Seasonal changes in energy balance of rural Beninese women

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Proefschrift
ter verkrijging van de graad van
doctor in de landbouw- en milieuwetenschappen,
op gezag van de rector magnificus,
dr. H. C. van der Plas,
in het openbaar te verdedigen
op vrijdag 18 januari 1991
des namiddags te vier uur in de aula
van de Landbouwuniversiteit te Wageningen.

Aan mijn ouders en Machteld

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STELLINGEN

1. The statement: "major fluctuations of human energy balance are not to be expected in areas with bimodal climatic conditions" does not apply to all rural African populations living in such areas. (Zie: Ferro-Luzzi A, Pastore G, Sette S. Seasonality in energy metabolism. In: Schurch B, Scrimshaw NS, eds. Chronic energy deficiency: consequences and related issues. Lausanne: International Dietary Energy Consultative Group, 1987:37-58).

2. Loss of body weight during the pre-harvest period may impair the health and physical capacity of many rural Africans (dit proefschrift).

3. The distribution of rain throughout the year is more important than annual rainfall in determining seasonal weight loss (dit proefschrift).

4. The decision of the Fifth World Food Survey (FAO, 1987) to classify people with an energy intake less than 1.2 times basal metabolic rate as undernourished, provides a too optimistic view of the number of undernourished people in the world.

5. Diarrhoeal disease control programmes do not improve the overall nutritional status of children in poor communities in developing countries. (Briend A. Is diarrhoea a major cause of malnutrition among under-fives in developing countries? A review of available evidence. Eur J Clin Nutr 1990;44:611-28).

6. De kwaliteit van onderwijs en onderzoek op universiteiten in ontwikkelingslanden met een relatief geringe bevolking zou verbeterd kunnen worden als meerdere universiteiten van een aantal landen zouden samengaan.

7. AIDS is voor de Afrikaanse plattelandsbewoner slechts een probleem temidden van vele, voor hem veel urgentere, problemen.

8. -Aangezien een proefschrift steeds vaker bestaat uit een bundeling van een aantal artikelen die aangeboden worden aan engelstalige vaktijdschriften, is het wenselijk een cursus engels op te nemen in het onderwijsprogramma voor AIO's.
-Since theses often comprise a collection of articles written in English for submission to journals, a course in English should be included in all teaching programmes for "assistenten in opleiding".

9. Het feit dat tegenwoordig het grootste deel van de studenten bij de studierichting voeding van de mens aan de Landbouwuniversiteit uit vrouwen bestaat, zou onder andere veroorzaakt kunnen worden door traditionele denkbeelden over de rolverdeling van man en vrouw in de samenleving.

10. Mensen die eenmaal in de tropen gewerkt hebben worden gestimuleerd om dit nog eens te doen door onder andere de mogelijkheid om zich daar op een goede en gemakkelijke manier aan de dagelijkse huishoudelijke activiteiten te kunnen onttrekken.

Proefschrift J.W. Schultink
Seasonal changes in energy balance of rural Beninese women.
Wageningen, 18 januari 1991.

CONTENTS

PREFACE

Between 1985 and 1987 a multi-center study was carried out with the objective to investigate seasonal influences on human energy balance. This study was financed by the European Community (STD1-programme) and was a joint venture between the National Institute of Nutrition in Rome, the University of Glasgow and Wageningen Agricultural University and nutrition institutions in respectively Ethiopia, India and Benin. Research questions were studied using the same protocol. The results of the multi-center study, in which I participated, were encouraging, but some points remained unclear. Therefore, it was decided at the Department of Human Nutrition of Wageningen Agricultural University to continue doing research in this field of study. This continuation was made possible through financial support from the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), and the support received from the STD2-programme.

Professor J.G.A.J. Hautvast gave me the opportunity to carry out this research. I gratefully acknowledge the confidence he had in me, and I thank him for the stimulating conversations we had together. An important person was Dr.Ir. J.M.A. van Raaij who supervised my work in an excellent way and whose visits to Benin were not only stimulating and helpful but also sociable.

