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Development of Dry land Weeders with Ergonomic Principles for Higher Efficiency

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Abstract

As natural postures and movements are necessary for an efficient work, the tools, equipment and work places need to be designed to suit the body size of the workers (Grandjean, 1982). It is not possible to make designs to suit everybody i.e. from the biggest to the smallest workers, from male to female agricultural workers. Keeping this in view, design recommendation was made for modifying the existing wheel hoe and wheel finger weeder, those are generally of dry land weeders operated in push-pull mode. Different anthropometric parameters like stature, accromial height, elbow height, olecranon height, elbow rest height, elbow-elbow breadth, and hand length at metacarpal-III were taken into consideration. The mean value of stature of male and female workers observed to be 165.3 cm for male and 151.6 cm for female agricultural workers in Odisha. The mean value of push force by both hand in standing was recorded highest 224N for male against 143N for female workers whereas as the pull force was recorded 158N for female against 218N for male counterparts. Higher cardiac cost was recorded in case of manual mode of weeding i.e. with trench hoe against wheel hoe and wheel finger weeder, may be due to the fact that bending posture is adopted during weeding operation.

Key words: Ergonomics, weeders, anthropometric, weeding index.

Introduction

One of the major, labor intensive and costly farm operations is the weeding and intercultural operation is to provide best opportunity for the crop to establish and grow vigorously up to time of harvest. Keeping this, in view of design recommendation has been given for the wheel hoe, a push pull type weeder. The anthropometric and strength parameters have been incorporated while designing a weeder. The benefits of improved weeder will be reduction of efforts and effectiveness of operation. Musculoskeletal disorders constitute one of major problem in occupational environment. Considerable attention has been given determination of safe levels of exertion in MMH activities such as lifting, lowering, pushing and holding. Other activities such as shoveling, digging, weeding have not been studied extensively. Keeping this in view, manual push-pull weeders i.e. wheel hoe and

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wheel finger weeders were studied with male and female workers. The anthropometric parameters and strength parameters have been incorporated in designing a wheel hoe and wheel finger weeder. The weeders should be designed to suit the body size of operator's. Since it is not possible to make designs to suit everybody, i.e. from biggest to smallest workers, one has to be content with meeting requirement of majority of user and it is generally taken as 90 per cent of user population. Many times scientists/ designers use the concept of average men or women and start designing for average user. However, use of this value of design many times may lead to great consequence and design deficiencies. Therefore, to have proper design of equipment the concept of 5^{th} percentile and 95^{th} percentile are used. Effort is made in this research work to show the use of various anthropometric and strength data in designing a wheel hoe. These weeders are used for weeding and intercultural operation in upland row crops in black soil region. Both male and female workers can operate this weeder in push pull mode.

Materials and Methods:

Six male and six female subjects were selected for this study and the ergonomical parameters were measured and tabulated and placed at Table no 3. Prior to that the detail anthropometric parameters and strength data are presented in Table No.1. To evaluate the physiological workload, the relationship between heart rate and oxygen consumption was determined for each subject. Their anthropometric and physiological parameters were recorded in the laboratory. Their resting heart rate, oxygen consumption rate, blood pressure were measured. Five sub maximal loads (varying walking speed on tread mill) were applied by means of speed regulator in the tread mill (Astrand and Rodahl, 1977). This test was conducted on a tread mill and the experiment was conducted at natural environmental condition (29.4±2.4^{0}C and 74±8.3 RH) in the ergonomics laboratory of CAET, Bhubaneswar. Polar heart rate monitor and Metamax II were utilized to measure the physiological parameters of the subjects in the laboratory and also in the field.

