Full Length Research Paper

Study of ergonomical characteristics of farm workers

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Ergonomics is system design compressed of man-machine and environment relationship to bring about some output against some given inputs considering different physical, anatomical, physiological, and psychological limits of human being. Based on different workloads (N) and speed (rpm), the experiment was conducted on MONARK 828E Ergometer, to evaluate heart rates of different age groups with variable weights and heights. The farm workers (both men and women) of 20-30 years age group have developed a maximum working heart rate as compared to other age groups of 31-40 and 41-50 years. The energy expenditure rate (EER) for all the farm workers obtained were graded as 'moderately heavy'. The body mass index (BMI) of age groups 20-30 and 31-40 years were considered as 'Normal' and 41-50 were considered as 'Obese Grade I'. The ponderal index (PI) of all age groups, that is, 20-30, 31-40, and 41-50 years were 'Ectomorph' in nature. Further, statistical analysis was performed to develop regression based prediction equation for EER using age, weight, height, heart rate, and maximal oxygen uptake (VO2max) as input variables.

Key word: Ergonomics, heart rate, energy expenditure, ponderal index, body mass index.

INTRODUCTION

Ergonomics is the scientific study of the relationship between man and his working environment. It is concerned with ways of designing machines, operations, and work environments so that they match human capabilities and limitations. Its goal includes increasing the productivity in operations, decreasing the amount of effort needed to operate machines, increasing human comfort during work, decreasing accidents, and eliminating error provocative features. In brief, it can be said that the application of ergonomics aims at heightening the quality of life in work conditions. The productivity of any work environment not only depends on the quality and complexity of the tools being used, but

also on the human being involved towards operating the tool and his work environment (Agrawal and Satapathy, 2006).

Normally while designing the machine human take almost care on the technical part of the machine, but they do forget about the operator. As a result, most of the controls and displays are positioned beyond normal human accessibility or they have to be operated in very cramped awkward posture. For any ergonomist, it is therefore essential to design the work environment based on the anthropometric limitations of the operations. The human body is built for action not for the rest. Once upon a time this was a necessity: the struggle for survival

demanded good physical condition. But the optimal function can only be achieved by regularly exposing the heart, circulation, muscles, tendons, skeleton, and nervous system to some loading and training. In olden days, the body got its exercise both at work and at leisure. In modern society, however, machines have taken over an ever increasing share of the tasks which are formerly accomplished with muscular power alone. Many operations increase the stress on the labor and machine operators. This stress results in an increase of heart rate (HR), energy expenditure rate (EER), and decrease of maximal oxygen uptake (VO_{2max}) rates. The sensitivity of above three parameters depends mainly on age, weight, and height of farm workers.

In most form workers (men and women), HR monitoring provides one of the most efficient and economical means of estimating EER. In a range of approximately 90-150 bpm, which is of "flex heart rate", the relationship between HR and VO_{2max} is linear (Rennie et al., 2001). Instead of linear relationship, a non-linear, discontinuous function is found to be more accurate in predicting EER from HR and VO_{2max}. In addition to HR and VO_{2max}, the factors age, weight, and height may have a significant effect in EER prediction.

Most of the previous studies have used individual calibration of the HR and EER in the prediction of energy expenditure (Luke et al., 1997). This requires that each farm worker should complete a progressive exercise test, during which HR is simultaneously measured, along with indirect calorimetry to estimate EER. This procedure is very time consuming and requires well trained healthy and active human power to complete the test. These limitations demonstrated the utility of developing prediction equations for estimating EER from the HR, age, weight, height, and VO_{2max} in representative samples of individuals, with reasonable accuracy and the potential for wide application in epidemiological studies.

Hiilloskorpi et al. (1999) developed a multiple linear (MLR) regression based prediction equation for EER from HR on a sample of 87 healthy, active subjects (men and women). Results found that the age, weight, and gender had a significant interaction with EER. Similarly, Rennie et al. (2001) developed a MLR based prediction model using a sample of 789 individuals for estimating EER from sitting HR, age, weight, and gender. The EER prediction equation was then further validated on an independent sample of 97 individuals and found to have a correlation coefficient (r) of 0.73.

