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Study of VO_{2max} of agricultural workers for different farm operations

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Abstract
The individual's oxygen uptake i.e. VO_{2max} has been widely used as an index for determining his/her work capacity. An experiment was conducted to assess the VO_{2max} by direct method of ten selected agricultural workers inside laboratory and while performing two different field operations viz., arecanut dehusking operation in pedaling mode and working with spade. The effect of type of operation/activity on VO_{2max} was also studied by statistically comparison. The mean VO_{2max} observed during laboratory measurement (2.56 ± 0.50 l/min) was significantly different from that of observed during dehusking operation in pedaling mode (2.81 ± 0.55 l/min) and working with spade (2.37 ± 0.47). The VO_{2max} was observed to vary for each worker and also with the type of activity he was performing.

Keywords: Aerobic capacity; oxygen consumption rate; heart rate; work capacity; VO_{2max}

1. Introduction
The physical work capacity of the worker depends on his/her ability to take up oxygen and its utilization for oxidation of food stuff. Individual's oxygen uptake is generally used as an expression of rate of work or rate of energy output (Rodahl, 1989) [13]. The maximum aerobic capacity also called as VO_{2max} is the maximum oxygen consumption rate. The workers maximum work capacity is directly related to maximum oxygen uptake (i.e. VO_{2max}) (Bridger, 1995) [2]. Maximum oxygen uptake limits individual's maximum performance.

VO_{2max} can be determined by direct method or indirect method. The direct method is often regarded as most accurate method where measurements are made inside controlled laboratory with precise instrumentation. The subject exercises at successively higher rates of work until a level is reached at which further increase in rate of work does not produce a significant increase in rate of oxygen uptake (Maritz *et al*., 1961) [7]. However as direct measurement is restricted within the laboratory and is often considered as expensive, exhaustive, laborious and complicated therefore it is not possible to use this method for large group or in the field. Scientists often determine VO_{2max} by indirect methods (Cooper, 1968; Fox, 1973) [5, 6].

In India, various efforts have been made to determine maximum oxygen uptake i.e. VO_{2max} by direct and indirect methods. Scientists reported determination of maximal oxygen uptake, acceptable workload and occupational workload for Indian men/women workers, agricultural workers and household women workers with some researchers reporting prediction equations to determine VO_{2max} (Nag *et al*., 1980; Nag, 1981; Nag and Chatterjee, 1981; Nag, 1987; Varghese *et al*., 1994; Varghese *et al*., 1995) [8, 9, 10, 11, 17, 18]. Researchers also worked on validation of different indirect methods for VO_{2max} determination in Indian scenario and reported prediction equations for VO_{2max} (Chatterjee *et al*., 2005; Singh *et al*, 2008; Verma *et al*., 2009; Chatterjee *et al*., 2011; Bandhyapadhyay, 2011) [3, 16, 19, 4, 1].

VO_{2max} is affected by various personal and environmental parameters. It is clear from the past research that, VO_{2max} varies from person to person and it can also be interpreted that, VO_{2max} of individual remains nearly same for all kind of activities he/she performs within similar environmental conditions. But, there is possibility that the individual can perform certain activity better and for longer duration than other activities having same physiological demands. This might happen due to his/her likeliness of that activity, type of body muscles involved while performing activity and motivation while performing that activity. So, there is need to study the effect of type of activity he/she is performing on VO_{2max} of individual.

Also, studies have showed that the direct measurement of VO_2 is necessary for accurate estimation of VO_2 max of subject while performing any activity. Now a day, advancements in instrumentation with development of portable VO_2 measuring instruments helps to access VO_2 while performing laboratory as well as outdoor activity. With consideration of above discussion, an experiment was conducted to access the VO_{2max} of the selected subjects by

directly measuring VO_2 with portable instruments while performing different types of activities/operations and study the effect of type of activity on VO_{2max} of the individual as well as within selected subjects.

2. Material and Methods

2.1 Study Population

Ten (10) healthy male subjects were selected by random sampling from the group of agricultural workers working on the University farms. The average age, height and weight of the selected subjects was 29.5±7.0 years, 166.8±7.5 cm and 60.8±9.3 kg, respectively. The selected subjects had no history of any major disease and addiction to tobacco and alcohol. Also, they had received no physical conditioning program prior to the experiment. The selected subjects were trained and made habitual with the working environment, type of field operations and use of different instruments for better measurements.

The experiment was conducted in the premises of the office of AICRP on Ergonomics and Safety in Agriculture, Dept. of Farm machinery & Power, CAET, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India.

