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EFFECT OF DIETARY ENERGY INTAKE ON ENERGY BALANCE AND HUMAN ENERGY REQUIREMENTS OF ADULT WOMEN OF NIGERIA

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ABSTRACT

Thirteen normal healthy female adults aged 21 to 32 years participated in an energy balance study while they consumed their habitual diet at two energy levels (33.8±2.96 and 48.4±3.7 kcal/kg/day) and a protein level of 0.47g protein/kg/day. The physical activity of the subjects was closely monitored and kept fairly constant. Energy balance calculated from the gross energy intake, energy excreted (urine, feces and sweat) and expenditure on activity was affected considerably by the level of the gross energy intake. Energy balances were -6.35±2.57 and +7.31±2.24 kcal/kg/day for the low and high energy intakes respectively. Energy balance improved by a factor of 0.94±0.1 for every kcal/kg rise in gross energy intake. Mean energy requirement to achieve energy balance in all the subjects was estimated at 40.3±1.4 kcal/kg body weight.

Key words: Energy intake, Energy balance, Energy requirement.

INTRODUCTION

Several factors which can affect the estimation of minimum protein requirements of man include stress, heat infection, physical activity and energy intake. It is generally accepted that energy restriction leads to loss of nitrogen from the body. Thus an immediate increase in nitrogen has been demonstrated in human subjects when some of the energy sources are withdrawn from an adequate diet (1). Also, Calloway and Spector (2) concluded from a survey of published data on human subjects that at fixed adequate protein intake, energy level is the deciding factor in nitrogen balance. Thus addition of protein to the diet of an undernourished population may not be fully effective if the energy intake is not adequate. It is therefore essential that the energy requirements of any population be taken into consideration for N-balance experiments concerned with estimating protein requirements or assessing protein quality.

However, many difficulties are encountered in the estimation of individual energy requirements. Estimation of energy requirements based on changes in body weight and composition is not adequate (3-4). This is because of individual responses to altered energy

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intake in relation to physical activities. Also changes in the efficiency of energy utilization at various calorific levels further complicate the estimation. The purpose of this study is to estimate energy requirement of a group of young women in Nigeria based on energy balance method on a predetermined protein level as well as provide a data base for the country.

MATERIALS AND METHODS

Subjects: The subjects were all female Nigerian undergraduates of the University of Ibadan. The average age, body weight, body mass index (BMI) and basal metabolic rate (BMR) were 26.2 (21-32) years, 52.6 (40.0-64.0) kg, 20.9 (16.7-24.4) kg/m^2 and 24.5 (22.5-27.1) kcal/kg respectively as shown in Table 1. They were in good health as determined by medical history, physical examination, urine and blood analysis. No medication or surgical procedure was necessary during the study and all the subjects remained essentially healthy throughout the experiment. The study was approved by the Ethical Committee of the College of Medicine and subjects were required to sign a consent form.

Physical Activity: All subjects continued with their normal daily routine which included their full academic schedule, but refrained from any unusual physical activity. To monitor accurately the energy expenditure on activity, subjects were interviewed daily concerning their physical activities and they maintained a diary record of all their daily activities starting from the time of waking to bedtime. All subjects were closely supervised. They all lived in the female halls of residence of the University. The importance of strict adherence to experimental diets was emphasised to all subjects.

Duration of Study: The subjects were studied for 28 days for energy balance response at two levels of energy intake of 33.8 and 48.4 kcal/kg/day from the habitual Nigerian diet, during two experimental periods respectively. Each experimental period was ten days, proceeded by one day on a protein free diet and followed by three days on a free choice diet after the first experimental period. All subjects were first tested on the low energy intake, which was then followed by the high energy intake. The two levels of gross energy intake provided were about 20% above and below the amount judged to be sufficient to meet the subjects' requirements. The requirement was estimated from a carefully monitored daily activity pattern of young female undergraduates in Nigeria. The average estimated energy requirement on activity was 40.2± 2.8 kcal/kg/day.

