of work.

Measurements of postural parameters

The mean positions and motions in the twisting (transverse), sagittal and lateral planes are given in Table 2. Average twisting velocity of subjects operating modified wheel hoe was highest for (5%-400mm) and (10%-400), lowest for (10%-400mm).From the experiment, it was observed that average twisting velocity, maximum sagittal flexion and maximum lateral velocity remain unchanged as there was negligible change in the movement of trunk motion.

It was also observed that existing wheel hoe handle width was 540 mm, which was more than elbow to elbow width of woman farm workers. The handle width was reduced to 400-480 mm based on anthropometric dimension of elbow width of female worker with a permissible allowance of upper arm abduction. Handle with three different widths 400mm, 440mm and 480mm were made considering elbow to elbow width (bideltoid breadth) of female workers (Mean-371 mm, and a range of 5^{th}-95^{th} percentile: 318-423 mm). A quick height adjustment system with fly nuts, which can be easily done by female worker, was incorporated for the ease of operation suitable for their stature.

Table 4 ANOVA of energy expenditure, weeding efficiency and field capacity

Source of variation	DF	Sum of squares	Mean squares	F-calculated
Energy expenditure				
Replication	17	550.009		
Treatment	6	367.641	61.273	13.437*
Error	102	465.121	4.56	
Total	125	1382.77		
Weeding efficiency				
Replication	17	51.621		
Treatment	6	925.395	154.233	83.884*
Error	102	187.541	1.839	
Total	125	1164.56		
Field capacity				
Replication	17	4921.43		
Treatment	6	38142.86	6357.14	28.911*
Error	102	22428.57	219.888	
Total	125	65492.86		

*Significant

From the experiments, it was observed that with the modification in the handle the range of movements shifted to preferred zone for most movements, subjected to minimal stress on muscles and joints, i.e. zone 0 or 1. Shoulder abduction of modified wheel hoe reduced to zone 1 from zone 2. The back deviation of existing wheel hoe was in the range of 25^o-32^o which was under zone 2, i.e. more extreme position for the upper extremities with greater strains on muscles and joints. After these modifications back deviation reduced to 4^o-28^o (zone 0 to zone 1).Similar result was also obtained for shoulder extension (Zone 2 to Zone 1 or 0). It is observed that minimum deviation was obtained for handle width 440 mm.

Modification facilitated the worker to perform the weeding operation close to neutral position as deviations of body parts reduced. From the results, it was inferred that the deviation of modified wheel hoe increases preferred zone for movement resulting in minimal stress on muscles preventing musculoskeletal disorders.

Body part discomfort score and overall discomfort

Based on the Corlett and Bishop technique, the body part discomfort scores (BPDS) and overall discomfort (ODS) of all the subjects for all the experiments are given in Table 2. Most common body parts affected were hands, wrists, arms, thighs, knees and palms. The average body part discomfort of subjects operating existing wheel hoe was 31.01 which were close to the result reported in the previous study (Kumar *et al.* 2002). They found that body part discomfort score was 29.5 for wheel hoe. The body part discomfort score and overall discomfort score were lowest for subjects operating modified wheel hoe (10%-440 mm). The highest value of mean body part discomfort score was observed in (10%-400 mm) wheel hoe. The body part discomfort score and overall discomfort of workers reduced to 18.38 and 1.47 for (10%-440 mm) wheel hoe as compared to the existing wheel hoe (body part discomfort and overall discomfort score, i.e. 32.01 and 2.51).

Some of the workers commented on the modified tool as "*it reduced bending and enhanced back comfort*" , "*easy adjustment to suit my height*", " *comfortable for upper limbs*" but one of the workers opined her preference for "*sitting/ squatting posture of traditional weeding*".

Weeding performance

The performance of the wheel hoe was evaluated in the Division of Agricultural Engineering experimental farms. The soil moisture content was between 10.41 to 12.72 % (db), soil type was sandy loam and bulk density of soil varied from 1370 kg/m^3 to 1591 kg /m^3. The weeding efficiency, man hour per ha and field capacity is tabulated in Table 2. Weeding efficiency and field capacity of existing wheel hoe was 84.37 % and 145 m^2/hr respectively, similar results were reported in previous study (Goel *et al*. 2008). The field capacity was higher even after a reduction in the size of cutting blade. This was achieved due to reduced rest pause requirements. The reduced heart rate made worker to perform the operation at higher speed, resulting in more covered area.