2.2 Selection of Operation

The present study was concentrated on agricultural workers of Konkan region of Maharashtra. Arecanut is one of the prominent crops of this region and dehusking being one of the important post-harvest operation in which more farm labours are involved also, manually making raised beds with spade is one of the drudgerious farm operations carried out in this region. Considering this, two operations i.e. dehusking of arecanut using pedal operated arecanut dehsuker and making of bunds in the field with the use of spades were selected for the experiment. Laboratory measurement of VO_{2max} with standard protocol was carried out as a standard for comparison of VO_{2max} obtained while performing other two activities.

2.3 Study Design

The VO_{2max} of each selected subject was determined by laboratory measurements and measurements made while performing two field operations. The laboratory measurement can be considered as standard because of controlled conditions inside laboratory. The interval of 4 days was kept between laboratory measurements and field measurements. The subjects were asked to take rest of 30 minutes prior to the actual measurements so that pulmonary ventilation and the heart rate would be steady state before the measurements (Bandhyapadhyay, 2011; Chatterjee *et al*., 2011) [1, 4]. After 30 minutes rest, the heart rate values of subjects were recorded for few minutes and averaged as resting heart rate (RHR). The average temperature and humidity during the laboratory measurements were 22.5 ºC and 58 percent, respectively whereas during field measurements the average temperature and humidity was observed as 27.5 ºC and 72 percent, respectively.

2.4 Laboratory Measurement of VO_{2max}

Laboratory measurement of VO_{2max} has been considered as a standard method of determining one's working capacity or aerobic capacity where environmental conditions are maintained to better suit the subject's requirements. Computerized bicycle ergometer (Model: Ergomedic 839 E., Monark Exercise AB, Sweden) was used for loading and oxygen consumption rate was measured using mobile breath to breath metabolic system (Model: K4b2, Cosmed, USA) whereas heart rate monitor (Make: Polar, USA) was used to record heart rate. All the subjects were trained of breathing through the K4b2 mask in order to allay apprehension if any. The pedaling rate of bicycle ergometer was maintained as 50 rpm using visual metronome (Fig. 1). A protocol was developed so as to increase the load by 15 W for every two minutes interval. The peak heart rate for each subject was determined by following equation (Robergs and Landwehr, 2002) [12].

$$HR_{max} = 220 - \text{Age (years)} \ldots\ldots \quad (1)$$

The oxygen consumption rate (OCR) and heart rate (HR) were recorded while subject was pedaling ergometer for each given load. The measured values of HR and OCR were per breath for individual subject therefore, values were averaged using software so as to convert the data of a minute interval. The action was continued till HR increases to 75 percent of HR_{max} i.e. subjects are loaded up to sub-maximal limit. The calibration chart between HR and OCR for each subject was plotted and correlations between the heart rate and oxygen consumption rate for each subject was developed. The VO_{2max} was determined by extrapolating the calibration chart up to HR_{max}. The calibration charts/correlation equations were used to predict the OCR for particular value of HR recorded during the field work.

Fig 1: VO_{2max} measurement inside controlled laboratory

2.5 Field Measurements of VO_{2max}:

The same subjects were asked to perform two field operations viz., arecanut dehusking operation with pedal operated arecanut dehusker (Fig. 2) and making raised beds using spade (Fig. 3). The first operation involved pedaling/cycling in which maximum body muscles are engaged while later involved working in bending posture in the field. Similar to laboratory procedure, subjects were allowed to continue the given task until their heart rate reaches the 75 percent value of peak heart rate or they feel exhausted. The breath by breath oxygen consumption rate (OCR) was recorded with portable metabolic system i.e. K4b2 and heart rate was recorded with the Polar heart rate monitor. The VO_{2max} of each subject was calculated from the relationship between measured HR and OCR as explained earlier at section 2.4.

Three replications for each activity were taken, which were completely randomized.

Fig 2: VO_{2max} measurement while operating pedal operated arecanut dehusker

Fig 3: VO_{2max} measurement while making raised beds with spade in the field

2.6 Statistical Analysis

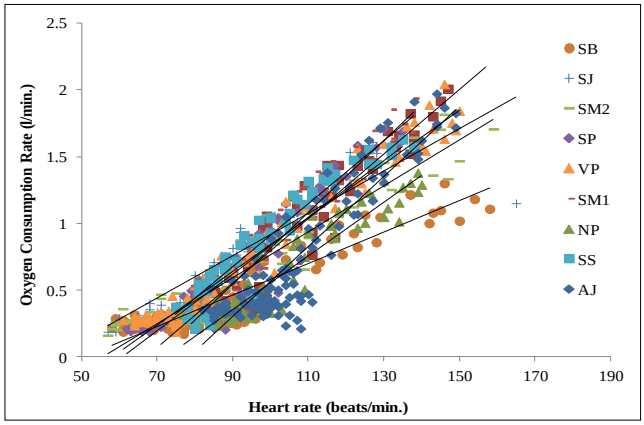
The data was statistically analyzed to study the effect of activity on VO_{2max}. ANOVA was carried out using Statistical Analysis Software (SAS) (University Edition).

