ISSN 2229-5518

Effects of Body Mass Index on Aerobic Power (VO_2max) and Energy Expenditure (EE): A Case of Manual Load Lifting in Agro-Processing

B.O. Afolabi & O.G. Akanbi

Abstract— The studies aimed at determine the effect of body mass index (BMI) on aerobic power (VO_2max) and energy expenditure (EE) during manual operation in primary agro-processing. Selected physiological and anthropometry properties of voluntary group of thirteen subjects were measured with respect to manual lifting of loads through the vertical distance of 0.92m from ankle level to inlet opening of thresher during threshing operation. The measured properties showed that height and weight ranged from 1.65m to 1.83m and 53g to 78g respectively, the calculated BMI ranged from 18.38kg/m^2 to 28.65kg/m^2. Heart rate at rest (HRrest) and maximum heart rate (HRmax) were measured with maximum; minimum values of 56beat/min; 89beat/min and 191beat/min; 200beat/min corresponded to mean ± SD of 72.5 ± 11.7 and 195.8 ± 3.0 respectively. The calculated EE and VO_2max have minimum; maximum values of 94kj/min; 396kj/min and 32.2ml/min/kg; 52.5ml/min/kg corresponded to mean ± SD of 238.7 ± 92.5 and 41.5 ± 6.9. Results on relational effects showed that increase in EE relate positively to BMI, while increase in VO_2max relate negatively to BMI. Also, it was found that heights of the subjects relate directly to lifted loads, while body weights relate inversely to the lifted loads. Regression models that could be used to express the relationship existing between independent variables EE (e) and VO_2max (a), and dependent variable BMI (y_B) are; y_B = 6.2792e + 106.9 (R^2 = 0.0361) and y_B = - 0.4858 a + 51.689 (R^2 = 0.039) respectively. Also, the regression models for relationship that occurred between independent variables height (h) and weight (w) and dependent variable load quantity (y_L)are; y_L= 0.2465h +164.58 (R^2 = 0.091) and y_L = -0 .4018w +78.592 (R^2 = 0.1389)respectively. Environmental conditions such as relative humidity, air temperature and atmospheric pressure were noted, and has the values of 84.57%, 21.79^{o}C and 765mmHg respectively. The relationship existing between the physiological factors and BMI were found to be adequately expressed by regression equations.

Index Terms—Aerobic power, agro-processing , anthropometry properties, body mass index, energy expenditure, environmental conditions, manual load lifting, physiological properties, regression models.

1 Introduction

Agricultural operations majorly in the developing nations are characterized by series of manual labour raging from land preparation through to post-harvest processing of farm produce, and can be described as moving loads from place to place by lifting, lowering, pushing, pulling, or carrying in a work environment.

Manual materials handling is ubiquitous in various working environments, including, for example, industrial workers pushing heavy levers, utility personnel moving spools of cable, or nurses lifting bed-ridden patients. In a developing country, a large percentage of the working population is involved in manual labour, where the physical demands of the task often over – tax the physical capabilities of the worker (Scott and Charteris, 2004).

The body's physiological responses to physical workload involve the musculoskeletal and cardiovascular systems. Muscular forces are required to perform the physical work, that is, to hold and move the load from one point to another. Muscular activities (muscle contraction and extension) during physical work require energy. Supplying the demanded energy creates loads on the cardiovascular system (heart and blood vessels) and respiratory system. The heart must pump faster to deliver the increased oxygen demand through blood vessels to the involved muscles. The rate of ventilation (inhalation and exhalation) must increase to supply the additional oxygen requirements. These physiological responses are directly related to the work intensity (workload). They are assessed in terms of such parameters as heart rate, body temperature (e.g. oral, rectal, and/or skin temperature), blood pressure, respiration (ventilation) rate, oxygen consumption rate, and concentration of metabolites in saliva, blood, and/or urine. (Health Uottawa, 2003).

