Aerobic Capacity of Indian Farm Women Using Sub-maximal Exercise Technique on Tread Mill

S P Singh[1], L P Gite[2], J Majumder[3] and Nidhi Agarwal[4]

[1, 2 & 4] Senior Scientist (FMP), Scientist Incharge and Technical Assistant (Agril. Engg.), N R C for Women in Agriculture (Bhopal Sub-centre).
[3] Research Associate (Human Physiology) , Ergonomics and Safety in Agriculture,

Central Institute of Agricultural Engineering, Nabi Bagh, Bhopal- 462 038

spsingh_phd@yahoo.co.in, lpgite@ciae.res.in, jm78ergo@gmail.com and agar_nidhi@yahoo.co.in

ABSTRACT

For sustained physical activities, the aerobic capacity, i.e., maximal oxygen consumption (VO_{2max}) of a worker sets the limit for their maximum performance. Therefore to know the aerobic capacity of farm women, a study was carried out at NRCWA Bhopal Sub-centre, CIAE, Bhopal on fifteen farm women workers (nine in 25 to 35 year and six in 36 to 45 year age group) using sub maximal exercise (workload) technique on a computerized tread mill. The stature of subjects lied between the values of 5th to 95th percentile of Madhya Pradesh farm women. The mean body weights of these workers of 25 to 35 year and 36 to 45 year age groups were 49.8 $\pm$ 9.3 kg and 46.0 $\pm$ 7.1 kg, respectively. Corresponding mean VO_{2max} of farm women were 33.5 $\pm$ 4.86 ml kg^{-1} min^{-1} and 32.65 $\pm$ 5.77 ml kg^{-1} min^{-1}. At mean aerobic capacity of farm women for the age of 25 to 45 year of 33.18 ml kg^{-1} min^{-1}, the heart rate levels of 120 beats per min or work pulse of 40 beats per min may be considered as optimal criteria, for the quick appraisal of the state of activity that may be continued for longer period with proper rest pauses A linear relationship between heart rate and oxygen consumption rate was also observed and regression equations have been suggested for estimating the oxygen consumption rate of farm women from their measured heart rate data for agricultural activities in the field.

Keywords: Gender, maximal oxygen consumption **(**VO_{2max}), graded exercise, heart rate, agricultural activities, India

1. INTRODUCTION

The aerobic capacity, i.e., maximal oxygen consumption (VO_{2max}) sets the limit of an individual's cardio-respiratory fitness or capability to give maximum performance for sustained physical activities. Physical work performed by the human body is accomplished by muscular contractions, supported by oxidative metabolic process in the muscle cells, in which fuel (essentially carbohydrate and fat) is oxidized in presence of oxygen. Oxygen uptake, therefore, is an expression of the rate of energy output or rate of work (Rodahl, 1989). Considering this, the most important determinant of endurance fitness is the maximum oxygen uptake or aerobic power or physical work capacity (a litre of oxygen uptake per min). It is also expressed as percentage of the individual's maximum aerobic power, i.e., how much of individual's maximum aerobic power has to be taxed in order to complete the work with

exhaustion. Rodahl (1989) stated that aerobic capacity is higher in men than women. Nag and Chatterjee (1981) conducted study to get aerobic capacity of eight farm women of Eastern region of the country using Harvard step up test and average aerobic capacity was found to be 37.8 ml kg^{-1} min^{-1}. Aerobic capacity of sedentary female university students of same socio-economic background was also determined by both direct method, using bicycle ergometer, and indirect method, using Queen's College Step Test by Chhaterjee et al (2005) at Kolkatta. They found significant difference on aerobic capacity obtained by both methods and based on their study; they also suggested a regression equation for predicting oxygen uptake. Varghese et al (1995) conducted study on aerobic capacity of urban women home makers in Mumbai, using bicycle ergometer and treadmill. They found significantly higher maximal oxygen consumption (VO_{2max}) with treadmill as compared to cycle ergometry. It is clear from above that limited study is available in the country on farm women. Though, Indian farm women used to spend a considerable amount of energy while performing farm operations in addition to their routine household activities. Therefore, knowledge of farm women's aerobic capacity can be of great importance in organizing work, work methods and modifying/refining/ developing farm tools and equipment for them as their share in agricultural workforce in the country is estimated to 55% of total agricultural workforce by 2025 as per Government of India (2006).