3. Results and Discussion

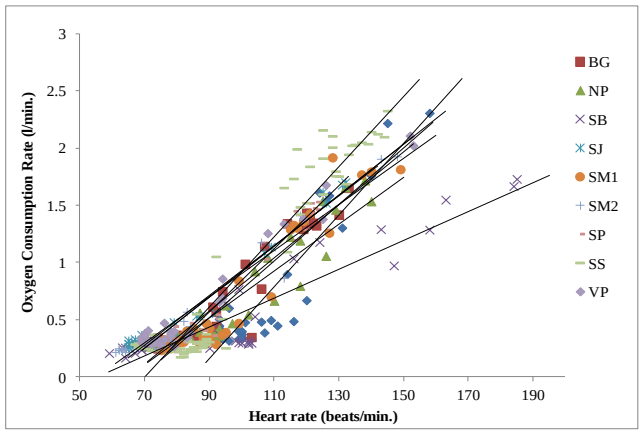
The relationship between heart rate (HR) and oxygen consumption rate (OCR) obtained for each subject while performing three different activities was plotted and is shown in Fig. 4. The linear relationship was obtained as represented by following equation. The values of the constants obtained for selected subjects during different activities are presented in Table 1.

$$y = m x + c\ldots \quad (2)$$

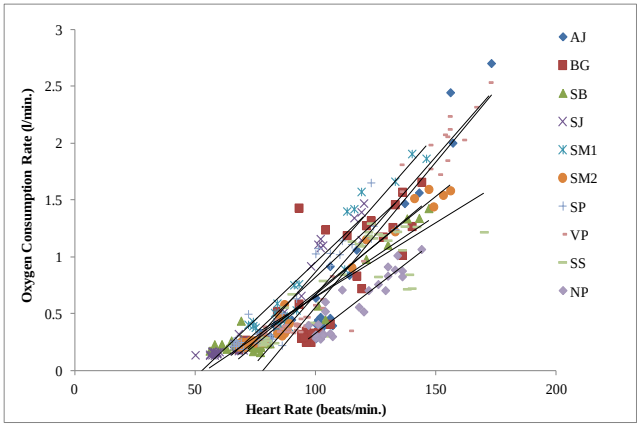
Where, y is oxygen consumption rate (l/min.); x is the heart rate (beats/min.) and m, c are constants.



a) Laboratory measurement



b) Pedal operated arecanut dehusker



c) Making raised beds with spade

Fig 4: Calibration chart for selected subjects obtained while performing selected activities

Table 1: Regression coefficients and constants for relationship between HR and OCR

Subject	Equation Constants	Laboratory Measurement	R^2	Pedal Operated Arecanut Dehusker	R^2	Working with Spade	R^2
NP	c	- 1.442	0.88	- 1.336	0.84	- 1.295	0.85
	m	0.020		0.020		0.016	
SS	c	- 1.450	0.91	- 2.147	0.90	- 0.660	0.64
	m	0.023		0.030		0.013	
SP	c	- 1.297	0.81	- 1.942	0.84	- 1.145	0.88
	m	0.021		0.027		0.019	
SM1	c	- 1.871	0.84	- 1.702	0.90	- 1.539	0.91
	m	0.026		0.024		0.024	
SJ	c	- 0.668	0.82	- 1.245	0.94	- 1.012	0.93
	m	0.015		0.021		0.020	
SB	c	- 0.597	0.86	- 0.702	0.85	- 0.769	0.90
	m	0.011		0.012		0.014	

BG	c	- 1.617	0.91	- 1.509	0.89	- 1.012	0.69
	m	0.024		0.023		0.017	
VP	c	- 1.165	0.94	- 1.303	0.96	- 1.754	0.94
	m	0.020		0.022		0.024	
SM2	c	- 0.959	0.88	- 1.112	0.94	- 1.539	0.97
	m	0.017		0.020		0.017	
AJ	c	- 2.055	0.82	- 2.668	0.85	- 2.000	0.88
	m	0.026		0.031		0.025	