Therefore, the present study is carried out with the following objectives:

1. To study the ergonomical characteristics of farm workers such as HR, VO_{2max}, EER, Body Mass Index (BMI), and Ponderal Index (PI).
a. With different age groups of male farm workers (20-30, 31-40, 41-50 years).

b. With different workloads (N) and speed (rpm).
c. With different heights (cm) and weights (kg) of workers.
2. To develop a prediction equation for EER from age, weight, height, HR, and VO_{2max} as input variables.

MATERIALS AND METHODS

Monark Ergometer cycle 828E

This experimental analysis was done at Instrumentation Lab in the campus of College of Agricultural Engineering, Bapatla, Andhra Pradesh (India) using Monark cycle Ergometer 828E (Figure 1). The Monark Ergometer model 828E is a completely housed flywheel and further strengthened the frame. It is specially made for efficient exercise where one get immediate feedback and it has an adjustable brake system, where the brake can be set/read in Newton (N). The dependent variables are age, weights, and heights, time, workloads (N), speed (rpm), HR (beats per minute, bpm), and VO_{2max} (ml/kg/min), whereas the EER(kJ/min) is independent variable. The farm workers three in each age group of (20-30, 31-40, and 41-50) free from respiratory or any serious health problem were selected for the study (Table 1). A total of 39 farm workers are volunteered to participate in the study. The farm workers (men and women) represented a wide range of morphology and fitness: age 20–50 years of age, body weight 42–92 kg, heights 152-185 cm, HR 172-195 bpm, VO_{2max} 59.5-72.7 ml/kg/min, and EER 44-53 kJ/min.

The univariate (means and standard deviations) statistical summary of farm workers is shown in Table 2. There were no differences in mean age and VO_{2max} between the men and women participants who underwent cycling using Ergometer. There were significant differences in weight, height, maximum working heart rate, and EER between the sexes (Table 2, P<0.05). Based on this analysis, a mixed model for predicting EER is fitted in following sections. The factors age, weight, height, HR, and VO_{2max} were modeled as fixed effects to predict EER.

The cycle is equipped with an electronic meter (Figure 2) showing pedal revolutions per minute (rpm), heart rate (bpm), exercise time (min), an imagined cycling speed (kph), covered the distance (km), burned calories (cal), and the power on the cycle (W).

The product includes heart tronic's new integrated transmitter/belt. This device is water resistant and may used for all water related exercises. Attach the elastic strap to the transmitter (Figure 3). Observe the each end of the transmitter has an open slot and two teeth extended slightly from the end. The heart tronic logo should be centered on the chest.

Switch ON the instrument by pressing the Power ON switch. Initially, the beat LED will flash erratically. After a few seconds, it will stabilize and will flash in accordance with the heart beat. With every LED flash a buzzer (beep) sound will be heard (Figure 4). It is very important to fix the electrodes in the proper way. Wash the skin and remove hair on the site where the electrodes are going to be placed. There should be no cut marks on the skin. Remove the transparent plastic cover sheet. Place the electrodes on the three sites (Figure 5). Then clip the sensor lead buttons to the electrodes. The weighing balance and metal wire tape has been used for measuring the weights and heights of the subjects.

Protocol of ergonomical tests

The Monark 828E software is an easy-to-use package, designed to work with Monark 828E ergometer. By using this software, three

Figure 1. Monark Ergomedic cycle 828E.

Figure 2. Electronic meter.

Figure 3. Heart rate monitor transmitter belt.

Figure 4. Polar heart rate monitor.

tests Astrand, WHO, and YMCA are performed.

Astrand test

The 'Astrand protocol' is designed to determine the VO_{2max} by exercising the farm workers on Ergometer at a sub maximal workload and measuring the steady state HR. The workload, in conjunction with the resultant heart rate, is compared to the predicted relationship, adjusted for age and sex and VO_{2max} is computed.

WHO test

This protocol is recommended by World Health Organization (WHO), because it is considered reliable and accurate, and it is in widespread use in many health clubs and physiological research centers throughout the world. The test uses branching multiple workloads, and takes into account the executor's age, weight, and sex. This means that the workload is adjusted at each level to correspond those values that the WHO has recommended.