Accordingly, a study was undertaken to determine the aerobic capacity of farm women of Madhya Pradesh at Bhopal using sub-maximal workload technique on treadmill as treadmill was judged superior to the bicycle ergometer, with the step test occupying an intermediate position (Shephard, 1980 and Rodahl, 1989). This may be due to involvement of total body weight with more muscle mass during treadmill exercise whereas with bicycle ergometer only leg muscles were employed and thus, subjects fatigued earlier resulting in lower aerobic capacity.

Various researchers used to measure the heart rate during field experiment due to getting difficulty in getting oxygen consumption in the field. Presently, Varghese et al (1994) formula is being used by many research workers to get the energy expenditure. This study was conducted for urban homemakers and partly college students while the lifestyle and working of urban housewives and farm women are quite different. Keeping this in view, an attempt was also made to develop regression equations for estimating oxygen consumption at known/measured heart rate based on the relationship between heart rate and oxygen consumption.

2. MATERIALS AND METHODS

Fifteen farm women working in various farm operations have been randomly selected for conducting the study. The care was taken while selecting the subjects such that they are physically fit to undergo the trials. Such subjects were selected among farm workers whose stature lied in between the values of 5^{th} to 95^{th} percentile of Madhya Pradesh farm women i.e., 142.7 cm to 159.7 cm (CIAE, 2005) so that they can be representative of farm women of the state. Farm women were categorized in two age-groups of 25-35 year and 36-45 year based on phenomenon of aging as reported by Shephard (1998). The lean body mass of the subjects was calculated using Hume's (1966) formula [(0.29569 x body weight, kg) + 0.41873 x body height, cm)- 43.2933] and body surface area was calculated using Mosteller formula (Mosteller, 1987). The body mass index was calculated by dividing square of height (m^2) to weight (kg) of subject. The details of subjects are given in Table 1.

Table 1. Details of participated subjects in the experiment.

Sl. No.	Particulars	Participated Subjects	
		Group-I	Group-II
1.	Age range (years)	25-35	36-45
2.	Number of subjects	9	6
3.	Age, years	31.3 ± 3.5	42.7± 2.7
4.	Height, cm	151.6± 3.1	152.8 ± 5.7
5.	Body mass, kg	49.8 ± 9.3	46.0 ± 7.1
6.	Lean body mass, kg	34.91	34.29
7.	Body surface area, m^2	1.448	1.397
8.	Body mass index	21.67	19.7

Naughton protocol (Naughton et al, 1963) was followed in principle for the sub-maximal exercise on treadmill. As per the specific requirement, a protocol for conducting the experiment to determine aerobic capacity using sub maximal exercise was framed with slight change. The maximum heart rate of each subject was determined by using Robergs and Landwehr (2002) equation (HR max= 205.8 – 0.685 x age). The speed for walk on treadmill was decided based on the field experiment carried out by Singh (2005), where they perform the various farm operations at speed varying from 2.5 to 4.5 km/h. The work rate for each subject was increased stepwise at intervals of 3 min on load (slope) until exhaustion as suggested by Naughton et al (1963) and Rodahl (1989). In addition to this, the heart rate of each subject was limited to their approximately 75% of maximum heart rate during the exercise to avoid any complexity with the subject. Accordingly, the exercise (work) schedule was developed for conducting trial with each subject at different speed (2.5, 3.5 and 4.5 km/h) and slope (0, 3, 6, 9, 12, 18, 21 and 24%) on treadmill. One to two days training was provided to each subject on tread mill at different speed and slope. Prior to start of experiment, preliminary warm up of subjects at approximately 70% of their maximal heart rate was carried out. Warm up exercise was done on treadmill for 15 min and followed by rest of 30 min to each subject.

