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# BASAL METABOLIC RATE AND ENERGY EXPENDITURE OF RURAL FARMERS IN MAGUBIKE VILLAGE, KILOSA DISTRICT, TANZANIA

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**ABSTRACT**

Measurement of basal metabolic rate (BMR) provides an important baseline for the determination of an individual's total energy requirement. The study sought to establish human energy expenditure of rural farmers in Magubike village in Tanzania, through determination of BMR, physical activity level (PAL) and total energy expenditure (TEE). In addition, the study intended to provide an indication of the level of energy requirement for the rural people of Tanzania. The objective of the study was to determine energy expenditure of farmers in comparison to the mean caloric intake per capita and the WHO/FAO recommended energy requirements for developing countries. A cross-sectional study design involving 33 male and 31 female farmers was conducted on randomly selected households. Basal Metabolic rate and household activities were measured by indirect calorimetry, using the Douglas bag technique. Physical activity Level was measured by twenty-four hour activity diary and TEE calculated as a product of BMR and PAL. Men's BMR was 4.7 MJ/day while that of women was 4.3 MJ/day. Farmers mean PAL was 2.20 ± 0.25 in men and 2.05 ± 0.23 in females and TEE was 10.24 MJ/day in men and 8.57 MJ/day in women. Both BMR and TEE were higher in men than in women. The measured energy expenditure for digging and weeding were 1.57 ± 0.3 kJ/min; 1.36 ± 0.31kJ/min in men and 1.58 ± 0.3 kJ/min; 1.49 ± 0.33 kJ/min in women. It was revealed that total energy expenditure of farmers in Magubike village was high with the values being above the mean daily calorie requirement per capita for Tanzania (8.15 MJ/day) but within the WHO/FAO recommended energy requirements (11.26 MJ/day) for developing countries. High energy expenditure was attributed to high energy levels spent in farm activities which were manual and labour intensive. This is likely to be the situation in many rural areas of Tanzania. More work on measurement of costs of farm activities and farmers work capacity are necessary to provide recommendations on energy needs of rural farmers.

**Key words:** BMI, PAL, Anthropometry, Body composition

## INTRODUCTION

The livelihood of rural households in developing countries, Tanzania inclusive, is critically dependent on their ability to produce food. For many farmers, family labour represents their main or only asset for production. Hence, high productivity demands adequate energy intake and reasonable health. The Food and Agriculture Organization (FAO) recommendation on energy and protein requirements for humans are based on energy expenditure and various components of energy expenditure are expressed as multiples of BMR [1]. Schofield and James, Cole and Henry through different studies developed predictive equations that have been used to determine BMR, which accounts for 60 -70 % of energy expenditure, but not much data is available from developing countries [2,3]. Research in Nigeria showed that subsistence farmers in Africa maintain high energy expenditure especially during the cultivation and harvesting seasons, yet their energy intake in comparison to energy requirement is low [4].

Likewise, data from families in Sierra Leone showed that energy intake is related to productivity in the farm [5]. These studies showed that food intake affects physical activity and work output thus recommending appropriate energy requirements is of great importance. This study was carried out to determine BMR of farmers in Magubike village, then use the BMR to calculate energy cost of various farm activities and to determine farmers' energy expenditure and compare the values obtained against recommended FAO energy requirements.

## MATERIALS AND METHODS

### Subjects

The study involved farmers from Magubike village in Kilosa District- Tanzania. Farmers were randomly selected and recruited on voluntary basis based on their willingness to participate in the study. A total of 64 farmers, 33 males and 31 females aged 18 years and above participated.

### Study protocol

To carry out the measurements, a group of four farmers arrived daily from Magubike village, a day before the measurements. Subjects were housed in a rest house near the BMR laboratory at the Solomon Mahlangu campus of Sokoine University of Agriculture. The meals, drinks and activities done were monitored to ensure compliance with conditions required for BMR measurements [6]. An interval of one hour was used to differentiate and schedule the last (evening) meal given to the individual farmers. This was done to ensure that farmers did not become hypoglycemic as they waited to be measured in the following morning. Measurements for each subject started at 6.00 am. Anthropometry and body composition measurements were carried out first. Thereafter, the subjects were allowed to lie down while quiet for 30 minutes after which BMR was measured.