YMCA test

The YMCA protocol is based on the "Y's Way to Physical Fitness" bicycle test. The design is a sub maximal test; using branching multiple workloads in which the next work load is determined by the steady state heart rate elicited by the previous level. Every three minutes the work load is advanced until the farm worker has completed three levels requiring a total of nine minutes. If the subject has an abnormally high heart rate response to the initial work load (110 bpm or more), the test is terminated at the end of
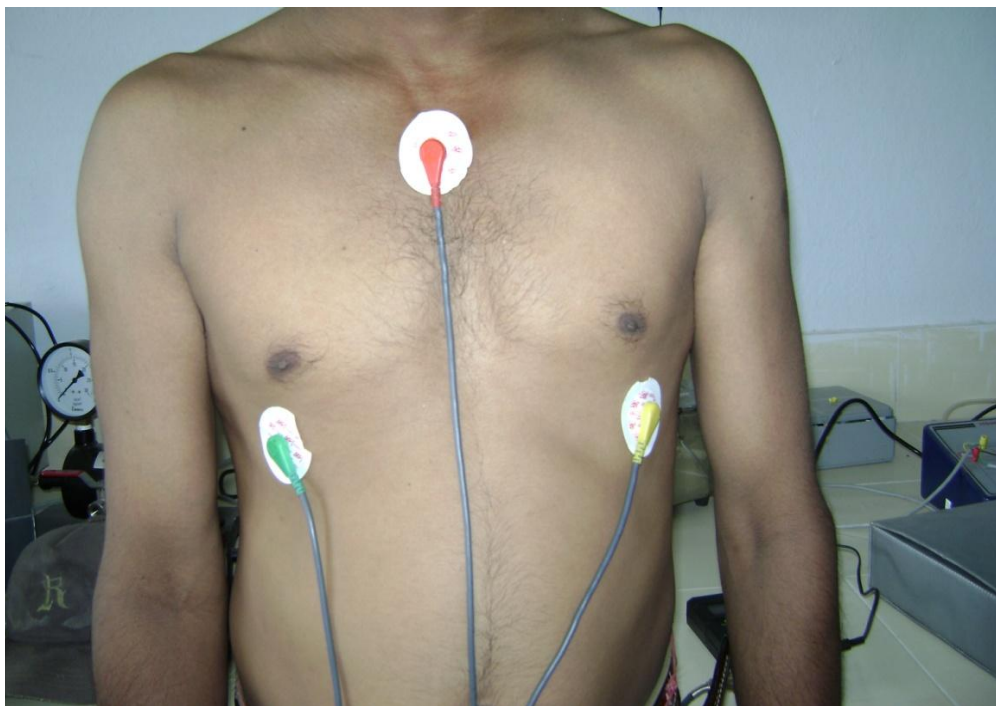
Figure 5. Arrangement of electrode leads (green, red and yellow buttons) to the farm worker for measuring the heart rate at rest position.

second level. If the operator senses that the subject is experiencing difficulty completing the third level of the protocol, the test can be concluded before the third level is finished. If the test is aborted prior the end of the second level, no VO_{2max} calculation can be done.

Computation of parameters

Energy expenditure rate (EER)

The EER is calculated using the following empirical relationship:

EER = (HR-66)/2.4   (1)

Where EER = Energy Expenditure Rate (kJ/min) and HR = heart rate (beats/min).

Body mass index (BMI)

BMI of the selected subjects was calculated by using the following formula:

$$BMI = \frac{(\text{Weight, kg})}{\text{Height}^2 \text{ (m)}}$$ (2)

Ponderal index (PI)

Body composition was assessed using PI as given below:

$$PI = \frac{(\text{Weight, kg})}{\text{Height}^3 \text{ (m)}}$$ (3)

RESULTS AND DISCUSSION

Variation of HR of farm workers with different workloads (9.8, 14.7, and 19.6 N) at 50 rpm

The variation of HR of farm workers during cycling Ergometer with different workloads (9.8, 14.7, and 19.6 N) at 50 rpm speed is shown in Table 3. At a workload of 9.8 N, the mean values of increased working heart rate (1-6 min) and decreased resting heart rate were 126.17 and 98.3 bpm graded as 'heavy' and 'light', respectively (Zander, 1973). The EER varies from a minimum of 21.67 kJ min^{-1} to a maximum of 28.75 kJ min^{-1}. The mean of EER was 25.07 kJ min^{-1} and it is graded as moderately heavy' (Zander, 1973).

At 14.7 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate are 136.17 and 107.3 bpm, respectively graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 24.58 kJ min^{-1} to a maximum of 33.75 kJ min^{-1}. The mean of EER was 29.235 kJ min^{-1} and it is graded as 'moderately heavy' (Zander, 1973).