An ambulatory metabolic measuring system (Cortex Metamax-II) was used to measure the heart rate and oxygen consumption data of workers during sub-maximal exercise on the treadmill. The experiment was conducted in a controlled environment in a laboratory on computerized treadmill. The dry bulb temperature and relative humidity were 21.9 ± 1.1 ^{0}C and 44.1 ± 4.0 %, respectively. The observed data of heart rate and oxygen consumption uptake at all speed for each subject was noted. Statistical treatment of the data obtained was carried out using WINDOSTAT statistical software. The data were plotted on graph for extrapolation of oxygen uptake at maximal heart rate of each subject to determine the aerobic capacity. For estimating the aerobic capacity, the oxygen consumed at heart rates of 110, 120, 130, 140, 150, 160, 170 and 180 beats per min was plotted for group-I and for farm women workers of group-II, it was plotted at a heart rates of 110, 120, 130, 140, 150, 160 and 170 beats per min. After determining the aerobic capacity of each worker, it was divided by their body mass and the aerobic capacity was presented in ml. kg-body $mass^{-1}$ min^{-1}.

For getting equations to estimate oxygen consumption at known heart rate, oxygen consumption recorded/measured at different heart rate (resting and at varying load) was plotted for each subject. Thereafter, oxygen consumption at heart rate of 80 beats per min to 180 beats per min was plotted for group-I and for group-II, it was plotted up to 170 beats per min. For getting general equation, graph was plotted up to 170 beats per min.

3. RESULTS AND DISCUSSION

The maximal heart rate of subjects of both age groups is given in Table 2. The variations in maximal heart rate of subjects of age group-I were from 181.8 beats per min to 188.7 beats per min while it was 174.9 beats per min to 179.1 beats per min for the subject of age group-II. The mean maximal heart rate for group-I and II subjects was 184.3 ± 2.401 beats per min and 176.6 ± 1.871 beats per min, respectively.

Table 2. Maximal heart rate of subjects as determined using Robergs and Landwehr equation*.

Subject Group-I	Maximal Heart Rate*, beats per min	Subject Group-II	Maximal Heart Rate*, beats per min
S1	188.7	S1	179.09
S2	186.62	S2	178.4
S3	185.25	S3	177.03
S4	185.25	S4	174.98
S5	184.57	S5	174.98
S6	183.195	S6	174.98
S7	181.83		
S8	181.83		
S9	181.83		
Mean	184.342		176.577
SD	2.401		1.871

* Robergs and Landwehr (2002).

The mean exercise time, targeted heart rate and oxygen consumption at various speed and slope on tread mill of subjects of both age groups are given in Table 3. It is clear from table that the mean exercise time was in decreasing order as the speed of walking/running increased for both age groups, while the heart rate and oxygen consumption increased with speed of walking. This may be due to increment of load for more walking per unit time.

Table 3. Mean exercise time, targeted heart rate and oxygen consumed at various speed and slope on tread mill.

Particulars		Mean Values of Subjects	
		Group-I	Group-II
Speed : 2.5 km/h	Exercise Time, min	26.2 ± 1.9	25.3 ± 3.2
	Targeted HR, bpm	150.4 ± 6.4	142.0 ± 6.6
	Oxygen Consumed, l/min	1.004 ± 0.269	0.961 ± 0.143
Speed : 3.5 km/h	Exercise Time, min	22.2 ± 2.0	21.5 ± 5.1
	Targeted HR, bpm	155.6 ± 9.1	146.5 ± 7.8
	Oxygen Consumed, l/min	1.107 ± 0.277	0.973 ± 0.210
Speed : 4.5 km/h	Exercise Time, min	16.9 ± 2.3	16.6 ± 3.4
	Targeted HR, bpm	154.8 ± 9.6	149.2 ± 5.4
	Oxygen Consumed, l/min	1.096 ± 0.282	1.032 ± 0.241