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**Weight and height**

Body weight was measured to the nearest 0.1 kg using a portable digital seca scale (Vogel & Haike, Hamburg, Germany) with subjects wearing minimal clothing and in the fasting condition. Height was measured to the nearest 0.1 cm using a Leicester height measure stadiometer. The height and weight measurements were used to calculate Body Mass Index:

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

**Basal metabolic rate (BMR)**

Basal metabolic rate was measured twice for each individual for 10 minutes by open circuit indirect calorimetry using the Douglas bag technique. The measurements were performed under standardized conditions in the morning, after an overnight fast ≥ 12 hours after a preliminary period of bed rest for 30 minutes, free from physiologic and psychological stress, in a thermo neutral environment). Volume of the expired air was measured by a calibrated gas meter (Harvard Apparatus Ltd, Edenbridge, Kent, and England). Samples of expired air were analysed for oxygen concentration using a Servomex type 572B portable paramagnetic oxygen analyzer (Wagtech International Ltd, Thatcham, Berkshire, England). Analysis of expired air was determined using a portable oxygen gasman monitor (Crowcon Detection Instruments, UK). The gas analyzer was repeatedly calibrated each day by using certified gases white spot nitrogen (oxygen free nitrogen) and atmospheric air to adjust the oxygen span for the servomex oxygen analyser.

**Physical activity level (PAL)**

Physical activity level was determined by a 24-hour activity diary, a method used to record detailed information on how the 24 hours of an average day were spent by each farmer. The recording was done for two week days and one weekend day. Total Energy Expenditure, which is equal to 24 hours energy expenditure was then expressed as a multiple of BMR and determined PAL values.

**Body composition**

The body composition of each subject was determined using a Tanita body composition analyser (Model BF 350, Tokyo Japan) which uses the "foot to foot" pressure contact electrode Bioelectrical Impedance Analysis (BIA) technique [7]. The percent body fat was then calculated and displayed by the analyser through a formula that combined the measurements set and impedance.

The following formulae were then used to calculate Percent Fat-free Mass (% FFM), Fat Mass (FM) and Fat Free Mass (FFM):-
% FFM = 100 - % Body Fat
FM = Body weight (kg) x % Body Fat
FFM = Body weight (kg) x % FFM

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**Data analysis**
All statistical analyses were performed using the statistical package for social sciences (SPSS) version 12.0. Differences were considered to be significant at $p < 0.05$.

## RESULTS

Physical characteristics and nutritional status of the farmers are given in Table 1. The mean age of male farmers was 46 ± 12 years (range 29 - 71 years) and that of female farmers was 39 ± 10 years (range 25 - 62 years). There was a significant difference ($p < 0.01$) in height between the two genders, males being taller than females. Likewise, the mean weight of male farmers was slightly higher than that of female farmers though not significantly different ($p < 0.05$). Ninety four percent of the farmers were between 18-64 years old. The remaining 6% were above 65 years and were considered not to be economically active. There were more women (48.5%) in the economically active group than men (44.4%). With regard to the nutritional status of farmers, women had higher mean BMI than men although the difference was not significant.

The mean FFM was higher for men than females while the FM for males was lower than that of females. The BMR data of both sexes are shown in Table 2. The mean BMR of farmers was 1078 ± 232 kcal/day (4.5 ± 1.0 MJ/day). Males had higher BMR than that reported for females. However, the observed difference between the two sexes was not significant.

Male farmers had higher PAL compared to female farmers (Table 2). The variations in PAL between the two sexes were significant ($t = 2.43$; $p = 0.018$). It was observed that labour intense farming activities such as digging, weeding, and some house chores such as fetching water, firewood and washing had high energy cost and contributed to the observed PAL. The measured energy cost for digging and weeding were 6.56 ± 1.25 kcal/min; 5.67 ± 1.28 kcal/min in men and, 6.60 ± 1.49 kcal/min; 6.21 ± 1.38 kcal /min in women. Farmers' TEE was a product of BMR and PAL. The results in Table 2 indicated that TEE of males was significantly higher ($t = 2.54$; $p = 0.014$) than that of females.