Diet: Food ingredients of the habitual Nigerian diet were selected as shown in Table 2. The subjects were given three meals per day. The meals were served at 8.00am, 1.00pm and 7.00pm. Protein intake was maintained constant throughout at a level of 0.47g protein/kg/day which was a predetermined minimum protein requirement for young female adults in Nigeria (5).

All subjects were tested on the two dietary level of gross energy intake(33.8 and 48.4 kcal/kg). Due to variations in body weights, some adjustments were made in terms of energy intake in individuals like subjects E_1 and E_2 with low body weights and subjects E_{12} and E_{13} who were in the upper limit of the body weight range. E_1 had no orange flavoured drink supplement in the low energy period and only one bottle for the high energy period. While subjects E_{13} and E_{14} had two bottles each additional orange flavoured drink during the low energy and three bottles during the high energy period.

TABLE 1

Physical Characteristics of Thirteen Young Nigerian Women.

Subject	Age (yrs)	Body Weight (kg)	BMI* (kg/m²)	Body† surface area (m²)	BMR· (kcal/kg/day)
E_1	24	40.0	16.7	1.35	27.1
E_2	28	48.0	20,5	1.43	25.0
E_3	24	51.5	18.9	1.57	24.3
E_4	25	51.0	21.0	1.48	24.4
E_5	26	47.5	19.3	1.48	25.0
E_6	28	49.0	21.8	1.42	28.8
E_7	26	53.5	22.6	1.50	24.0
E_8	21	52.0	20.6	1.52	24.2
E_9	30	52.0	18.8	1.59	24.2
E_{10}	25	55.5	23.1	1.53	23.6
E_{11}	32	57.0	21.0	1.62	23.4
E_{12}	25	62.5	24.4	1.65	22.6
E_{13}	27	64.0	22.4	1.74	22.5
mean	26.2	52.6	20.9	1.53	24.5
SD	2.83	6.1	2.08	0.10	1.73

* Body mass index (BMI)=wt (kg)/ht (m²). † Estimated from body monogram (Weir, J.B. de V, 1949 J. phios. 109, 1). Basal metabolic rate (BMR) calculated from equation: BMR=14.7W+496kcal/day where W=body weight in kg, SD=standard deviation.

Indicators and Measurements: Linear regression analysis was performed on individual energy balance data with energy intake to obtain the mean energy requirements. Energy content of the diet and feces was determined by the bomb colorimetry method of the AOAC (6) using benzoic acid as standard. Energy content of urine and sweat was estimated from standards based on their nitrogen content. Urine was estimated to have

5 kcal/g urinary nitrogen and sweat had 8 kcal/g sweat nitrogen (7). The nitrogen content of urine and sweat was then estimated using the semi micro kjeldahl method (AOAC (6)).

Complete 24 hour urine collections under acid were made in the last five days of each period, and aliquot portions were taken for the determination of total nitrogen. Feces marked with carmine were collected in the last five days of each diet period, pooled, mixed in a waring blender and dried in a vacuum oven before analysis. Sweat N-losses were collected and analyzed as previously described (8).

TABLE 2

Composition of Experimental Diets, Weight of Food at Different Levels of Energy Intake.

Ingredients	Level of Energy Intake (kcal/kg bodyweight)	
	33.8	48.4
Bread	90	90
Refined Sugar	15	30
Margarine	-	*30
Pepper (dried)	4	4
Tomato (fresh)	80	80
Onion (fresh)	40	40
Palmoil	53	53
Cassava (grated)	100	100
Beef	40	40
Vegetables	10	10
Rice (cooked)	300	300
Soft drinks (bottles)	1	2
Caloreen packs (1 pack is 400 kcal)	-	1
Nutrients: Protein (gm)	24.93	24.93
Calories (kcal)	1706.71	2505.71

* Weight of food is expressed in grams; 1 bottle of soft drink contains 120 kcal.