The aerobic capacities of subjects of both age groups are given in Table 4. The variations in aerobic capacity for group-I subjects were from 1.449 l min^{-1} to 2.085 l min^{-1} while for group-II, it varied from 1.206 l min^{-1} to 2.159 l min^{-1}. The mean aerobic capacity of group-I and group-II subjects was 1.704 $\pm$ 0.33 l min^{-1} and 1.454 $\pm$ 0.404 l min^{-1}, respectively. The mean aerobic capacity of group-I subject was 17.2% higher than group-II subjects. This is also in agreement to the findings of Nag, 1986. The correlation coefficients (r^2) of individual subjects varied from 0.491 to 0.9499 for group–I while it varied for group–II subjects from 0.5407 to 0.806. The F and T values of observed and calculated oxygen consumption for individual subjects of both the groups varied from 1.0096 to 2.3446 and 0.0292 to 0.5526, respectively. There is no significant difference between the values observed and calculated from regression equation at various increasing heart rates (110 beats per min to 160 beats per min) at 5% confidence level. The oxygen uptake by the subject of both age groups was increased by 0.161 l/min and 0.145l/min for every ten heart beat increment (approximately equivalent to 9.6%of VO_{2max}). Relative loads at 110 beats per min and 140 beats per min were 26% and 54% of VO_{2max} for the subject of 25-35 year age group and 37% and 67% of VO_{2max} for 36-45 year of age group. This means that the relatively higher oxygen uptake at a targeted heart rate in the older subjects may be due to an increase in stroke volume/arteriovenous oxygen difference.

Table 4. Aerobic capacity of subjects.

Subject	Aerobic Capacity of Farm Women			
	Group-I		Group-II	
	l min^{-1}	ml kg^{-1} min^{-1}	l min^{-1}	ml kg^{-1} min^{-1}
S1	1.852	40.19	1.338	35.55
S2	1.449	40.03	2.159	37.06
S3	1.66	36.68	1.206	26.78
S4	1.532	30.53	1.92	40.2
S5	1.599	28.2	1.217	26.35
S6	1.549	27.58	1.226	29.96
S7	1.508	36.37		
S8	2.085	30.92		
S9	1.519	31.37		
Mean	1.704	33.54	1.454	32.65
SD	0.330	4.86	0.403	5.77

For agricultural activities, up to 40% of the individual's aerobic capacity should be taken a limit for longer period of work (Nag and Chatterjee, 1981, and Tewari, 1985). On the basis of aerobic capacity per kg body -mass min^{-1} for 25-35 year age, the variations in aerobic capacity were 27.58 ml to 40.19 ml whereas it varied from 26.35 ml to 37.06 ml for 36 year to 45 year of age group. Corresponding mean value was 33.54 $\pm$ 4.86 ml and 32.65 $\pm$ 5.77 ml. The mean aerobic capacity of farm women, irrespective of age group, was 33.18 $\pm$ 5.06 ml kg^{-1} min^{-1}. This average value of aerobic capacity of farm women seems to be close to the aerobic capacity (33.9 $\pm$ 2.95 ml kg^{-1} min^{-1}) obtained by Varghese et al (1995) of same country as living standard and socio-economic condition of urban housewives and farm women are quite different. At this aerobic capacity of 33.18 ml kg^{-1} min^{-1}, the heart rate level of 120 beats per min or work pulse of 40 beats per min, as suggested by Saha et al (1979) and Brundke, (1984) may be considered as optimal criteria, for the quick appraisal of the state of activity that may be continued for a longer period.

The value of correlation coefficient (r) for graph plotted between heart rate and oxygen consumption (resting to exhaustion level or targeted heart rate) of group-I subjects varied from 0.8571 to 0.985 and for group-II it varied from 0.8862 to 0.9511. The VO_2 at varying heart rate of 80 beats per min to 170-180 beats per min at increment of 10 beats was plotted for developing regression equations for both age groups and also for general in Figure 1 to 3.

