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ENERGY DEMAND FOR MAKING MOUNDS USING MANUAL HOE

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ABSTRACT: Manual work, which requires human muscle energy, is still common today despite automation and mechanization of activities especially in developing industries. Agricultural activities include land clearing, ridging/ mounding, planting and post harvest operations. There is presently limited data for energy requirements for making mounds for sowing of crops using manual hoes in Nigeria, necessitating this study. The participants in the study were a random sample of seven men and five women in two villages in Abeokuta, Ogun State. The subjects' heart rate HR was recorded before the mounding operation (HR_R) and at the end (HR_W). The energy expenditure of the farmers was determined using three models from the literature. The maximum energy expenditure obtained from the study was 12.92kJ/min (215.33 Watts) while the maximum work rate was 3.23 kJ/min (53.83 Watts). It was concluded that though mounding operations was a moderate work, there was the possibility of postural load, which would necessitate the design of appropriate simple motorized tools for mounding operations.
KEYWORDS: Energy expenditure, Mounds, Manual work, Heart rate

INTRODUCTION

Farming has been rated one of the most dangerous occupations (Mazza, 1997) with a considerable number of adverse health conditions, including musculoskeletal disorders.

Yisa (2005) stated that peasant farmers cultivate 80 percent of the food consumed by Nigerians and Oyedemi and Olajide (2002) estimated that 86 percent of the land cultivation in Nigeria is done using hoes, cutlasses and similar tools. The import of these findings is that farmers using hoes, cutlasses and similar tools cultivated the majority of the foods being consumed by Nigerians. The use of these tools results in multiple risk factors for musculoskeletal discomfort and injuries (Fathallah et al., 2008; Janowitz et al., 2000).

Few studies have evaluated the use of hoes in developing countries (Badiger et al., 2006; Oyedemi and Olajide, 2002; Nwuba and Kaul, 1986; Tewari, 1991). Because of the socio-economic conditions of farmers in several developing countries including Nigeria, human muscle power is used for many farm activities. Human power is still one of the major contributors of energy for agricultural activities in developing industries and is likely to continue for the next two decades (Tiwari et al., 2011). Human energy has generally been utilised through arms, hands, and back. It was only with the invention of the mechanised farming, which also involve little effort of man's energy depending on the posture that less emphasis has been placed on human energy. Manual labour contributes an estimated 90% of the energy used for crop production (FAO, 1987), which includes making of ridges/mounds/heaps. Manual work requires high-energy expenditure. The main aim of ergonomics is to focus on man and machine interaction (Grandjean, 1986) as any incompatibility between these two key components, within the work environment, will result in the worker experiencing physical and/or mental strain, resulting in poor performance and decreased productivity (Scott and Christie, 2004).

In developing countries the physical demands of the task usually exceed the physical capabilities of the worker (Scott and Charteris, 2004).

Physical tests have been used by organizations to assess the capability of workers for physically demanding jobs as in military formations (Blizon, 2002). Because of this fact, many ways have been adopted in measuring workers, responses to manual tasks in order to appraise the incompatibility, and to evaluate the effectiveness of intervention strategies. In order to match a person's work capacity with the requirements of his/her job, there is a need to know the individual's energy capacity and how much the job demands from this capacity (Ismaila et al., 2012). A range of methods has been *developed to measure physical activity and the methods include questionnaires, diary techniques, heart rate, doubly labeled water, mechanical or electronic motion sensors (Bouten et al., 1994).*

To estimate the energy expenditure or physical strain during sports, work or daily activities, the heart rate is now commonly used (Ismaila et al., 2012; McArdle et al., 2001; Bot and Hollander, 2000). The method is based on fact that there is a linear relationship between heart rate (HR) and oxygen uptake (VO_2) during steady state conditions and gives the opportunity of an easy and relatively inexpensive determination of the VO_2 (Scott and Christie, 2004; Strath et al., 2004; McArdle et al., 2001; Bot and Hollander, 2000). There is presently limited data for energy requirements for making mounds for sowing of crops using manual hoes in Nigeria, necessitating this study.

METHODOLOGY

The participants in the study were a random sample of 7 men with a mean age of 47.3 (SD = ± 10.33) years and 5 women with a mean age of 33 (SD = ± 6) years.

The protocols for the study were explained to the participants and their consent obtained. The field experiment was conducted in the month of December 2011 in Abule Ojere and Onikolobo area of Abeokuta South in Ogun State. During the experiment, various parameters namely heartbeat per minute, weight and height, were recorded for each subject just before the exercise started and at the end of each exercise respectively. The subjects were weighed on a scale before the physical work.

The subjects HR was recorded before the physical work, then at the end of the exercise the subject's heart was also recorded to determine the rate per minute, the heart rate was measured by a means of a portable HR monitor (OMRON M2, China). Three replications of the measurements were taken to ensure correctness, however, no changes were observed.

The data was analyzed statistically by using SPSS 17.0 statistical package and descriptive and analytical statistics were generated.

The energy demand of making mounds was determined using the equation 1(Kwatra et al., 2010) and equation 2 (Saha et al., 1979) while work rate was determined using equation 3 (Igbeka et al., 1986)

$$\text{Energy Expenditure, EE (kJ/min)} = 0.159 \times \text{HR (beats/min)} - 8.72 \quad [1]$$

$$\text{Energy Expenditure, EE (kJ/min)} = \frac{HR - 66.0}{2.4} \quad [2]$$

$$\text{Work Rate, WR (kJ/min)} = \frac{R - 67.0}{9.3} \quad [3]$$

RESULTS

The photograph of a female participant while making the mounds using manual hoe is shown in Plate 1.