At 19.6 N workload, the mean values of increased

Table 1. Details of the farm workers involved in the pedaling or cycling of Ergometer.

Age group (years)	Name of the operator	Sex	Age (years)	Weight (kg)	Height (cm)	Maximum working HR (bpm)	VO$_{2max}$ (ml kg^{-1} min^{-1})	EER (kJ/min)
	N. Ashok Kumar	Male	27	62	170.2	192	70.82	52.52
	N. Surya Prakash	Male	25	68	170.2	194	70.26	53.33
	S. Venkat Reddy	Male	26	52	157.5	193	72.74	52.91
	K. Tirupati	Male	22	70	168.5	190	71.71	51.66
	R. Prasad	Male	29	59	163.0	189	71.02	51.25
	K. Sathyanarayana	Male	27	72	179.0	192	69.12	52.50
20-30	V. Shankar	Male	26	80	165.0	185	69.25	49.58
	B. Bhuchanna	Male	22	92	172.0	186	68.61	50.00
	D. Rajayya	Male	30	77	185.0	195	66.64	53.75
	A. Narsakka	Female	20	45	155.0	185	72.19	49.58
	Ch. Manga	Female	21	48	157.0	189	70.67	51.25
	N. Bhulaxmi	Female	25	42	152.0	183	71.08	48.75
	G. Vani	Female	30	44	156.0	182	68.96	48.33
	N. Thirupathayya	Male	33	56	157.5	189	69.98	51.25
	S. Srinivasa Rao	Male	34	62	157.5	188	68.73	50.83
	K. Srinu	Male	34	74	167.6	188	66.69	50.83
	Ch. Kutumba Rao	Male	39	88	182.3	190	62.07	51.67
	M. Mallikarjuna	Male	32	90	176.2	189	64.60	51.25
	N. Veeranna	Male	36	76	165.2	172	68.08	44.16
31-40	U. Gangaram	Male	38	63	181.2	185	67.48	49.58
	A. Daniel	Male	33	75	175.0	188	66.91	50.83
	U. Sukumar	Male	32	70	168.0	187	68.30	50.41
	M. Padmaja	Female	30	60	155.0	182	66.24	48.33
	K. Sandhya	Female	31	54	156.0	183	66.72	48.75
	B. Sujata	Female	33	52	155.0	181	66.59	47.91
		Female	40	42	152.0	188	64.48	50.83
	P. Salmon Raju	Male	40	64	157.5	184	66.69	49.16
	G. Narasiah	Male	46	73	167.6	186	62.52	50.00
	A. Seetiah	Male	46	85	169.2	192	59.55	52.50
	B. Dubbanna	Male	43	88	181.2	186	61.14	50.00
	G. Chinniah	Male	42	92	179.5	189	60.38	51.25
	R. Ashok	Male	49	63	164.2	175	64.78	45.41
41-50	V. Kiran	Male	50	77	159.3	183	60.76	48.75
	K. Srinivasa Rao	Male	46	62	162.6	186	64.39	50.00
	V. Buchi Reddy	Male	49	70	160.0	190	61.24	51.66
	D. Gangulu	Female	45	55	158.0	185	60.81	49.58
	G. Laxmi	Female	48	58	154.0	182	59.60	48.33
	S. Rani	Female	40	53	155.0	184	63.24	49.16
	A. Sharada	Female	45	45	152.3	180	63.28	47.51

Table 2. Characteristics of sample used to develop the prediction equation (mean ± s).

Variable	Ergometer	
	Male	**Female**
Sample size	27	12
Age (years)	35 ± 9	34 ± 10
Weight (kg)*	73 ± 11	50 ± 6
Height (cm)*	169 ± 9	155 ± 2
Maximum working heart rate (bpm)*	188 ± 5	184 ± 3
VO_{2max} (ml kg^{-1} min^{-1})	66.5 ± 3.8	66.2 ± 4.1
EER (kJ min^{-1})*	51 ± 2	49 ± 1
* $P < 0.05$, difference between the sexes; s = standard deviation		

Table 3. HR of farm workers with different workloads at 50 rpm speed.