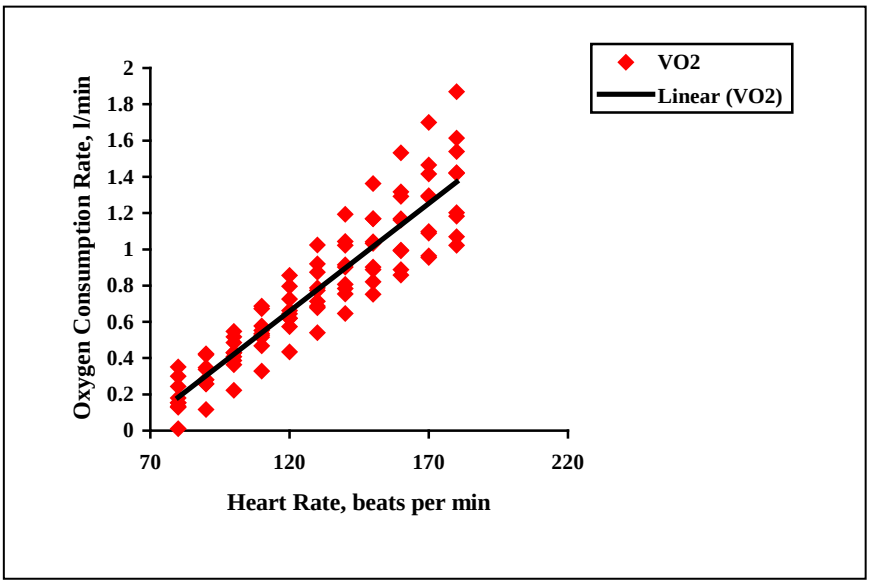

Figure 1. Relationship between heart rate and oxygen consumption of women subjects of 25 to 35 years during treadmill exercise at varying load.

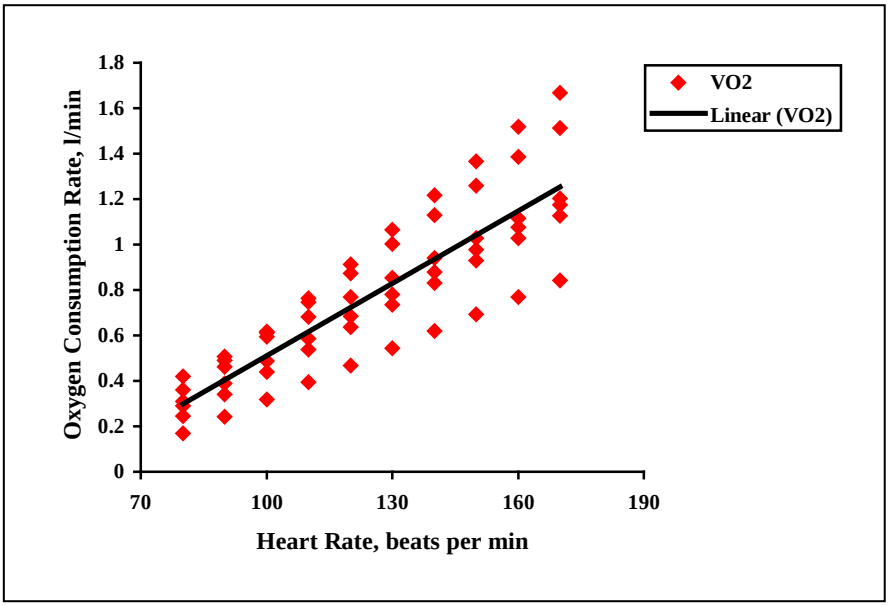

Figure 2. Relationship between heart rate and oxygen consumption of women subjects of 36 to 45 years during treadmill exercise at varying load.

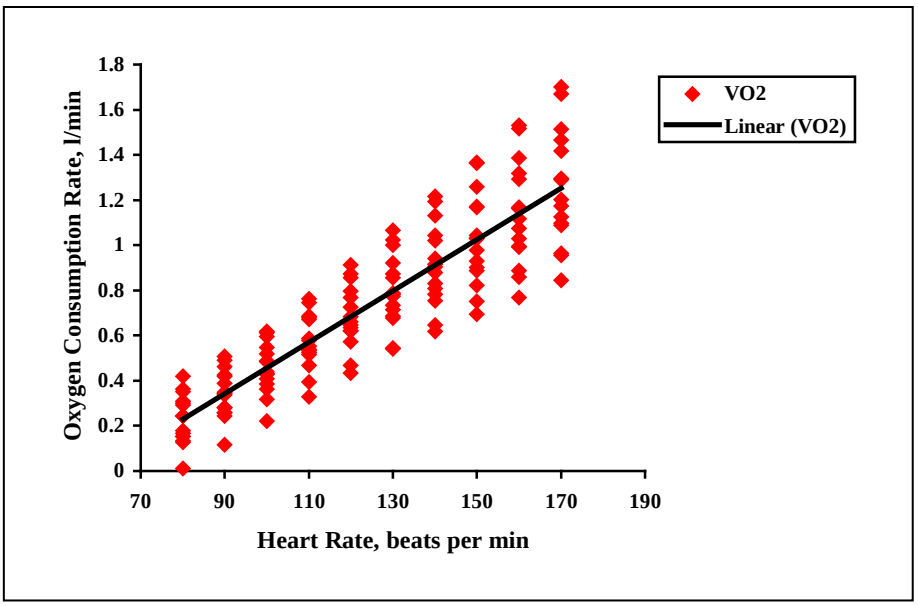

Figure 3. Relationship between heart rate and oxygen consumption of women subjects during treadmill exercise at varying load.