There are a number of factors that influence BMR. In the study, it was observed that weight, height, kg FFM had a significance influence on BMR. Other factors such as age, BMI and Kg FM did not show significant influence. The results as shown in Table 3, indicated a significant association ($p< 0.01$) between kilograms fat free mass of farmers and their BMR. An increase in lean tissue mass among farmers resulted in an increase in BMR. There was also a significant relationship ($p<0.05$) between weight height and BMR in that the greater the body size (body mass) and stature of the individuals, the higher the BMR.

## DISCUSSION

This study observed the mean nutritional status of farmers to be within normal range. However, determination of their body composition and body energy through BMR measurements showed energy deficits in the same well nourished farmers. This supports studies done over the years that have continued to show that Basal metabolic rate (BMR) is important in estimation of energy requirements and early detection of energy deficit that subsequently manifests as weight loss [1]. Different studies conducted on African farmers over the years have detected a variation and loss of weight that ranges from 0.7 kg which is equal to 1.4% of the body weight [8]. This variation has been known to result in a persisting decrease in BMR, even after adjusting for body weight and FFM losses and represents one of the earliest and best known adaptive responses to energy deficit, which has been extensively described under experimental and controlled laboratory conditions [9].

The study showed a significant association ($p < 0.01$) between FFM and BMR with an increase in lean tissue mass being associated with an increase in BMR. Body composition results showed a higher FFM in men than women explaining the higher BMR in men. The sex differences in BMR have been reported in different studies that have equated these differences due to FFM [10; 11; 12; 13]. The high BMR could possibly be explained by muscles and visceral tissues within the FFM. Weight and height also had a significant association ($p < 0.05$) with BMR. There are a number of factors that influenced BMR. An increase in lean tissue mass among farmers resulted in an increase in BMR. This is in line with the results by James and Schofield [14], and Soares and Shetty [15]. Both studies showed a high correlation coefficient between weight ($r = 0.875$), height ($r = 0.87$) and BMR. The study inferred that weight had a stronger correlation with BMR than height, FFM and FM. Likewise, in this study the correlation coefficients of weight ($r = 0.31$) was higher than height ($r = 0.27$) but lower than those reported in other studies [15]. Furthermore, a study by Durnin[10] showed that BMR was a function of all the separate active tissues of the body and is dependent on the relative masses of these tissues hence the individual's weight. The findings of the present study imply that for any given BMR, there is a direct link to the weight of an individual and since BMR contributes 60 - 70% of one's energy expenditure, there is a link to energy output [6]. The observed BMR of farmers was below normal acceptable range (46 – 50%). When an adult has an adequate amount of food, body weight and body energy stores that are within the acceptable range of normality, their health will not be impaired and physiological function will not be compromised. Thus, they will have sufficient energy for economically necessary productive work and domestic chores as well as social and leisure activities.

For farmers involved in agricultural productivity in rural Tanzania, matching energy output to energy intake is necessary if they are to sustain productive and economically vital activities, many of which occur at the peak energy output periods such as planting, weeding and harvesting seasons. Lack of sufficient energy stores during this period results in the energy deficiency phase taking place, body weight falls and BMR

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is lowered. Ferro–Luzzi [16, 17] explained that energy imbalance leads to marked changes in body weight as well as quantity and quality of energy output. Therefore, long standing energy deficiency is reflected by both changes in body weight and activity pattern.

The effect of increased aging causing a BMR decline due to reduced FFM as reported in earlier studies [10, 18, 19] was not observed in this study, although the age range of farmers was 29 –71 years in males and 25 – 62 years in females. However, these study results can be compared to the findings of Van Pelt *et al.* [20] whose work, though on resting metabolic rate (RMR) showed that BMR per unit FFM declined with age in highly active men when there is reduction in exercise volume and energy intake. This decline does not occur in men who maintain exercise volume and /or energy intake at a level similar to that of young physically active men. Since the older farmers in the study were still involved in farming activities, it is plausible that their level of physical fitness delayed the decline of FFM and BMR.

The normal range of PAL for active to moderate lifestyle is between 1.70 - 1.99 [1]. In the present study, variation in PAL between sexes was significant ($p< 0.05$) with the value for men being higher than that of women. General evaluation of factors relating to PAL showed farming activities that included digging, weeding and house chores such as fetching water, fetching firewood and washing to have contributed to the high PAL in the study. The energy cost of farm activities (digging and weeding) and fetching water were higher in the present study than the established WHO values [21].