Brown (1961) reported corroborating results for occupations involving much physical activity. He found a linear relationship between gross body weight and energy expenditure. The studies indicate that in dynamic activity the weight of the body itself constitutes the energy load. Energy expenditure per unit of body weight is therefore an ap-

- *B.O. Afolabi is currently pursuing doctoral degree program in industrial and production engineering in the University of Ibadan, Nigeria, PH-08073242515. E-mail: bukkyblessed@yahoo.co.uk*
- *O.G. Akanbi is currently a senior lecturer in the department of industrial and production engineering in the University of Ibadan, Nigeria, PH-08023387396. E-mail: author_name@mail.com*

ISSN 2229-5518

proximate measure of dynamic task intensity.

Tayyari and Smith, 2003 recorded that VO_2 and VO_2max vary significantly among individuals and that they are affected by many factors, such as:

- Somatic factors: body size, age, sex
- Psychic factors: attitude, motivation
- Environment: altitude, temperature, humidity, etc.
- Nature of work: workload (or intensity), duration, rhythm, technique.
- Physiological characteristics of the individual which are genetically determined (inherited at birth).
- Posture.

As a part of the efforts to minimize manual material handling in agro-processing in the developing nations, this paper reports on the relational effect of body mass index (BMI) to aerobic power (VO_2max) and expended energy(EE) in manual lifting of loads.

2 Materials and Methods

2.1 Determination of Body Mass Index (BMI), Aerobic Power (VO_2max) and Energy Expenditure (EE)

The study was carried out by a voluntary group of thirteen randomly selected students, eleven males and two females. Preliminary data were collected on the subjects by taking some of their anthropometric and physiological measurements. For each iteration which lasted for a minute, individual subject had three iterative performances of lifting the load from ankle level to the feeding chute of the stationary grains processing machine. The materials weight is measured by mechanical weigh balance ISO 9001 (Capacity 120kg; Grade 1kg) and the quantity lifted by individual subject was determined by re-weighing the remaining mass after each iteration.

BMI is determined by weight in relation to height, and it is calculated metrically as weight divided by height squared (kg/m^2). Resting heart rates (HRrest) and post task heart rates were taken using sphygmomanometer OMRON MX3 Plus. Maximum heart rate (HRmax) was estimated according to the formula 220-age (Rodahl, 1989). VO_2max was obtained using equation created by a group of researchers to estimate VO_2max in ml/min/kg (Henrik, et al., 2004) i.e.

$$\mathrm{VO_2\ max} = 15\frac{\mathrm{HR}_{max}}{\mathrm{HR}_{rest}} \qquad (1)$$

Where HR_{max} = maximum heart rate and HR_{rest} = resting heart rate

While EE is determined by an established relationship between oxygen consumption and energy expenditure (Singh et al., 2008) i.e.

$$1\ \mathrm{KJmin^{-1}} \equiv 20.88 \times \text{Oxygen consumption} \qquad (2)$$

The relative humidity, atmospheric pressure and air temperature during the study period were observed.

3 Results and Discussion

3.1 Age, Sex, Height and Weight Measurements and Body Mass Indexes Determination

Age, height and weight of thirteen subjects measured, and their BMI are presented in Table 1. Ages of the male subjects ranged from 21 to 30years, while that of females ranged from 21 to 22 years. On the average the height of male subjects is 3.213m higher than the average height of female subjects which is 2.220m, however, weight of female subjects of 73kg is heavier than the male subjects by 11.36kg. The body mass indexes (BMI) ranges from approximately 18.38 kg/m^2 to 28.65 kg/m^2 with the maximum corresponded to female subject of 21years and the minimum to male of 25 years (Table 1).