Following regression equations are obtained and suggested for estimating oxygen consumption (y) at their known heart rate (x) during agricultural operations.

1. $y = 0.0119\ x - 0.7665$ For 25 to 35 year of age

2. $y = 0.0106\ x - 0.5501$ For 36 to 45 year of age

3. $y = 0.0114\ x - 0.68$ General equation

The 'r' values of equation 1, 2 and 3 are found to be 0.9166, 0.8645 and 0.8923, which suggest for its use to estimate oxygen consumption at known heart rate of subjects during agricultural operations in field during work. For the validity of developed equations, a comparison was made from direct measured oxygen consumption at varying heart rate with the Varghese et al (1994) formula for energy expenditure [Energy expenditure (kcal. min^{-1})= 0.039 x heart rate – 2.33] and developed equations (Table 5). From the Varghese et al (1994) formula, oxygen consumption was obtained by dividing energy expenditure to 5 kcal. min^{-1}.

It is clear from table 5 that the oxygen consumption obtained using Varghese et al (1994) formula was less as compared to the observed value of oxygen from source (direct measured and estimated based on calibration from laboratory) while the oxygen consumption obtained at known heart rate with present developed regression equation is comparable. Thus, the developed equation can be used for estimating the oxygen consumption rate of farm women at their measured heart rate data for agricultural activities in the field.

Table 5. Comparison of oxygen consumption data of farm women at varied heart rate with the equation developed under present study.

Source/ Author	Subject details	H R, bpm	Oxygen consumption, l. min^{-1}				
			As per source	Varghese et al, 1994	Present study for age-group of		
					25-35 Eq. 1	36-45 Eq. 2	General Eq. 3
Nag and Chatterjee, 1981	Age: 30.4 ± 3.0 years Range : 25 to 45 years Weight: 41.2 ± 2.5 kg Height: 149.4 ± 1.8 cm	87	0.261	0.2126	0.2688	0.3721	0.3118
		95	0.39	0.275	0.364	0.4569	0.403
		112	0.55	0.4076	0.5663	0.6371	0.5968
		119	0.61	0.4622	0.602	0.6689	0.631
		124	0.627	0.5012	0.6496	0.7113	0.6766
		131	0.811	0.5558	0.7091	0.7643	0.7336
		144	0.927	0.6572	0.7924	0.8385	0.8134
		152	1.035	0.7196	0.9471	0.9763	0.9616
Karunanithi and Tajuddin, 2003	Age: 40.3 ± 3.06 years Range : 37-43 years	100	0.5	0.314		0.5099	
		102	0.52	0.3296		0.5311	
		104	0.55	0.3452		0.5523	
		105	0.56	0.353		0.5629	
		108	0.58	0.3764		0.5947	
		111	0.63	0.3998		0.6265	
		120	0.73	0.47		0.7219	
Behra et al 2007	Age: 30.6 ± 6.0 years Range : 22-38 years Weight: 48.0 ± 5.6 kg Height: 149.8 + 7.4 cm	79*	0.228	0.1502	0.1736	0.2873	0.2206
		116	0.61	0.4388	0.6139	0.6795	0.6424
		116	0.65	0.4388	0.6139	0.6795	0.6424
		129	0.93	0.5402	0.7686	0.8173	0.7906
Rameshan et al, 2007**	Age: 25 years Weight: 58.2 kg Height: 145.2 cm	109	0.454	0.3842	0.5306		
		125	0.717	0.509	0.721		
		136	0.86	0.5948	0.8519		

* During rest ** Based on estimate from calibration curve

4. CONCLUSIONS

From the laboratory study conducted to determine the aerobic capacity of farm women, mean VO_{2max} (aerobic capacity) for the age of 25 to 45 year was found to be 33.18 ml. kg^{-1} min^{-1}. For the quick appraisal of the state of activity that may be continued for day long work with proper rest pauses, the heart rate levels of 120 beats per min or work pulse of 40 beats per min may be considered as optimal criteria.