Table No.1: Some anthropometric data of male and female workers (N=12)

Sl. No.	Anthropometric parameters	Male			Female		
		5^{th} percentile	Mean	95^{th} percentile	5^{th} percentile	Mean	95^{th} percentile
1.	Stature, cm	153.1	165.3	177.56	141.34	151.6	161.8
2.	Accromial height, cm	126.2	136.7	147.2	114.6	124.7	134.88
3.	Elbow height, cm	95.3	103.89	112.48	88.79	96.11	103.43
4.	Olecranon height, cm	92.51	101.01	109.51	85.56	93.34	101.12
5.	Elbow rest height, cm	16.40	21.12	25.84	16.81	21.93	27.05
6.	Elbow elbow breadth, cm	21.98	28.23	34.48	27.83	34.49	41.15
7.	Hand length, cm	16.10	18.55	21.00	14.74	16.75	18.76
8.	Hand length at Metcl. III, cm	5.93	8.08	10.23	5.38	6.99	8.60
9.	Push force by both hand (standing), N	132	224	316	79	143	208
10.	Pull force by both hand (standing), N	142	218	294	95	158	223

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Design criteria

Accromial height, Elbow-elbow breadth, Grip diameter (inside), Middle finger palm grip diameter, Push force by both hands (standing), Pull force by both hands (standing) etc. have been taken into consideration while designing a weeder.

i. Push and pull strength

It is a push/pull type of equipment but generally operated in push mode. Weeding is a continuous work and the desirable force limit should be 30 per cent of the 5^{th} percentile value of push force. The regional variation in force is also to be considered.

a) If the equipment is to be operated by male workers, 30 per cent of the 5^{th} percentile push force of male works is to be considered.
b) If the equipment is to be operated by female workers, 30 per cent of the 5^{th} percentile push force of female workers is to be considered.
c) If the equipment is to be operated by both male as well as female workers, 30% of the 5^{th} percentile push force of female workers is to be considered.

As per the data collected, the 5^{th} percentile value of push and pull force with both hands in standing posture for female workers are 79 N and 95 N , respectively. Therefore, the wheel hoe should be such that the operator does not have to exert more than 24 N push or 29 N pull. If more force is needed than this, the operator would have to take frequent rest breaks in between the work schedule depending on severity of work.

ii. Handle height

Weeding is a continuous work and desirable height of the handle is to be such that if gives least fatigue and 0.7 to 0.8 of the accromial height is the suitable handle height for work (Gite & Yadav, 1989).

a) If the equipment is to be operated by male workers, 0.8 of the 5^{th} percentile and 0.7 of the 95^{th} percentile accromial height of male workers are to be considered.
b) If the equipment is to be operated by female workers, 0.8 of the 5^{th} percentile and 0.7 of the 95^{th} percentile accromial height of female workers are to be considered.
c) If the equipment is to be operated by both male as well as female workers, 0.8 of the 5^{th} percentile accromial height of female workers and 0.7 of the 95^{th} percentile accromial height of male workers are to be considered.

As per the data collected, the 5^{th} percentile value of accromial height for female is 1168 mm and the 95^{th} percentile value of accromial height for male workers is 1468 mm. Therefore, the handle height should be adjustable between 0.93-1.03 m. If the handle is of fixed type, the handle height may be kept as 0.98 m.

iii. Cross handle bar length

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As this operation is a continuous work, the desirable position of holding the cross handle bar should be in the line of the arms, for least fatigue. So, elbow-elbow breadth is to be considered for cross handle bar length.

a) If the equipment is to be operated by male workers, 95th percentile elbow-elbow breadth of male workers may be considered.
b) If the equipment is to be operated by female workers, 95th percentile elbow-elbow breadth of female workers is to be considered.
c) If the equipment is to be operated by both male as well as female workers, 95th percentile elbow-elbow breadth of female workers is to be considered.

The 95th percentile values of elbow-elbow breadth for female and male workers are 413 and 452mm, respectively. Therefore the crossbar handle length can be taken as 450 mm.

iv. Handle length

Length of the handle of tool and the angle of operation are interdependent. Angle of operation is based on functional design and geometry of the tool and generally lies between 30^0 and 45^0. Once the height of handle is determined and the point of attachment is known, the length of handle can be calculated.

v. Handle grip

The desirable shape of handle grip is cylindrical.

vi. Size

The diameter of the grip should be such that while holding the grip, the operator's longest finger should not touch the palm. At the same time, the grip should not exceed the internal grip diameter.

a) If the equipment is to be operated by male workers, 95th percentile middle finger palm grip diameter is the lower limit and 5th percentile grip diameter (inside) of the male workers is to be considered as the upper limit.
b) If the equipment is to be operated by male workers, 95th percentile middle finger palm grip diameter is the lower limit and 5th percentile grip diameter (inside) of the female workers is to be considered as the upper limit.
c) If the equipment is to be operated by both male as well as female workers, 95th percentile middle finger palm grip diameter is the lower limit and 5th percentile grip diameter (inside) of the female workers is to be considered as the upper limit.