Workload (N)	Time (min)	Speed (kph)	Distance (km)	Heart rate (bpm)	Heart rate at rest (bpm)	EER (kJ min^{-1})
	1.00	23.3	0.5	118	110	21.67
	2.00	23.7	0.7	122	104	23.33
9.8	3.00	23.5	1.1	123	99	23.75
	4.00	23.4	1.5	127	95	25.42
	5.00	23.6	1.7	132	92	27.50
	6.00	23.7	2.2	135	90	28.75
	1.00	23.7	0.4	125	122	24.58
	2.00	23.6	0.6	129	115	26.25
14.7	3.00	23.4	0.9	134	109	28.33
	4.00	23.5	1.4	139	104	30.42
	5.00	23.2	1.6	143	99	32.08
	6.00	23.3	2.3	147	95	33.75
	1.00	23.3	0.4	128	134	25.83
	2.00	23.5	0.5	133	132	27.91
19.6	3.00	23.4	0.7	137	125	29.58
	4.00	23.6	1.2	142	115	31.67
	5.00	23.5	1.5	146	101	33.33
	6.00	23.1	2.2	151	98	35.42

working heart rate (1-6 min) and decreased rest heart rate were 139.5 bpm and 117.5 bpm, respectively graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 25.83 kJ min^{-1} to a maximum of 35.42 kJ min^{-1}. The mean of EER was 30.62 kJ min^{-1} and it is graded as 'heavy' (Zander, 1973).

Variations of HR of farm workers with different workloads (8.14, 12.3, and 16.4 N) at 60 rpm

The variation of HR of farm workers during cycling Ergometer with different workloads (8.14, 12.3, and 16.4 N) at 60 rpm is shown in Table 4. At 8.14 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 130 and 101.2 bpm, respectively and graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 22.51 kJ min^{-1} to a maximum of 30.42 kJ min^{-1}. The mean of EER was 26.67 kJ min^{-1} and it is graded as moderately heavy (Zander, 1973).

At 12.3 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 133.67 and 109 bpm, respectively and graded

Table 4. HR of farm workers with different workloads at 60 rpm speed.

Workload (N)	Time (min)	Speed (kph)	Distance (km)	Heart rate (bpm)	Heart rate at rest (bpm)	EER (kJ min^{-1})
8.14	1.00	26.8	1.2	120	118	22.51
	2.00	26.7	1.8	124	114	24.17
	3.00	26.5	2.4	129	99	26.25
	4.00	26.4	2.5	133	95	27.92
	5.00	26.5	2.8	135	92	28.75
	6.00	26.6	3.5	139	89	30.42
12.3	1.00	26.8	0.9	122	135	23.33
	2.00	26.7	1.4	126	121	25.00
	3.00	26.5	1.8	131	115	27.08
	4.00	26.4	2.2	136	98	29.17
	5.00	26.5	2.7	141	95	31.25
	6.00	26.3	3.3	146	90	33.33
16.4	1.00	26.9	0.8	129	141	26.25
	2.00	26.7	1.3	134	132	28.33
	3.00	26.5	1.9	139	120	22.50
	4.00	26.5	2.5	143	105	32.08
	5.00	26.6	2.8	148	98	34.17
	6.00	26.3	3.3	154	95	36.67

as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 23.33 kJ min^{-1} to a maximum of 33.33 kJ min^{-1}. The mean of EER was 28.19 kJ min^{-1} and it is graded as 'moderately heavy' (Zander, 1973).

At 16.4 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 141.2 bpm and 115.2 bpm, respectively and graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 26.25 kJ min^{-1} to a maximum of 36.67 kJ min^{-1}. The mean of EER was 29.95 kJ min^{-1} and it is graded as 'moderately heavy' (Zander, 1973).

Variations of HR of farm workers with different workloads (6.96, 10.5, and 14.0 N) at 70 rpm speed

The variation of HR of farm workers during cycling Ergometer with different workloads (6.96, 10.5, and 14.0 N) at 70 rpm is shown in Table 5. At 6.96 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 132 bpm and 110.2 bpm, respectively and graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 23.75 kJ min^{-1} to a maximum of 30.83 kJ min^{-1}. The

mean of EER was 27.50 kJ min^{-1} and it is graded as 'moderately heavy' (Zander, 1973).

At 10.5 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 142 and 118.3 bpm, respectively and graded as 'heavy' and 'moderately heavy' (Zander, 1973). The EER varies from a minimum of 26.67 kJ min^{-1} to a maximum of 37.08 kJ min^{-1}. The mean of EER was 31.66 kJ min^{-1} and it is graded as 'heavy' (Zander, 1973).