TABLE 1
SOME PARAMETERS OBTAINED FROM THE SUBJECTS AND THEIR BODY MASS INDEXES (BMI)

Subjects	*Age (year)*	*Sex*	*Height (m)*	*Weight (g)*	*BMI (kg/m^2)*
1	21	m	1.72	58	19.71967
2	24	m	1.73	60	20.16383
3	21	m	1.77	65	20.74755
4	29	m	1.82	62	18.77941
5	29	m	1.71	56	19.19607
6	30	m	1.80	65	20.06173
7	24	m	1.73	59	19.82777
8	25	m	1.70	53	18.38233
9	28	m	1.81	68	20.75639
10	25	m	1.83	77	22.99262
11	24	m	1.68	55	19.48696
12	22	f	1.68	68	24.09297
13	21	f	1.65	78	28.65014

3.2 Physiological Factors and Corresponded Lifted Loads

Table 2 shows heart rates of the subjects at rest (HRrest) as well as their maximum heart rates (HRmax), their aerobic power (VO_2max), energy expended (EE), and load lifted by individual. HRrest ranges from 56beat/min to 89 beat/ min,

ISSN 2229-5518

while HRmax ranged from 191beat/min to 200beat/min. The means and standard deviations (SD) of VO_2max, EE, and loads lifted by the subjects are 41.5 and 6.9, 238.7 and 92.5, and 37.8 and 7.3 respectively (Table 2). Subject 12 (female) has the least lifted load of 20 kg with average expended energy of 313 kj/min, while subject 11 (male) with minimum expended energy of 94 kj/min on average lifted the highest load of 47kg (Table 2). From table 2, subject 11 (male) has the maximum aerobic power of 52.5ml/min/kg, while subject 4(male) has the minimum aerobic power of 32.2ml/min/kg and expended more energy on average (396kj/min) to lift 40kg of load which is lesser than that of subject 11.

TABLE 2

HEART RATES, AEROBIC POWER, ENERGY EXPENDED AND LOAD LIFTED

Subjects	HRrest (beat /min)	HRmax (beat /min)	VO_2max (ml/min /kg)	EE (Kj/ min)	Load Lifted (kg)
1	86	199	34.7	311	42
2	75	196	39.2	232	29
3	63	199	47.4	132	43
4	89	191	32.2	396	40
5	78	191	36.7	330	39
6	65	200	46.2	202	36
7	75	196	39.2	277	39
8	65	195	45.0	165	42
9	65	192	44.3	130	45
10	56	195	52.2	208	38
11	56	196	52.5	94	47
12	81	196	36.3	313	20
13	89	199	33.5	313	32
MEAN	**72.5**	**195.8**	**41.5**	**238.7**	**37.8**
SD	**11.7**	**3.0**	**6.9**	**92.5**	**7.3**

3.3 Effects of Quantity of Load Lifted on EE and VO_2max

The effect of loads lifted by individual subject on their expended energy (EE) and aerobic power (VO_2max) is shown in figure 1. From this figure, it can be deduced that subjects with relatively high VO_2max expended lesser energy compare to subjects with low VO_2max. Also from the figure, the line graph representing VO_2max variations falls below the line graph representing EE variations for the subjects 1, 4, 5, 12 and 13 with respective lifted loads of 42kg, 40kg, 39kg, 20kg and 32kg.

Fig. 1: Effects of Load Lifted by Individual Subject on their EE and VO_2max

3.4 Physiological Factors and Corresponded Lifted Loads

Figure 2 shows the relationship between load lifted by individual subject to their respective heights and weights. From this figure, it can be seen that the quantity of load lifted is directly proportional to the height of the subjects and inversely proportional the weight of the subjectsthis implies that weight has negative correlational effects on quatity of loads lifted by individual subjects. The relationships are established through the regression lines with the following regression equations;

$y_L = 0.2465h + 164.58 \quad (R^2 = 0.091) \quad (3)$

$y_L = -0.4018w + 78.592 \quad (R^2 = 0.1389) \quad (4)$

where y_L = load quantity (kg), h = height of subject (m) and w = weight of subject (g)

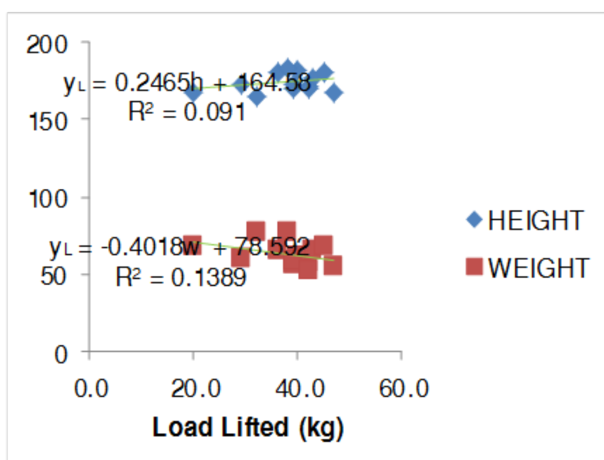

Fig. 2: Relationship between Loads Lifted by Individual Subject to their Height and Weight