The choice to carry out the studies in the Republic of Benin was influenced to a large extent by the existence of a Beninese-Netherlands university cooperation programme, which is financed by the Netherlands Organisation for International Cooperation in Higher Education (Nuffic). In the framework of this programme the Department of Human Nutrition of Wageningen Agricultural University cooperates with the Department of Human Nutrition and Food Science (NSA) of the Faculty of Agricultural Sciences (FSA) of Benin National University.

Due to this cooperation programme it was possible for me to conduct studies in Benin, and I am very grateful to the Dean of the FSA Dr. Mama Adamou N'Diaye who allowed me to be a

visiting scientist and guest lecturer at his Faculty. I am indebted to the staff of the NSA: Dr. M.C. Nago and Dr. H.F. Nouwakpo who introduced me to the study area, and who showed a continuous interest during the whole study period. I want to thank the former and present Dutch co-ordinators Dr. J.A. Zwartz and Dr. A.P. den Hartog for letting me work in the framework of the cooperation programme.

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A large number of people helped me in carrying out the measurements and I enjoyed working with them:

- The Dutch students who participated in the research activities in Benin: Ank Simons, Sylvia Mecking, Nicole Jacobs, Dorine Huisman, Romke Vrijburg, Andi Tan, Anja Huisman and Christianne Hupkens.
- The Beninese field assistants: Madeleine Nouagbe, Marie Bleossi, Cyprienne Dekpey, Akouele Houinsou and Pauline Gnagnon.
- Students and personnel of the NSA: Celestin Ayite, Charlemagne Zinsou, Lynne Mahouekpo and Emanuel Tangni.

Jan Burema is thanked for the advice he gave me on statistical matters, and the staff of the Central Service Department of the Biotechnion for preparing the figures.

Finally I want to thank:

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- Staff and research assistants of our Department of Human Nutrition for their interest they showed in my work.

A special word for my collegues Eric Ategbo and Marti van Liere in Benin: we had many good discussions and I wish them a lot of success with their work.

Wageningen, September 1990 Werner Schultink

ABSTRACT

This thesis reports on human energy balance in relation to seasonal changes in food availability of rural populations in developing countries.

Body weight measurements were carried out every two weeks among Beninese subsistence farmers who live in two different climatological zones (one and two rainy seasons). Significant seasonal weight changes occurred in both areas, but pre-harvest weight loss in the area with one rainy season (about 3 kg) was larger than in the area with two rainy seasons (about 1.9 kg). Correlation existed between body mass index and pre-harvest weight loss, suggesting that people with larger body size loose more weight.

Basal metabolic rate (BMR), physical activity pattern, physical activity level (PAL) and energy intake (EI) were measured during three succesive seasons in women with a BMI<18 (n=18) and BMI>23 (n=16) and in women who had shown small (n=18) and large (n=15) pre-harvest weight loss in a previous year. Aim was to investigate whether changes in metabolic efficiency or changes in activity pattern may occur in individuals in order to prevent large seasonal weight loss. EI decreased by 160-260 kcal/day during the pre-harvest season in all groups. Physical activity pattern showed seasonal changes but the resulting PAL did not change throughout the year in any of the four groups. BMR of women with BMI<18 was significantly reduced by 3% during the pre-harvest season and BMR of very thin women with BMI<17 (n=5) was reduced by 12%. It was concluded that individuals use different adaptive mechanisms in order to decrease energy expenditure. Most important mechanism is by lowering body weight. Only lean people who can hardly afford to loose weight may increase metabolic efficiency.

CHAPTER 1.

INTRODUCTION.

In developing countries food availability in rural areas may be limited during certain periods of the year. These periods are related to the rainy seasons, and food availability displays therefore seasonal fluctuations. These seasonal fluctuations occur especially among people who depend economically almost completely on their own agricultural production (1-4). Seasonal changes in food availability may affect both nutritional status and human health, and therefore they may have implications for social and economic planning policies.