At 14.0 N workload, the mean values of increased working heart rate (1-6 min) and decreased rest heart rate were 148.67 bpm and 123.67 bpm, respectively and graded as 'heavy' and 'moderately heavy'(Zander, 1973). The EER varies from a minimum of 30.00 kJ min^{-1} to a maximum of 39.17 kJ min^{-1}. The mean of EER was 34.44 kJ min^{-1} and it is graded as 'heavy' (Zander, 1973).

Heart rate response and EER of different age groups of farm workers with constant speed (50 rpm) and workload (14.7 N)

From Table 6, the mean values of increased working heart rate (1-12 min) and EER in the age group of 20 to 30 years were 143.58 bpm and 32.32 kJ min^{-1}, respectively and it can be graded as 'heavy'(Zander, 1973).

Table 5. HR response of farm worker with different workloads at 70 rpm speed.

Workload (N)	Time (min)	Speed (kph)	Distance (km)	Heart rate (bpm)	Heart rate at rest (bpm)	EER (kJ min^{-1})
6.96	1.00	29.9	1.2	123	129	23.75
	2.00	30.3	1.8	127	120	25.42
	3.00	30.2	2.4	131	118	27.08
	4.00	30.4	2.9	133	102	27.92
	5.00	30.3	3.5	138	99	30.00
	6.00	30.5	3.8	140	93	30.83
10.5	1.00	30.2	1.00	130	140	26.67
	2.00	30.5	1.4	135	133	28.75
	3.00	30.4	1.9	139	128	30.41
	4.00	30.6	2.6	144	112	32.50
	5.00	30.7	2.9	149	100	34.58
	6.00	30.3	3.5	155	97	37.08
14.0	1.00	30.7	0.9	138	144	30.00
	2.00	30.3	1.4	141	139	31.25
	3.00	30.5	1.8	146	130	33.33
	4.00	30.2	2.5	151	121	35.41
	5.00	30.6	2.8	156	109	37.50
	6.00	30.4	3.3	160	99	39.17

Table 6. HR and EER of different age groups of farm workers with 50 rpm speed and 14.7 N workload.

Time (min)	Age group 20-30		Age group 31-40		Age group 41-50	
	Heart rate (bpm)	EER (kJ min^{-1})	Heart rate (bpm)	EER (kJ min^{-1})	Heart rate (bpm)	EER (kJ min^{-1})
1.00	122	23.33	118	21.67	110	18.33
2.00	127	25.42	120	22.50	118	21.67
3.00	133	26.67	128	25.83	120	22.50
4.00	137	28.75	134	28.33	127	25.41
5.00	140	30.00	137	29.58	130	26.67
6.00	143	31.25	139	30.42	135	28.75
7.00	147	32.92	143	32.08	138	30.00
8.00	150	34.58	147	33.75	141	31.25
9.00	153	35.83	150	35.00	145	32.92
10.00	158	38.33	154	36.67	149	34.58
11.00	161	39.58	157	37.92	152	35.83
12.00	165	41.25	160	39.17	158	38.33

In the age group of 31-40, these values were 140.58 bpm and 31.07 kJ min^{-1}, respectively and it can be graded as 'heavy' (Zander, 1973). In the age group of 41-50, these values were 135.25 bpm and 28.85 kJ min^{-1}, respectively and they can be graded as 'heavy' and 'moderately heavy' respectively (Zander, 1973).

Table 7. Comparison of weights and heart rates of farm workers at different speeds.

Weight (kg)	Speed (rpm)	Heart rate (bpm)			Average heart rate (bpm)
		1-4 min	4-8 min	8-12 min	
55	50	133	147	162	147
	60	134	148	164	148
	70	135	150	165	151
65	50	131	145	163	146
	60	133	146	164	147
	70	135	148	165	148
75	50	130	139	151	140
	60	132	141	154	142
	70	134	144	159	146

Heart rate response of farm workers at different speeds (50, 60 and 70 rpm) and weights (55, 65, and 75 kg)

The effect of heart rate with different age group workers at different weights and speeds are shown in Table 7. The mean values of increased working heart rate (1-12 min) for a weight of 55 kg at three different speeds 50, 60, and 70 rpm are 147.3, 148.67, and 150 bpm, respectively (Table 7). Similarly, the HR values at three different speeds 50, 60 and 70 rpm for a weight of 65 kg are 146, 147, and 148 bpm and for a weight of 75 kg are 140, 142.3, and 145.67 bpm, respectively.