However, as the wheel hoes are mostly used by women workers and their 95th percentile value of middle finger palm grip diameter is 31 mm. Therefore the handle grip diameter recommended is 30-35 mm.

vii. Posture

A good posture is one which can be sustained with a minimum of static muscular effort and in which it is possible to perform the given task more effectively and with least muscular discomfort. It has been observed that weeding either in squatting or bending posture did not cause a marked difference in energy expenditure. But, the drudgery caused due to bending is reflected in terms of postural discomfort experienced by the worker. Therefore,

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when work can be done in standing posture, it should not be done in a bending posture. Use of long tools such as wheel hoe can help to avoid the bending posture of the operator during work.

viii. Mean foot pressure

The mean foot pressure is calculated by the given formula:

MP= 0.15+0.0026WT

Where MP= mean foot pressure, kg/m^2

WT= weight of the subject, kg

Table 2. Specification of weeders developed as per the anthropometric and strength parameters of male and female workers.

Parameters	Wheel hoe	Wheel finger weeder	Trench hoe
Overall dimensions, cm			
Length	182	170	83
Height	107	117	33
Width	39.2	39	15
Weight, kg	6.5	5	1.5
Working width, cm	20.6	12	15
Material of construction	Mild steel, MS flat	Mild steel MS rod	High Carbon steel
Type of wheel	MS flat	MS-rod (10mm)	-
Diameter of wheel, cm	34	34	-
Height of handle from ground level, cm	107	117	63
Handle width, cm	40	39	3.5
Handle length, cm	138	128	-
No. of tyne / cutting blade	1	5	-

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Fig1:Calibration of male subject in the laboratory with treadmill

Fig2: Measurement of heart rate using Heart Rate Monitor during weeding with trench hoe

Fig3 :Weeding with wheel hoe

Fig 4 Measurement of oxygen consumption rate using Metamax II during weeding with wheel finger weeder

Result and discussion:

Six male and six female agricultural workers were evaluated with push-pull weeders in the groundnut crop in the Central Farm of OUAT. The physiological parameters and mechanical parameters were presented in Table No. 3. The average working heart rate and oxygen consumption rate of each subject was measured with the help of a heart rate monitor

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and Metamax II. Each trial was conducted for a period of 15 minutes of continuous working operation. The average data of heart rate and oxygen consumption rate from 6th to 15th minute of continuous operation of both male and female workers were recorded and presented in Table no.3.

Table:3 Physiological parameters of during weeding operation (N=12)

Sl. No.	Parameters	Wheel Hoe		Wheel Finger Weeder		Mannual weeding(Trench hoe)	
		Male	Female	Male	Female	Male	Female
1.	Working heart rate, beats/min	138.5	129.9	128.8	126.8	140.2	136.3
2.	Work pulse	63.5	59.9	53.8	51.8	65.2	61.3
3.	VO_2work, l/min	1.40	1.35	1.29	1.28	1.42	1.36
4.	EER, kJ/m^2	29.2	28.2	26.9	26.8	29.7	28.4
5.	Weeding index, %	89.9	92.9	90.4	89.5	92.5	92.6
6.	Plant damage,%	8.2	8.7	6.39	6.5	3.5	4.2
7.	Actual field capacity, ha/h	0.015	0.018	0.032	0.029	0.011	0.015