Daily body weights under standardized conditions were obtained (preprandial, post voiding and with light indoor clothing). Other anthropometric measurements of height and skinfold thickness at four sites (triceps, biceps, subscapular and suprailiac) were taken at the start and end of each dietary period.

Energy balance was calculated by subtracting from the gross dietary energy intake, the fecal energy, urinary and sweat energy losses, and the total energy expenditure on activity. Energy expenditure on activity was calculated by monitoring all physical activities. The energy expended on each physical activity was classified and estimated based on BMR. This was a method adopted by the 1981 FAO/WHO/UNU Committee on energy and protein requirements (9). Our subjects were classified as having light activity because 75% of their activity and waking hours were involved in sitting listening to lectures and doing tutorials, and standing doing practicals. Subsequently all activities recorded for the day were partitioned and calculations based on the recommendation of the FAO/WHO/UNU Committee for women under light activity (9). The BMR was calculated from predictive equations (FAO/WHO/UNU) report (9) involving the body weights of the subjects.

Statistical Analysis: Using individual subjects as blocks and diet periods as independent variables and data obtained at the two levels of energy intake as dependent variables, the paired t-test was used to determine the significance of differences obtained. A 5% confidence level was chosen as significant. Linear regression equation was performed similarly on individuals to test association between energy intake and energy balance.

RESULT

Anthropometric changes: Daily body weights for each diet period are graphically illustrated in Fig 1. There was a significant weight change for all subjects during both phases of the experiment ($P<0.05$). With the low gross energy intake, a significant loss of about 2.6±1.37% body weight (1.38±0.82 kg) was observed while a gain of 1.6±1.32% in body weight (0.69±0.66 kg) was recorded with the high gross energy intake. The weight changes observed with the two energy levels were statistically different. The slight reductions of 5.7±4.8%, 3.3±3.4% and 2.0±2.2% for total skinfold, % bodyfat and mid arm muscle circumference respectively with the lower energy intake group was significant and different at ($P<0.05$) from the increases observed with the high gross energy intake. The increases were 4.2±5.5%, 2.6±3.6% and 0.8±1.4% respectively for total skinfold thickness, % body fat and mid arm muscle circumference.

Energy Absorption: Table 3 gives the mean fecal energy excretion and apparent energy absorption of all subjects for all the two levels of gross energy intake. Fecal energy as determined from bomb calorimetry gave a mean value of 5.4±0.54 kcal/kg/day with the low gross energy intake and 6.0±0.92 kcal for the high gross energy intake. The two values were statistically different ($P<0.05$) indicating that fecal energy output was influenced by changes in gross energy intake.

Gross energy intakes of 33.8 and 48.4 kcal/kg bodyweight resulted in significantly different apparent energy absorption of 84.5±2.17 and 87.7±1.87% of the gross energy intake respectively.

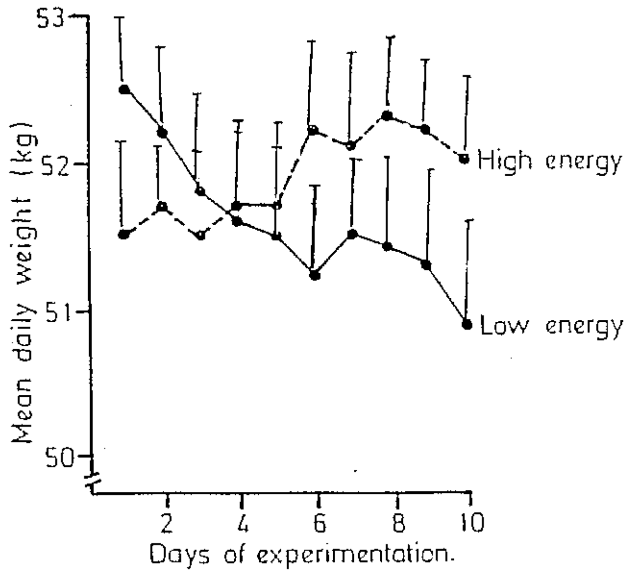

FIG. 1: Daily Body Weight of Subjects on the High and Low Energy Intakes
Results are mean values n=13 with the standard deviation(T). The T represent 10X the scale.