BMI and PI of the farm workers with different age groups

The mean values of BMI and PI for the farm workers in the age group of 20-30 years were 22.51 and 13.58, respectively (Table 8) and they were graded as 'Normal'

and 'Ectomorph' respectively (Garrow, 1981; Florey, 1970). Further, for the 31-40 age group, the mean values of BMI and PI values were 24.05 and 14.57 and they were graded as 'Normal' (Garrow, 1981) and 'Ectomorph' (Florey, 1970), respectively. For the age group of 41-50, the mean values of BMI and PI values were 25.33 and 15.52 and they were graded as 'obese grade I' and 'Ectomorph', respectively (Garrow, 1981; Florey, 1970).

Statistical analysis

A regression based prediction equation for estimating EER is developed with age, weight, height, heart rate, and maximal oxygen uptake (VO_{2max}) as input variables. To develop this equation, a total of 39 form workers sample data was used. The equation was developed separately for men and women as there is a significant difference in weight, height, maximum working heart rate, and EER between the sexes (Table 2). The developed regression based prediction equations are expressed as:

$$\text{EER}_{\text{Men}} = \left[\left(-0.0875 \times \text{Age} \right) - (0.0383 \times \text{Weight}) + (0.000011 \times \text{Height}) + (0.3813 \times \text{HR}) - (0.2257 \times \text{VO}_{2\text{max}}) \right]$$

(4)

$$\text{EER}_{\text{Women}} = \left[\left(-0.0916 \times \text{Age} \right) - (0.0401 \times \text{Weight}) + (0.0002 \times \text{Height}) + (0.3797 \times \text{HR}) - (0.2363 \times \text{VO}_{2\text{max}}) \right]$$

(5)

Where EER_{Men} = energy expenditure rate for men (kJ min^{-1}), $\text{EER}_{\text{Women}}$ = energy expenditure rate for women (kJ min^{-1}), Age is in years, Weight is in 'kg', Height is in 'cm', HR = heart rate (bpm), VO_{2max} = maximum oxygen consumption rate (ml kg^{-1} min^{-1}).

The above equations are developed in Matlab (MATLAB

version 7.10.0 [Computer software]. Natick, MA, MathWorks.) software. For inner validation, both the models for women and men farm workers were tested on an independent sample of total 39 participants. The scatter plots between observed and regression model predicted EER (kJ min^{-1}) for men and women is shown in

**Table 8.** BMI and PI of the farm workers with different age groups.

Age group (years)	Name of the operator	Sex	Age (years)	Weight (kg)	Height (m)	BMI	PI
	N. Ashok Kumar	Male	27	62	1.702	21.40	12.58
	N. Surya Prakash	Male	25	68	1.702	23.47	13.79
	S. Venkat Reddy	Male	26	52	1.575	20.96	13.31
	K. Tirupati	Male	22	70	1.685	24.65	14.63
	R. Prasad	Male	29	59	1.63	22.21	13.62
	K. Sathyanarayana	Male	27	72	1.79	22.47	12.55
20-30	V. Shankar	Male	26	80	1.65	29.38	17.81
	B. Bhuchanna	Male	22	92	1.72	31.10	18.08
	D. Rajayya	Male	30	77	1.85	22.50	12.16
	A. Narsakka	Female	20	45	1.55	18.73	12.08
	Ch. Manga	Female	21	48	1.57	19.47	12.40
	N. Bhulaxmi	Female	25	42	1.52	18.18	11.96
	G. Vani	Female	30	44	1.56	18.08	11.59
	N. Thirupathayya	Male	33	56	1.575	22.57	14.33
	S. Srinivasa Rao	Male	34	62	1.575	24.99	15.87
	K. Srinu	Male	34	74	1.676	26.34	15.72
	Ch. Kutumba Rao	Male	39	88	1.823	26.48	14.53
	M. Mallikarjuna	Male	32	90	1.762	28.99	16.45
	N. Veeranna	Male	36	76	1.652	27.85	16.86
31-40	U. Gangaram	Male	38	63	1.812	19.19	10.59
	A. Daniel	Male	33	75	1.75	24.49	13.99
	U. Sukumar	Male	32	70	1.68	24.80	14.76
	M. Padmaja	Female	30	60	155.0	24.97	16.11
	K. Sandhya	Female	31	54	156.0	22.19	14.22
	B. Sujata	Female	33	52	155.0	21.64	13.96
		Female	40	42	152.0	18.18	11.96
	P. Salmon Raju	Male	40	64	157.5	25.80	16.38
	G. Narasiah	Male	46	73	167.6	25.99	15.51
	A. Seetiah	Male	46	85	169.2	29.69	17.55
	B. Dubbanna	Male	43	88	181.2	26.80	14.79
	G. Chinniah	Male	42	92	179.5	28.55	15.91
	R. Ashok	Male	49	63	164.2	23.37	14.23
41-50	V. Kiran	Male	50	77	159.3	30.34	19.05
	K. Srinivasa Rao	Male	46	62	162.6	23.45	14.42
	V. Buchi Reddy	Male	49	70	160.0	27.34	17.09
	D. Gangulu	Female	45	55	158.0	22.03	13.94
	G. Laxmi	Female	48	58	154.0	24.46	15.88
	S. Rani	Female	40	53	155.0	22.06	14.23
	A. Sharada	Female	45	45	152.3	19.40	12.74