Physiological parameters of selected male and female subjects were presented in Table:3 of ergonomically designed weeders. Higher working heart rate was recorded for male subjects as compared to female subjects. This may be due to the fact that heart rate at rest of female was noticed lower than that of male subjects. In case of wheel hoe, the working heart rate was observed 138.5 beats/min for male and 129.9 beats/ min for female workers but in case of wheel finger weeder , it was 128.8 and 126.8 beats /min for male and female workers respectively. It was observed that the HR_{work} during weeding operation for female workers for all three types of weeders was lower than that of the male workers. Similar result was also reports by (Nag & Datta, 1979 and Gill & Choudhry, 1987). This may be due to the fact that female's maximum aerobic power (MAP) is about 70 to 75 per cent of that of male workers (Astrand and Rodahl, 1970, Astrand et al, 1973 and Rebok et al, 1975). The HR_{peak} was observed almost during 6th minute of continuous operation and which was stabilized during the process of weeding operations for all the workers. Similar result was also reported in earlier studies (Vidhu, 2001). The oxygen consumption rate was observed to be 1.40 and 1.35 l/min for male and female workers respectively in case of wheel hoe and 1.29 and 1.28 l/min for male and female respectively in case of wheel finger weeder. The average oxygen consumption rate VO_2 during weeding operations of male workers was observed to be higher than that of female workers. This may be due to the fact that VO_2 has a linear relationship to HR_{work} (McArdle et al, 2001). Similar result of oxygen consumption rate was also reported by researchers while evaluating the workers of different age groups (Astrand, 1967 and

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Astrand & Christensen, 1964). The mean foot pressure of male workers was recorded more than female workers. The weeding index in case of ergonomically designed weeder was maximum i.e. 92.9 per cent in case of female workers working with wheel hoe. Plant damage was more i.e. 6.69 per cent in case of wheel hoe. Actual field capacity was observed to be 0.032ha/h (320m^2) by male worker in wheel finger weeder and 0.029ha/h (290m^2) by female workers.

Conclusion

The ergonomically designed dryland weeders designed as per the anthropometric and strength parameters of the male and female agricultural workers was observed to be better than that of weeding with the manual tool i.e. trench hoe adopting bending posture. The mean value of stature and accromial height of female agricultural workers was recorded 8.2% and 8.9% less for the workers to suit different stature of subjects. The elbow-elbow breadth, grip diameter, middle finger palm grip diameter, push force, pull force were taken into consideration while designing a weeder. The working heart rate of male workers was observed to be more than that of female workers. Higher cardiac cost was reported while weeding with trench hoe i.e. 140.2 and 136.3 beats per minute for male and female workers. The oxygen consumption rate and energy expenditure rate followed the same trend. Higher field capacity was reported in wheel finger weeder 0.032ha/h for male and 0.029 ha/h for female workers respectively. The designed weeders could not only increase the productivity of the workers but also it help in reducing the drudgery and fatigue of the workers. Keeping this in view the anthropometric and strength parameters should be incorporated while designing the tools and equipments for both male and female agricultural workers.

References

1. Astrand, P.O. and Rodahl, K. 1977. A Textbook of work physiology. New York, Mc. Graw Hill.

2. Astrand, P.O. and Rodahl, K. 1970. A Textbook of work physiology. New York, Mc. Graw Hill.

3. Astrand, I. 1967. Degree of strain during building work as related to individual Aerobic work capacity, Ergonomics 10,293

4. Astrand, P.O.; and Christensen,E.H. 1964. Aerobic work capacity in F Dickens, E . Neil and W.F. Widdas (eds), P 295 " Oxygen in the Animal Organism" Pentagamon Press. Newyork

5. Gill, H.S. and Choudhury, A. 1987. Ergonomic evaluation if few manually operated dryland weeders. B.Tech. Thesis College of Agricultural Engineering. Jawaharalal Nehru Krishi Vishwa Vidyalaya, Jabalpur
6. Gite, L.P., J. Majumdar, C. R. Mehta and A. Khadatkar : 2009, Anthropometric and Strength Data of Indian Agricultural Workers for farm equipment Design.
7. Gite, L.P. and Yadav, B.G., 1989. Anthropometric Survey for Agricultural Machinery design – An Indian case study. Applied Ergonomics 20(3) 191-196.

ISSN 2348 – 7968

8. Grandjean, E.1982. Fitting the task to the man-An ergonomic approach. Taylor and Francis Ltd., London

9. Mc Ardle,W.D .;Katch, F. I. And Katch, V. L. 2001. Exercise Physiology, 5th edition. Lippincott Willams and Wilkins publication
10. Nag, P.K. and Dutta, P. 1979., Effectiveness of some simple agricultural weeders with reference to physiological responses Journal of Human Ergology 8: 13-21.

11. Rebock, J.A. Jr.;Kroemer,K.H.E. and Thomson, W.G. 1975. Engineering Anthropometry Methods, A. Wiley. Inter Science Publication, John Wiley and Sons 159p.