In this thesis the results are presented of studies carried out in the Republic of Benin in West-Africa (Figure 1). The main aim of these studies was to investigate the effects of seasonal changes in food availability on human energy balance.

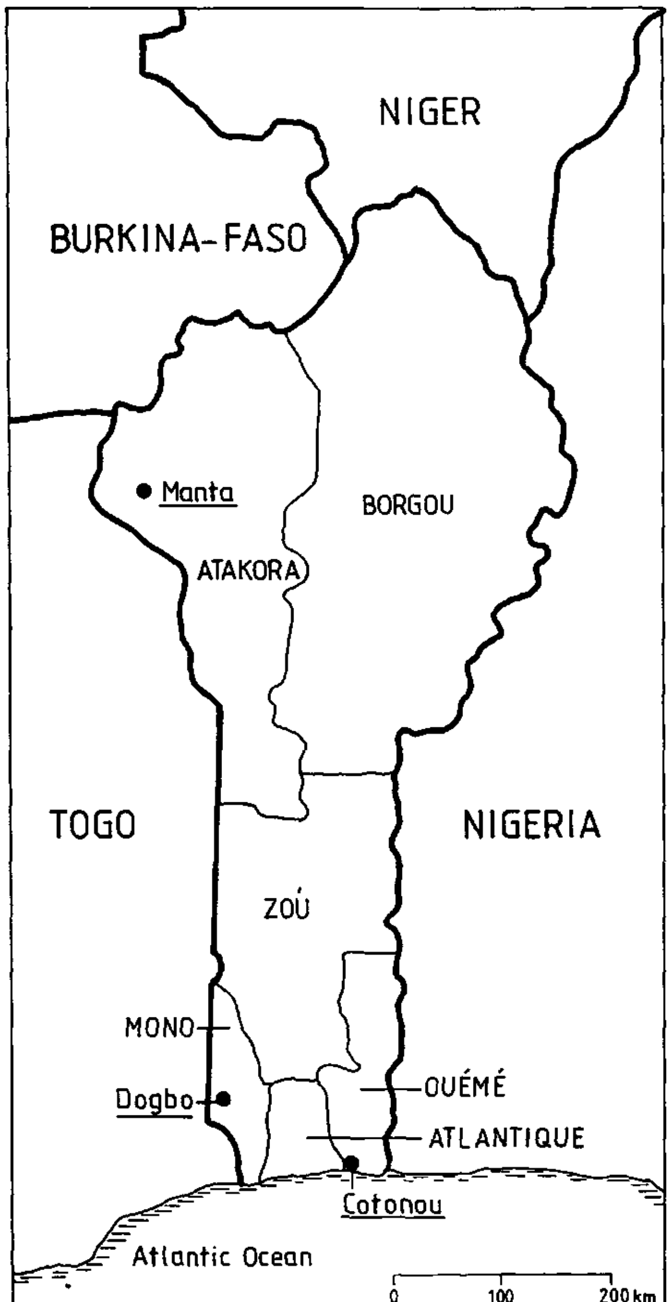
A short review of the determinants of energy balance and energy requirement is given in paragraph 1.1. In paragraph 1.2. causes of seasonal cycling of food availability and consequences of this cycling for human energy metabolism are described. In paragraph 1.3. the results of a pilot study carried out in the south-western region of the Republic of Benin, are shown. A more detailed description of the aims of the studies presented in this thesis are given in paragraph 1.4.