Figure 6a and b, respectively. The fit line equations ($y = a_0x+a_1$) are shown in Figures 6a and b along with the coefficient of determination (R^2) values. There is a quite good agreement between the observed and predicted EER with R^2 values as 0.738 and 0.645 for both the men and women, respectively.

Conclusions

From the results of experimental investigation the following conclusions were drawn:

1. The farm workers of 20-30 years age group have
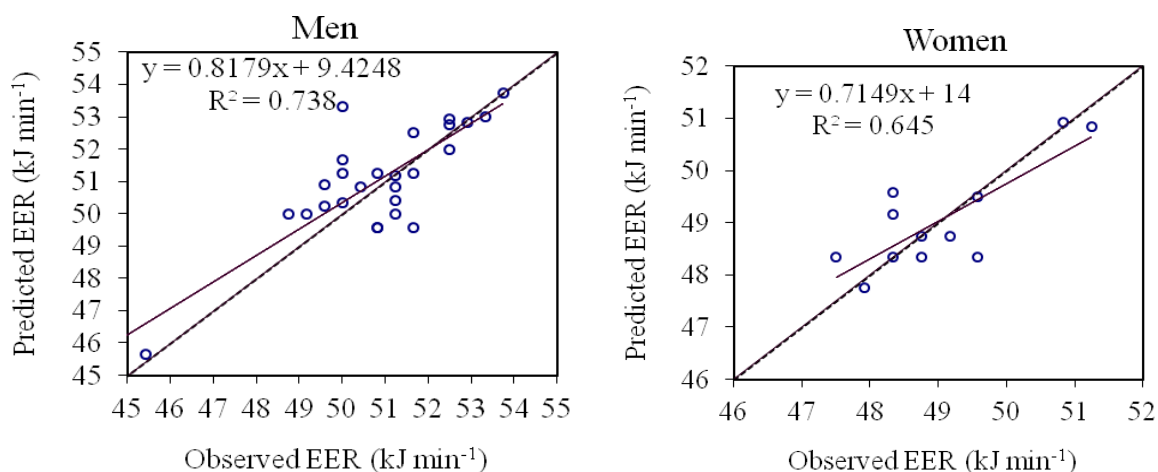
Figure 6. Scatter plots between observed and predicted EER for a) Men and b) women farm workers.

developed a maximum working heart rate as compared to other age groups of 31-40 and 41-50 years.

2. The EER for all the farm workers obtained was graded as 'Moderately Heavy'.

3. As the workload values increases, the heart rates of the farm workers increased.

4. The BMI of age groups 20-30 and 31-40 years were considered as 'Normal' and 41-50 were considered as 'Obese grade I'.

5. The PI of all age groups, that is, 20-30, 31-40 and 41-50 years were 'Ectomorph' in nature.

6. The regression based equations were developed and validated for both the men and women in predicting EER from age, weight, height, heart rate, and maximal oxygen uptake (VO_{2max}) as input variables.

Conflict of Interest

The author has not declared any conflict interest.

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