It was observed that the weeding efficiency of (10%-440mm) tool was highest and (5%-400mm) tool was lowest. Inversely the number of man hour required for the intercultural operation for one ha area of land was lowest for (10%-440mm) and highest for (5%-400mm). The effect of treatments on weeding performance and field capacity was found to be highly significant (Table 4). Mean, standard error, critical difference (CD), coefficient of variation (CV) and standard error of mean (SEM) for energy expenditure, BPDS, ODS, weeding efficiency and field capacity are given in Table 4 .

Conclusions

An existing wheel hoe was evaluated in terms of physiological, postural parameters and work output for women farm workers. The energy expenditure (21.5 KJ/min), working heart rate (115 beats/min), body part discomfort and overall discomfort were high, classifying the work as "heavy" for existing wheel hoe because of mismatch of tool dimensions with anthropometry of women worker. Body part deviations also fall in the "zone 2 and zone 3"indicating higher postural discomfort. Based on observations, wheel hoe was modified by reducing the handle width, decreasing the dimensions of cutting blade and modification in height adjustment system. Modification reduced the energy expenditure resulting in change of work category from "heavy" to "moderate". The postural stresses also reduced because of compatible tool dimensions. Field capacity, improved from 145 m^2/hr to185 m^2/hr.

REFERENCES

Bridger R S, Baltimore M D and Williams W.1995. *Introduction to Ergonomics*, pp 205-10. McGraw-Hill, Inc, New York.

Chakrabarti D and Bhattachheriya N. 2012.Ergonomic design intervention strategy for work tools development for women agro based workers in Northeast India.*Work*: *A Journal of Prevention, Assessment and Rehabilitation*: **43**.

Chaffin D, Andersson G B J and Martin B.1999. *Occupational Biomechanics*, Third Edition. John Wiley & Sons, Inc, New York.

Corlett E N and Bishop R P.1976. A technique for assessing postural discomfort. *Ergonomics* **19**:175–82.

Gangopadhyay S , Ghosh T, Das T, Ghoshal G and Das B.2010. Effect of working posture on occurrence of musculoskeletal disorders among the sand core making workers of West Bengal. *Cent European Journal of Public Health* **18**: 38–42.

Goel A K, Behera D, Behera B K, Mohanty S K and Nanda S K. 2008. Development and ergonomic evaluation of manually operated weeder for dry land crops. *Agricultural Engineering International: the CIGRE journal* **10**.

Kroemer K H E and Grandjean E. 2000. Fitting the task to the human. (*In*) *A Textbook of Occupational Ergonomics*, Fifth Edn. Taylor and Francis Ltd, UK.

Kumar A, Tandon S K and Saxena J P. 2002. Ergonomic evaluation of weeders. *Journal of Agricultural Engineering* **39**: 17–22.

Murrell K F H.1965. *Ergonomics: Man and His Working Environment*. Chapman and Hall, New York.

Nag P K and Datt P. 1979. Effectiveness of some simple agricultural weeders with reference to physiological responses. *Journal of Human Ecology* **8**: 13–21.

Naughton J G and Sevelluske B.1963. Physiologic responses of normal and pathologic subjects to a modified work capacity test. *Journal of Sports Medicine* **31**: 201.

Remesan R, Roopesh M S, Remya N and Preman P S. 2007. Wet land paddy weeding –A comprehensive comparative study from South India. *Agricultural Engineering International: the CIGRE journal*. **9**.

Rodahl K.1989. *The Physiology of Work.* Taylor and Francis, London.

Shirahatti S S, Badiger M S and Prakash K V. 2009. Agricultural engineering interventions to increase the productivity of women in agriculture: some studies from India. *Karnataka Journal of Agricultural Sciences* **20**(2).

Singh S, Mathur P and Rathore M. 2007. Weeders for drudgery reduction of women farm workers in India. *Journal of Agricultural Engineering* **44**: 33–8.

Singh S, Sinwal N and Rathore H.2012. Assessment of energy balance of Indian farm women in relation to their nutritional profile in lean and peak agricultural seasons. *Work: A Journal of Prevention, Assessment and Rehabilitation* **41.**

Vyas H, Nag A and Nag P.2016. Ergonomics evaluation of user-hand tool interaction. *Work: A Journal of Prevention, Assessment and Rehabilitation* **53**(4).