1.1. Energy balance and energy requirement

Energy balance

Energy balance is usually defined as the difference between food energy intake (metabolisable energy) and energy expenditure (metabolised energy). The daily energy expenditure consists of three components: basal metabolic rate (BMR),

Figure 1. Map of the Republic of Benin with an indication of the study areas Dogbo and Manta.



dietary induced thermogenesis (DIT) and work induced thermogenesis (WIT). The basal metabolic rate can be defined as the rate of energy expenditure at complete rest, without any physical activity and measured under strictly standardised conditions (lying down, shortly after being awake, in thermoneutral state, 12-14 hours after the last meal, emotionally undisturbed, without disease or fever). BMR covers about 50-60% of the total daily energy expenditure in the average adult individual. Dietary induced thermogenesis (DIT) is the increase in energy expenditure above BMR in response to feeding. The level of DIT depends upon the amount and type of food ingested, and amounts to about 10% of daily energy intake. So in the average individual DIT accounts for about 10% of total daily energy expenditure. The increase in energy expenditure above BMR (and DIT) after starting physical exercise is called work induced thermogenesis (WIT), and is the energy expended for physical activity. WIT is the component of total energy expenditure which can vary highly, but in most individuals it will amount to 30-40% of total energy expenditure.

Adaptation

An individual with a stable body weight and an established daily activity pattern who changes his habitual daily energy intake will get out of energy balance. The change in energy intake will provoke a change in dietary induced thermogenesis which will partly compensate the disturbance in energy balance (this compensation can cover at the most 10% of the disturbance, since DIT amounts to 10% of energy intake). To regain energy balance other adaptive mechanisms have to be used. In principle three types of adaptation in energy expenditure exist (5): biological adaptation, behavioural or social adaptation, and metabolic adaptation.

Biological adaptation means an alteration in body size and or body composition. A change in body size is the most powerful adaptive mechanism. When energy intake is lower than energy expenditure, energy will be drawn from the body's stores, resulting in a loss of body weight. After weight loss BMR and WIT will be lower because there is less tissue to maintain and to move, and total energy expenditure will be decreased. The process of loosing body weight may continue until the reduced energy expenditure will balance the new level of energy intake.

A behavioural or social adaptation means a modification in activity pattern (including changes in the pace of activities). By reducing physical activity total energy expenditure will be lower.

Metabolic adaptation includes mechanisms which increase the efficiency of energy metabolism. Best documented evidence of metabolic adaptation are reductions of BMR per unit body weight associated with a large weight reduction in response to a prolonged substantial fall in energy intake (6). It is unclear whether such adaptations in BMR can occur with moderate body weight reductions.

Several remarks can be made with regard to adaptations. The FAO/WHO/UNU Expert Consultation (7) defines adaptation as "a process by which a new or different steady state is reached in response to a change or difference in the intake of food and nutrients". This implies that a person can achieve energy balance at different levels of energy intake (different adapted states). However, it is important to realise that not every adapted state is advantageous. If an individual reaches a new level of energy balance by lowering his body weight (biological adaptation), this can only be considered as being 'successfully' if the loss of body weight does not cause an increased morbidity risk or an impaired functional capacity (5). A behavioural adaptation in order to re-establish energy balance is only acceptable if economically necessary and socially desirable activities can still be maintained. One could say that biological adaptation and behavioural adaptation have a 'price'. Only metabolic adaptation would be 'free of charge'. If metabolic adaptation would occur under 'normal circumstances' the social and economic consequences would be enormous.[1]

Energy requirement, survival requirement, maintenance requirement

As already stated, an individual can be in energy balance on different levels of energy intake, each level having its own advantages and disadvantages. Value judgements are needed to decide which level of energy balance is desirable. Therefore it is difficult to give one single value of an individual's energy requirement. It is especially difficult to make a judgement on desirable levels of physical activities and on this subject more information is needed. This gives the FAO/WHO/UNU Expert Consultation (7) definition of energy expenditure little practical relevance. This definition is as follows: "Energy requirement is the level of energy intake that will balance energy expenditure when the individual has a body size and composition, and a level of physical activity consistent with long term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity".