Comparison of the study PAL with the WHO classification rated farmers under the vigorous or vigorously active lifestyle category that has PAL values ranging from 2.00 – 2.40 [21]. This further pointed out the need for farmers to have adequate energy stores that will allow maintenance of energy balance and healthy state, as well as meet energy demands that arise from agricultural activities.

Determination of TEE using observed BMR and PAL revealed a higher TEE in both males and females above the mean daily calorie per capita of Tanzania which is 8.15 MJ/day [22]. However, the TEE was below 11.26 MJ/day, which is an energy intake level for developing countries [23]. The observed TEE showed that farmers had high energy expenditure above their energy intake due to labour demanding activities that dominate their way of life. This illustrated the need for their energy intake to reflect this energy demand.

Researchers conducting studies in different parts of Africa have agreed that high levels of productivity among farmers who labour to produce and harvest crops and are also involved in many other labour-intensive, work-related activities demands adequate energy intake and reasonable health [17, 23, 24]. Therefore, if rural farmers in Tanzania are to meet productivity demands especially during the farming season improvement of energy intake, maintenance of energy balance and good nutritional status remain essential.


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## CONCLUSION AND RECOMMENDATIONS

The present study results suggest that current mean daily calorie per capita of farmers in the study area does not meet the energy needs of farmers. Therefore, there is still a need for recommended energy requirements to be met to complement the energy needs of rural farmers. Also more work to determine energy costs of farm activities and farmers work capacity are necessary as they will provide more information on energy needs of farmers.

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**Table 1: Physical Characteristics and Nutritional status of farmers**

| Sex | N | % | Age (years)[1] | Height (cm)[2] | Weight (kg)[3] | BMI[4] ($kg/m^2$ |
|---|---|---|---|---|---|---|
| Male | 33 | 51.6 | 46 ± 12 | 162.70±6.88 | 55.50 ± 7.16 | 20.9 ± 2.10 |
| Female | 31 | 48.4 | 39 ± 10 | 152.71 ± 5.56 | 52.25 ± 9.74 | 22.4 ± 3.7 |
| Total | 64 | 100 | 43 ± 11 | 157.87 ± 7.99 | 53.92 ± 8.60 | 21.6 ± 3.10 |

[1-3]Values are means±standard deviation; [4]Body Mass Index

**Table 2: Farmers Energy Expenditures**

| Sex | N | FFM[1] (kg) Mean±SD | FM[2] (kg) Mean±SD | BMR[3] (MJ/day) Mean±SD | PAL[4] Mean±SD | TEE[5] (MJ) Mean±SD |
|---|---|---|---|---|---|---|
| Male | 33 | 46.9 ± 4.9 | 8.6 ± 3.1 | 4.7 ± 1.1 | 2.20 ± 0.25 | 10.24 ± 3.1 |
| Female | 31 | 38.4 ± 3.6 | 13.8 ± 6.9 | 4.3 ± 0.8 | 2.05 ± 0.23 | 8.57 ± 2.1 |
| Total | 64 | 42.8 ± 6.1 | 11.2 ± 5.9 | 4.5 ± 1.0 | 2.13 ± 0.26 | 9.43 ± 31 |

[1]Fat Free Mass; [2]Fat Mass; [3]Basal Metabolic Rate; [4]Physical Activity level;
[5]Total Energy Expenditure

**Table 3: Factors influencing BMR in farmers**

| | Basal Metabolic Rate (n= 64) | |
|---|---|---|
| Variables | r value | p value |
| Kg FFM[1] | 0.0381 | 0.002** |
| Kg FM[2] | 0.061 | 0.061 |
| Age | -0.244 | 0.052 |
| Weight | 0.311 | 0.012* |
| Height | 0.273 | 0.029* |
| BMI[3] | 0.150 | 0.238 |
| Temperature | -0.034 | 0.788 |

*Significant at 0.05; **Significant at 0.01
[1]Kilogram Fat Free Mass; [2] Kilogram Fat Mass; [3]Body Mass Index

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## REFERENCES


1. **FAO.** Human Energy Requirements. Report of a Joint FAO/WHO/UNU expert consultation Rome, 17-24 October 2001.