Plate 1: A participant making mounds using a manual hoe

Table 1 shows that the mean age of the participants was 41.33 years, mean body height was 1.7 m and mean body weight was 60.14 kg. The participants also had a mean body mass index of 20.94 kg/m^2. There were significant differences between the ages of the males and the females ($p = 0.024$). However, there were no significant differences between the weights of the females and the males ($p = 0.560$) and their heights ($p = 0.301$).

The mean working heart rate was 94. 92 beats per minutes (bpm) while the mean resting heart rate was 83.08 bpm. There were no significant differences between the resting heart rate of men and women ($p = 0.083$). Similarly, there were no significant differences between the working heart of the males and those of the females ($p = 0.468$). The average resting time was 68.16 minutes while and average length of time used for making the mounds was 284.25 minutes respectively signifying that the participants had a rest of about 24 percent of working time.

The maximum energy expenditure using the model of Kwatra et al. (2010) was 6.70 kJ/min (111.67 Watts) while it was 12.92 kJ/min (215.33 Watts) using the model of Saha et al. (1979). A maximum work rate of 3.23 kJ/min (53.83 Watts) was obtained from the study.

Table 1: Statistical analysis of anthropometric characteristics of the participants, calculated values of energy expenditure and work rate

Statistics	Age (yr)	Weight (kg)	Height (m)	^BMI (kg/m^2)	HR_R (bpm)	HR_W (bpm)
Mean	41.33	60.14	1.70	20.94	83.08	94.92
Std. Error of Mean	3.23	2.14	0.04	0.75	1.17	0.33
Std. Deviation	11.20	7.40	0.13	2.60	4.06	1.16
Minimum	27.00	50.00	1.55	16.88	78.00	93.00
Maximum	59.00	79.80	2.05	24.72	88.00	97.00

Statistics	^^EE (kJ/min)	*EE (kJ/min)	**WR (kJ/min)	Working time (mins)	Resting time (mins)
Mean	6.38	12.05	3.00	284.25	68.17
Std. Error of Mean	0.05	0.14	0.03	13.32	4.58
Std. Deviation	0.17	0.48	0.12	46.14	15.85
Minimum	6.10	11.25	2.80	180.00	50.00
Maximum	6.70	12.92	3.23	330.00	102.00

^obtained using BMI = Weight /Height^2 (kg/m^2)

^^ obtained using EE (kJ/min) = 0.159 × HR (beats/min) - 8.72 (Kwatra et al., 2010)

*obtained using EE (kJ/min) = $\frac{HR - 66.0}{2.4}$ (Saha et al., 1979)

**obtained using WR (kJ/min) = $\frac{R - 67.0}{9.3}$ (Igbeka et al., 1986)

The mean working time for mounding operation of 284.25 minutes obtained in the current study compared favorably with 274 minutes obtained by Dada and Abiola (2010) for ridging operation. Similarly, the mean resting time for mounding operation of 68.17 minutes obtained from the current study compared favorably with 68.5 minutes obtained by Dada and Abiola (2010) ridging operation. This may suggest that both mounding and ridging operations are energy demanding ones. However, mounding operations consumed less power of 215. 33 Watts (12.92 kJ/min) compared with 347 Watts (20.82 kJ/min) required by ridging operations as obtained by Dada and Abiola (2010). Nag et al. (1980) categorized agricultural work using energy expenditure as:

- Light Work: < 9.1 kJ/min
- Moderate Work: 9.11-18.15 kJ/min
- Heavy Work: 18.16-27.22 kJ/min
- Extremely heavy Work: > 27.23 kJ/min

Using the model of Saha et al. (1979), mounding operations could be regarded as a moderate work while ridging operations could be regarded as heavy work. The mean heart rate after work of 94.92 bpm obtained from this study was less than a mean heart rate of 102.9 bpm obtained by Gangopadhyay et al. (2005) for ridging operations. This further confirmed that ridging operations require more power than mounding operations. Astrand and Rodahl (1986) gave the following classification of severity of work load for prolonged physical work in terms of mean heart rate as:

- up to 90 bpm: 'light work';
- 90 to 110 bpm: 'moderate work';
- 110 to 130 bpm: 'heavy work';
- 130 to 150 bpm: 'very heavy work'
- 150 to 170 bpm: 'extremely heavy work'.

Using the classification of Astrand and Rodahl (1986), mounding operation could also be regarded as moderate work. The mean energy expenditure obtained from the present study using Saha (1979) compared favourably with the estimate of manual energy of men (0.75 MJ/hr i.e. 12.5 kJ/min) provided by Norman (1978).

Most of the literature seems to support the energy expenditure obtained using Saha et al. (1979) and is therefore relevant in the current study. In addition, the higher energy expenditure would be better used to determine energy requirements of mounding operations from the point of view of a design engineer for proper design to make provisions for the unknowns.

CONCLUSIONS

From the study, the work contents of mounding operation in farming can be categorized as moderate work based on heart rate. However, postural load may necessitate the development of simple motorized tool that could replace manual mounding using hoes and the energy required for mounding obtained from this study could be used in the design of such tools. This study is however limited due to the number of participants as few people now reside in the villages.

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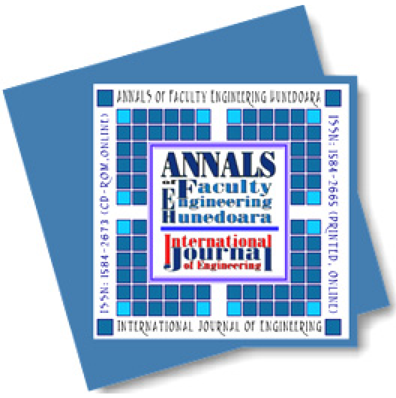

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