An absolute minimal energy requirement is more clearly defined. It is called a survival requirement and amounts to 1.27 times the BMR (7). It is emphasised that this requirement allows for minimal movement only and is not compatible with long term good health and makes no allowance for the energy needed to earn a living or prepare food. The survival requirement is calculated on basis of the energy need during 8 hours of sleep (1.0 times the BMR), and the energy needs

[1]According to Sukhatme and Margen (8) individuals can change their metabolic efficiency within certain limits. This change in efficiency would enable people to have the same level of physical activity on a lower level of energy intake without effect on body weight. However, the Sukhatme-Margen hypothesis is hotly debated and far from being accepted by experts (9,10). The idea of costless adaptation to low energy intakes was used in the Fifth World Food Survey (11) to estimate a new (lower) level of energy intake on which people were able to function, leading to a substantial reduction in the number of people assumed to be malnourished.

during the rest of the day while sitting, washing, dressing and short periods of standing (1.4 times the BMR).

The Fifth FAO World Food Survey of 1985 (11) used an energy intake of 1.4 times the BMR as one of the cut-off points where below an individual was classified as undernourished: the maintenance requirement. This requirement includes about three hours of activity while standing (also washing and dressing) but does not allow for occupational or socially desirable activity (12).

1.2. Seasonal changes in food availability in developing countries

A major part of the population of developing countries live in rural areas (for the Republic of Benin this is 70-80% (13)). Most rural households depend for their daily food largely on their own agricultural production, this is especially so for small scale farmers. Normally after the harvest the staple food crop is stocked. This stock has to provide food until the next harvest. However, it occurs often that food supplies diminish during the period just before the harvest, resulting in a lowered food intake during this pre-harvest season. Results of some recent studies on dietary food intake of African and Asian rural populations during different seasons are presented in Table 1. The results show that the level of daily energy intake changes throughout the different seasons. Especially during the pre-harvest season energy intake may be low. All results from the African studies indicate that the intake during the pre-harvest season was lower than the maintenance requirement.

The main causes for a seasonal cycling of food availability are climatic-environmental conditions. These conditions determine the growth of food and cash crops on which the rural households depend. The major factor limiting vegetal growth in equatorial and tropical areas is water. Therefore the yearly amount of rainfall as well as the

Table 1. Daily energy intakes in different seasons of rural populations from various countries

Subjects, country (reference)	Season	Energy intake (kcal/day)	Maintenance requirement[a] (kcal/day)
rural women Burkina-Faso(14)	post-harvest	1515	1717
rural women	post-harvest	2237	1548
Bangladesh(15)	pre-harvest	1863	1548
rural individuals	post-harvest	2022	
Bangladesh(16)	pre-harvest	1786	
rural individual	post-harvest	2106	
Senegal(17)	pre-harvest	1974	
male farmers	harvest	3690	2097
Burma(18)	summer	2900	2097
rural women	post-harvest	1654	1728
Gambia(19)	pre-harvest	1415	1728
rural women	post-harvest	2210	1831
Etiopia(20)	pre-harvest	1790	1831
rural women	post-harvest	2030	1230
India(21)	pre-harvest	1890	1230

a) Maintenance requirement was estimated as 1.4 times BMR; BMR was calculated (if possible) from weight and height using FAO/WHO/UNU (7) equations.