TABLE 3

Gross Energy Intake, Fecal Energy Excretion and Absorption of Energy as a Percentage of the Amount Ingested*.

kcal/kg bodyweight/day			% Digestibility
Energy Intake	Fecal Energy	Energy Absorbed	
33.3±2.9	5.20±0.54	28.5±3.0	84.5±2.2
48.4±3.7	6.00±0.92	42.4±3.6	87.7±1.9

* All data are mean±SD (n=13) where n is number of subjects; Energy absorbed = Energy intake-Fecal energy; % Digestibility= Energy absorbed/energy intake X 100; Value is significantly different from the low energy intake at (P<0.05).

Energy balance and Requirement: The energy balance data with the two gross energy intakes are shown in Table 4. Urinary energy (estimated from total urinary nitrogen as 5 kcal/g of nitrogen) accounted for less than 1% of total dietary energy intake. Urine energy was 0.95% of total dietary energy at the low intake. The value decreased significantly to 0.43% when the gross energy intake was increased. This implies an inverse relationship of urine energy with dietary energy intake. The 34% fall observed in urine energy from 0.32 to 0.21 kcal/kg bodyweight with the low and high gross energy intakes respectively was significant ($P<0.05$).

Energy loss through sweat estimated at 8kcal/g sweat nitrogen contributed very little to total energy loss. The value was 0.05 kcal/kg bodyweight (estimated from 6.65 mgN/kg/day for sweat loss (9)).

The mean energy expenditure on activity on the low and high gross energy intake were statistically the same at 34.6±1.5 and 34.8±1.7 kcal/kg bodyweight respectively. However there were slight individual variations.

Since the gross energy intake had no influence on energy expenditure on activity and the amount contributed from urine and sweat accounted for less than 1% of total dietary energy, thus, the total energy loss at the two levels of energy intake was greatly influenced by the fecal energy output.

Energy balance was -6.35±2.57 kcal/kg bodyweight with the low gross energy intake. With the high gross energy intake, balance increased significantly in all subjects and the group mean value was +7.31±2.24 kcal/kg/day.

TABLE 4

Energy Balance* Data of young Nigerian Women with Diet

Energy Intake	kcal/kg body weight/day					Energy Balance
	Urine Energy	Fecal Energy	Energy Expenditure on Activity	Sweat Energy	Total Energy Loss	
33.8±2.9	0.32±0.03	5.20±0.54	34.6±1.5	0.05	40.2±1.32	-6.4±2.6
48.4±3.7	0.21±0.03[†]	6.00±0.92[†]	34.8±1.7[‡]	0.05	41.1±1.95	+7.3±2.2[†]

* Energy balance was calculated from energy intake (bomb calorimetry) - fecal energy (bomb calorimetry)- urine energy (5 kcal/g urine) - Sweat energy (8 kcal/g sweat nitrogen 0.05 kcal/kg/day) - energy expenditure due to activity. All data are mean ± SD (n=13). [†]Value at the high energy intake is significantly different from value at the low energy intake ($P<0.05$); [‡]No significant difference between value obtained at the high energy intake from the low energy intake ($P>0.05$).

Table 5 gives the individual regression equations relating energy balance with gross energy intake. The energy intake when energy balance was zero varied between 38 and 42 kcal/kg/day among subjects. The mean value was estimated at 40.3±1.4 kcal/kg body weight/day. Energy balance increased by a factor of 0.94±0.1 for every one kcal/kg body weight rise in gross energy intake.