3.5 Relationship of BMI to EE and VO_2max

The results presented in figure 3 shows the relationship of body mass index (BMI) to expended energy (EE) and aerobic power (VO_2max). The BMI presented in the figure relates directly to EE, which implies EE increase with increase in BMI. Whereas, BMI is inversely proportional to VO_2max, that is, increase in VO_2max could result in decrease in BMI. For the spelled out reason, low BMI (not below normal) would be suitable for manual lifting operations. The relationship existing between BMI and, EE and VO_2max can be expressed by the following regression equations;

$$y_B = 6.2792e + 106.9 \qquad (R^2 = 0.0361) \qquad (5)$$

$$y_B = - 0.4858\,a + 51.689 \quad (R^2 = 0.039) \qquad (6)$$

where y_B = body mass index (kg/m²), e = energy expended(Kj/Min) and a = aerobic power (ml/min/kg).

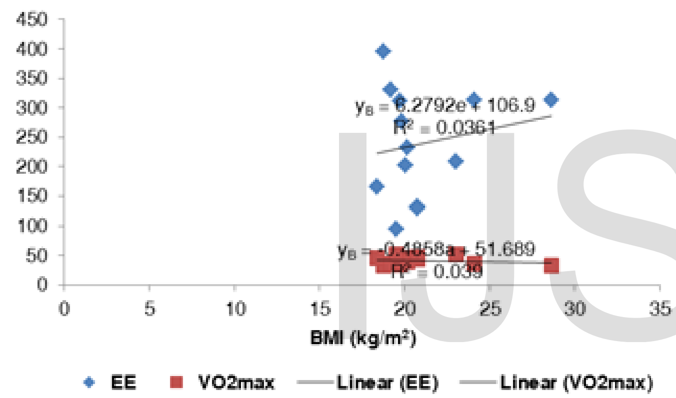

Fig. 3: Energy Expenditure and Aerobic Power (VO_2max) versus BMI

4 Conclusion

The effect of BMI on EE and VO_2max when lifting loads from ground level into the inlet of stationary threshing machine in agro-processing were determined. Quantity of loads lifted and BMI are directly proportional to the heights and EE of individual respectively, and inversely proportional to the weights and VO_2max of individual respectively. The relationship existing between the physiological factors and BMI were found to be adequately expressed by regression equations. Maximum lifted load of 47kg by male subject is found to be corresponded to 94kj/min of EE, 52.5ml/min/kg of VO_2max and 19.48kg/m² of BMI. Whereas, the minimum load by female subject of 20kg corresponded to 313kj/min of EE, 36.3ml/min/kg of VO_2max and 24.09kg/m² of BMI. The identified subjects male and female are found to be of the same height of 1.68m but of weights 55g and 68g respectively.

References

[1] Henrik S., Kristian O.,and Preben K. P. (2004). "Estimation of VO2max from the ratio between HRmax and HRrest--the Heart Rate Ratio Method". http://en.wikipedia.org/wiki/VO2_max Retrieved 27/07/2010

[2] Rodahl, K. (1989) "The physiology of work," Taylor and Francis, London

[3] Scott, P.A. and Charteris, J. (2004) "In cultural Ergonomics," chap. 8, pp 228 and 242. Elsevier, Oxford.

[4] Singh, S., Dixit, A.K., and Singh, S. (2008). "Ergonomic Evaluation of Cotton picking Operation." http://www.ieindia.org/pdf/89/89AG105.pdf.

[5] Tayyari, F. and Smith, J., (2003), "Occupational Ergonomics principles and applications." Kluwer Academic publishers: Massachusetts.