Suggested regression equations can be used for estimating the oxygen consumption rate of farm women at their measured/known heart rate for agricultural activities/operations in the field during work.

5. REFERENCES

Behra, B K , S Swain and. S K Mohanty 2007. Ergonomic evaluation of push-pull type weeders with women operators. *Journal of Agricultural Engineering*, 44(3): 39-43.

Brundke, J. 1984. *Langzeitmessungen der pulsfrequenz and moglichkeiten der aussage uber die arbeits beansprunchung.* I Pulsfrequenz und Arbeitsun chungen, Schriftenreihe Arbeitswissen schaft und Praxis, Band 28, Berlin, Beuth-vertrieb.

CIAE. 2005. *AICRP on ESA progress report of Bhopal centre 2002-05*, Central Institute of Agricultural Engineering (CIAE), Bhopal, India.

Chatterjee, S, P Chatterjee and A Bandyopadhya. 2005. Validity of queen's college step test for estimation of maximum oxygen uptake in female students. *Indian J. Med Res*, 121: 22-35.

Government of India. 2006. *Population projections for India and states 2001-06.* Report of the Technical Group on Population Projections, Constituted by the National Commission on Population as cited in Project Coordinator's, Tech. Report No. CIAE/ESA/2007/346, CIAE, Bhopal.

Hume R. 1966. Prediction of lean body mass from height and weight. *J Clin Path*., 19.

Karunanithi, K and A Tajuddin. 2003. Physiological response of agricultural workers in rice farming operations. *Journal of Agricultural Engineering*, 40 (1): 33-40.

Mosteller, R D. 1987. Simplified calculation of body surface srea. *N Engl J Med.* Oct 22;. 317 (17): 1098 (letter)

Nag, P.K. 1986. Maximal oxygen uptake of agricultural men and women in India. American *Journal of Physical Anthropology*, 74 (2):149 – 153.

Nag, P K and S K Chatterjee. 1981. Physiological reactions of female workers in Indian agricultural work. *Human Factors*, 23(5): 607-614.

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

Remesan, R, M S Roopesh, N Remya and P S Preman. 2007. Wet land paddy weeding- A comprehensive comparative study from south India. *Agricultural Engineering International: the CIGR Ejournal.* Manuscript PM 07 011. Vol. IX. December.

Rodahl, K. 1989. *The physiology of work.* (Reprint). Taylor and francis Ltd, London.

Robergs, R A and R Landwehr. 2002. The surprising history of the "Hrmax=220-age" equation. *Journal of Exercise Physiology Online*, 5(2):1-10.

Saha, P N, S R Banerjee, P K Banerjee and G G Narayane. 1979. An acceptable work load for Indian workers. *Ergonomics*, 22(9): 1059-1071.

Shephard, R J. 1980. *Human physiology work capacity*. International Biological Programme; 15, University press, Cambridge, Great Britain: 32-33.

Shephard, R J. 1998. *Aging and exercise.* In: Encyclopedia of Sports Medicine and Science, T. D. Fahey (Editor). Internet Society for Sport Science: http://sportsci.org. March 7.

Singh, S P. 2005. *Ergonomical evaluation of manually operated cleaner-graders, fertilizer broadcaster, seed drills and hand ridger with farm women*. Final Report of Project No. 496, National Research Centre for Women in Agriculture (Bhopal Sub-centre), Central Institute of Agricultural Engineering, Bhopal, India.

Tewari, V.K. 1985. *Development of weeder from engineering and ergonomic considerations.* Unpublished Ph.D. Thesis, Agricultural Engineering Department, Indian Institute of Technology(IIT), Kharagpur, India.

Varghese, M A, P N Saha and N Atreya. 1994. A rapid appraisal of occupational workload from a modified scale of perceived exertion. *Ergonomics*, 37(3): 485-491.

Varghese, M A, P N Saha and N Atreya. 1995. Aerobic capacity of urban homemakers in Bombay. *Ergonomics*, 38(9): 1877-1883.