From the obtained relationship, the VO_{2max} was calculated for corresponding HR_{max}. The mean maximum heart rate (HR_{max}) and VO_{2max} of ten subjects obtained during laboratory measurements and performing two field operations is presented in Table 2. The mean maximum heart rate of ten subjects was observed as 195.5 ± 2.3 beats/min. The mean VO_{2max} observed during laboratory measurement, working with pedal operated dehusker and working with spade was 2.56 ± 0.50 l/min., 2.81 ± 0.55 l/min. and 2.37 ± 0.47 l/min respectively. It was observed that, the mean VO_{2max} observed with pedal operated arecanut dehusker was 9.8 percent more as compared to standard laboratory measurements whereas mean VO_{2max} observed with making raised beds with spade operation was 7.4 percent less as compared to standard laboratory measurements.

The statistical analysis (ANOVA analysis) of the data shown in Table 3 indicated that, type of activity (method) and subject, individually have significant effect on VO_{2max} at 1 percent level of significance. The interaction of type of activity and subjects also found to have significant effect on VO_{2max} at 1 percent level of significance.

Table 2: Mean maximum heart rate and VO_{2max} of the selected subjects

Subject	Max HR, beats/min	VO_{2max}, l/min		
		Bicycle Ergometer (Laboratory)	Pedal Operated Dehusker	Working with Spade
NP	187	2.30	2.40	1.69
SS	187	2.85	3.46	1.77
SP	190	2.69	3.21	2.47
SM1	186	2.97	2.76	2.93
SJ	175	1.96	2.43	2.44
SB	196	1.56	1.65	1.98
BG	195	3.06	2.98	2.21
VP	197	2.78	3.03	2.97
SM2	195	2.36	2.79	2.30
AJ	197	3.07	3.44	2.93
Average	190.5(±2.3)	2.56 (±0.50)	2.81(±0.55)	2.37(±0.47)

Table 3: ANOVA for effect of type of activity on VO_{2max}

Source	Type III Sum of Squares	df	Mean Square	F	*P value*
Subject	14.828	9	1.648	945.038	0.000
Method	3.004	2	1.502	861.631	0.000
Subject * Method	6.232	18	0.346	198.584	0.000
Error	0.105	60	0.002		

It can be seen from the obtained results and ANOVA of the obtained data that VO_{2max} of each selected subject varied significantly for mentioned three activities. The higher values of VO_{2max} were obtained while performing dehusking operation with arecanut dehusker followed by that obtained during laboratory measurements and minimum VO_{2max} values were obtained for soil working operation with spade for most of the selected subjects.

While performing arecanut dehusking operation, the subject had to pedal arecanut dehusker at constant rate while feeding the arecanuts through feeding trough. In laboratory measurements with bicycle ergometer, subject has to pedal ergometer but the load was gradually increased and in soil working operation of making bunds with spade, subject had to perform the activity in bending posture. While performing dehusking activity, subjects maximum body muscles (lower body i.e. legs and arms) were engaged, with laboratory operation only lower body (legs) was engaged whereas with third operation subject was used to stand stationary while using only his upper body i.e. arms to dig and move the soil with spade. During any activity, as the amount of body muscles utilized increase, the demand for oxygen also increases. The capacity for exercise is dependent upon the amounts of muscle mass engaged (Shephard, 1967) [15]. Also, a person can generate more power (about four times) by pedaling than by hand cranking (Wilson, 1986) [20]. As, in case of dehusking and laboratory operations, subjects used leg power i.e. pedaling therefore it required more oxygen to perform those activities than that required while performing soil working operation where arms were used to perform operation. Therefore, even though subject's maximum heart rate (HR_{max}) remained constant, the oxygen requirement varied with type of activity he/she is performing based on the amount and type of muscles engaged during the activity.

Conclusions

An experiment was conducted to assess the VO_{2max} of the ten selected subjects by laboratory measurement and measurements made while performing two different field operations viz., arecanut dehusking with pedal operated arecanut dehusker and making raised beds with spade. A comparison was made between the VO_{2max} values observed during selected measurements. It was observed that the VO_{2max} values obtained while performing two field operations

were significantly different from the values obtained during the laboratory measurements for all selected subjects. From the analysis of the data it can be concluded that, individuals differ in their maximum aerobic capacity based on the type of operation they were performing. The variation in mean VO_{2max} as compared to standard was found within ± 10 percent.

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