TABLE 5

Individual regression equations relating energy balance with gross energy intake

Subjects	Equation	Maintenance Energy
E_1	Y=23.19+0.60x	38.65
E_2	Y=40.04+0.95x	42.14
E_3	Y=41.28+0.99x	41.15
E_4	Y=40.97+0.99x	41.15
E_5	Y=39.67+0.95x	41.81
E_6	Y=36.95+0.92x	40.07
E_7	Y=40.27+0.98x	40.93
E_8	Y=38.50+0.96x	40.77
E_9	Y=40.38+0.98x	41.43
E_{10}	Y=38.53+0.96x	40.23
E_{11}	Y=40.47+1.05x	38.40
E_{12}	Y=36.84+0.95x	38.65
E_{13}	Y=36.66+0.96x	38.13
Mean	0.94x	40.3
	±	±
SD	0.10	1.40

Y=Energy balance (kcal/kg/day) and X=gross energy intake (kcal/kg/day).

DISCUSSION

It has been shown that energy intake has a proportionately greater effect on nitrogen utilization than does nitrogen intake when energy and protein intakes vary around the maintenance level (2). Torun, Scrimshaw and Young (10) studying the effect of physical exercise on protein requirements, suggested that not only are energy requirements influenced by the level of protein intake but also protein requirements are affected by energy intake. Clearly, the interaction of protein and energy must be taken into account in defining the dietary requirements for both protein and energy.

In this study, the gross energy intake required to maintain energy balance was used to estimate the energy requirement. Increasing or decreasing the gross energy intake greatly affected the energy absorbed. We observed a significant increase in the amount of energy absorbed as the gross energy intake increased. Likewise energy content of feces increased with increase in gross energy intake. However Torum and Viteri (7,11) who studied the energy metabolism in young children did not observe any change in energy absorption, with changes in energy intake.

Increased physical activity when dietary energy was kept constant has been associated with negative nitrogen balance and weight loss, and thus an overall effect on energy balance. In this study, though our subjects were free living, their energy expenditure on activity was monitored and restricted to minimal level. Constant activity pattern was maintained at the two levels of gross energy intake.

Unlike fecal energy, increase in gross energy intake resulted in significant decrease in energy loss in urine. Though the protein was kept constant, calories due to protein in the diet (Pcal%) differed being 5.9% and 3.9% of the low and high diet, respectively. Administration of excess energy resulted in a decrease in the rate of energy loss through urine. This implies less efficient utilization of dietary energy at the higher intake. A major problem presented from the calculation of urine energy from the urinary output is that body tissues must be contributing to the intake side of the equation. However, the energy loss through urine accounted for less than 10% of total energy loss and therefore it did not make any appreciable difference to our energy balance.

Since the gross energy intake had no influence on the energy expenditure due to activity (which is the largest contributor to energy loss), the total energy loss with the two levels of energy were essentially the same and a considerable difference in the energy balance was observed. A linear relationship was observed with increase of one kcal in gross energy intake resulting in 0.94±0.1 unit increment in energy balance. The result did not follow the pattern of Torun and Viteri (7) who studied energy balance in Children. They did not observe any relationship of energy intake with energy balance. This was because their subjects had a free will of their activity and thus it increased with increase in their energy intake and invariably balances off. Data obtained in our study revealed that the subjects studied required about 38-43 kcal/kg bodyweight of gross energy intake to achieve energy balance.

Our observation with the low energy intake showed that our subjects lost about 2.6% of their body weight which resulted in a negative energy balance of about -6.35 kcal/kg/day. While increase in the energy intake resulted in a 1.6% gain in body weight corresponding to a positive energy balance of +7.31 kcal/kg/day. Thus the changes in body weight in response to a deficit was higher than changes induced by a caloric surplus. Our subjects have reacted more drastically to energy reduction in their diet than to energy increase. The increased loss in weight as compared to the balance can thus be attributed to individual subjects' variation. Moreso, loss in weight cannot be totally attributed to loss in only fat tissue, loss of water content can also be a factor. Randomization of future studies might mask the effect of going from one energy level to the other and thus minimize individual variations especially in relation to body weight changes.

Our result showed that an average energy intake of about 40kcal/kg body weight of the habitual Nigerian diet providing about 0.47g protein/kg body weight/day might be sufficient to maintain energy balance in the group of subjects studied.

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