2. **Schofield C and WPT James** Basal metabolic rate review and prediction. Human Nutrition: *Clinical Nutrition.* 1985; **39** (**1**)**:** S1-S96.

3. **Cole T J and CJK Henry** The Oxford Brookes basal metabolic rate database a re-analysis. *Public Health Nutrition* 2005; **8:** 1202 – 1212.

4. **Longhurst R** The Energy Trap: Work, Nutrition and Child Malnutrition in Northern Nigeria. Cornell University Program in International Nutrition. Monograph Series no.13. Ithaca, New York, U.S.A .1984.

5. **Strauss J** Does better nutrition raise farm productivity? *J Pol Econ.* 1986; **94**: 297-320.

6. **Krupa S and SB Roberts** Energy metabolism. **In:** Bowman A. Barbara and Russel M. Robert (Eds). Knowledge in Nutrition (Eighth Edition). International Life Sciences Institute. ILSI Press, Washington DC. 2001: 3-12.

7. **Nunez C, Gallagher D, Visser M, Pi-Sunyer FX, Wang Z and SB Heymsfied** Bio impedance analysis: Evaluation of leg to leg system based on pressure contact foot pad electrodes. Medical Science, Sports Exercise. 4th Series. 1997.

8. **Kennedy E and B Cogill** Income and Nutritional Effects of the Commercialization of Agriculture in Southwestern Kenya. International Food Policy Research Institute research report 63, Washington, DC. 1987.

9. **Ferro-Luzzi A, Pastore G and S Sette** Seasonality in Energy Metabolism.1987.

10. **Durnin JVGA** Basal Metabolic Rate in Man. Joint FAO/ WHO/UNU expert consultation on energy and protein requirement. Rome, Italy. 5th to 17th October 1981.

11. **Ferro-Luzzi A, Branca F and G Pastore** Body Mass Index defines the risk of seasonal energy stress in the third world. *Eur J Clin Nutr.* 1994; **48** (**3**): S165–S178.

12. **Latham MC** Human Nutrition in the Developing World. Food and Nutrition series, 1014 - 3181, No.29. FAO, Rome, Italy.1997.

13. **Roberts SB and GD Dallal** Energy requirements and aging. *Public Health Nutrition* 2005; **58** (**7A**): 1028-1036.

14. **James WPT and EC Schofield** Human Energy Requirements: A Manual for Planners and Nutritionists. Oxford University Press, New York, 1990.

15. **Soares MJ and PS Shetty** Validity of Schofield's predictive equations for basal metabolic rates of Indians. *Indian J Med Res*.1990; **88**: 253-260.

16. **Ferro-Luzzi A** Seasonality studies in three developing countries: Introduction and background. *Eur J Clin Nutr*.2000; **44**(**1**): S3-S6.

17. **Ferro-Luzzi A** Seasonal Under-nutrition in Rural Ethiopia. Magnitude Correlates, and Functional Significance. International Food Policy Research Institute publication, Washington D.C, U.S.A, 2001.

18. **Keys A, Taylor HL and F Grande** Basal metabolism and age of adult man. Metabolism: *Clinical and Experimental* 1973; **2**: 579–587.

19. **Tzankoff SP and AH Norris** Longitudinal changes in basal metabolism in man. *J. Appl. Physiol*.1978; **45**: 536–539.

20. **VanPelt RE, Dinneno FR, Seals DR and PP Jones** Age related decline in RMR in physically active men: relation to exercise volume and energy intake. *Am J Physiol Endocrinol Metab*.2001; **281**: E633 - E 639.

21. **WHO.** Energy and Protein Requirement: Report of a joint FAO/WHO/UNU.WHO technical report series No. 724 Geneva.1985.

22. **FAO.** Agriculture and Food Country profile - Tanzania Daily. Dietary Supply. 1999.

23. **Latham MC** Improving labour productivity through nutritional improvements: An expedient political justification? **In**: Per Pinstrup. A (Ed) The Political Economy of Food and Nutrition Policies. Johns Hopkins University Press.1993:133-148.

24. **Dasgupta P** Nutritional status, the capacity for work, and poverty traps. *JEconometrics.* 1997; **77**: 5-37.