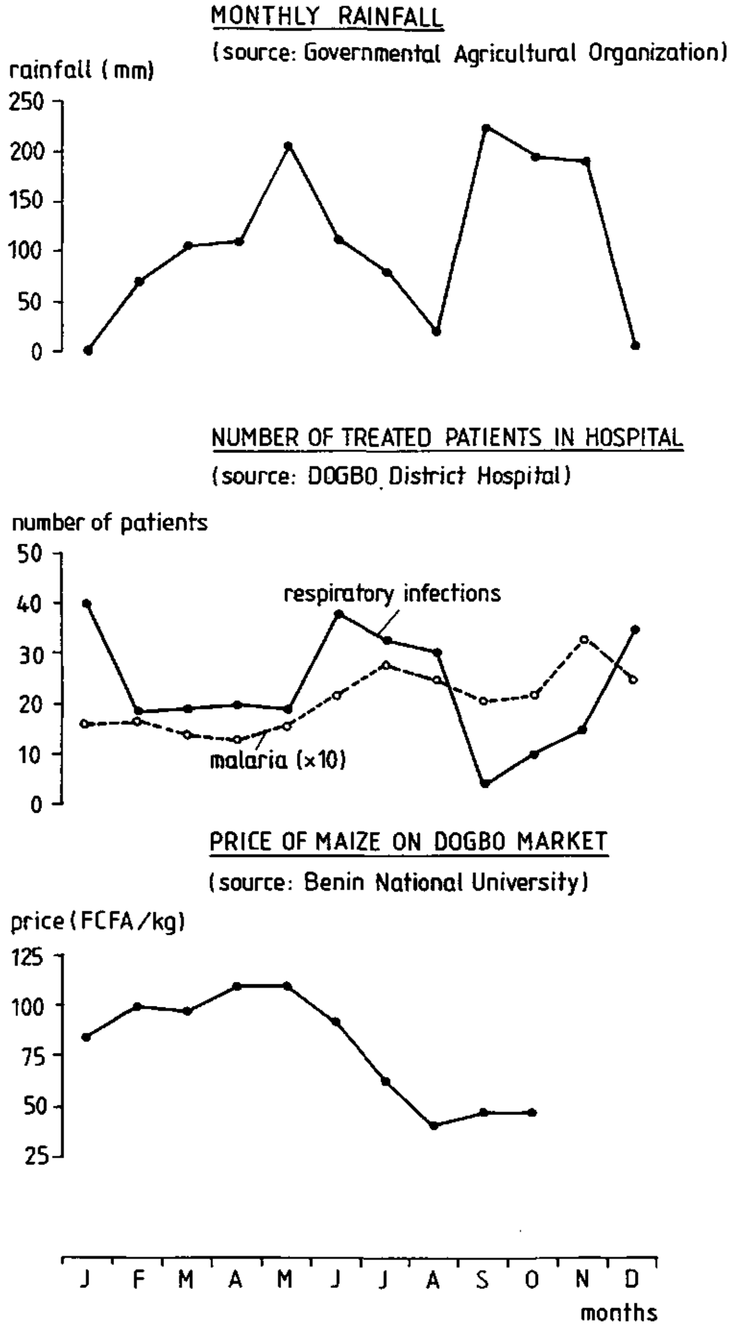
seasonal distribution of rains are directly linked with food availability.

The phenomenon of seasonality is not restricted to food availability alone. It concerns more facets of daily life which may be inter-connected such as: illness, birthweight, child growth and socio-economic factors. Figure 2 illustrates the seasonal changes in rainfall and in maize price in the study area in southern-Benin, and the seasonal changes in the number of cases of malaria and respiratory infections treated in the district hospital of the study area.

This thesis concerns seasonality in human energy metabolism which can be defined as: "a regularly recurring set of conditions leading to approximately annual alternations of restricted and unrestricted access to food energy, often coinciding with periods of variable demand for physical labour" (4). With this definition situations resulting from chronic food deprivation or acute famine have been left out.

As shown in Table 1 daily food intake may decrease during the pre-harvest season. It is thought that energy expenditure increases during the pre-harvest season due to a higher agricultural work load (preparation of the harvest). However, only a few studies have been published on seasonal changes in energy expenditure (14,18,20,22-24), and the general assumption that energy expenditure rises during the pre-harvest season is not confirmed in a study among Ethiopian women (20). A decreased food intake, possibly combined with an increased physical activity, may bring people into a state of negative energy balance. In order to regain energy balance body weight is lost. Literature values of seasonal weight loss in adults vary from about 1 kg (rural women in Zaire)(25) to 3 kg (nomads in Niger)(26). Data on possible seasonal changes in BMR (as a metabolic adaptation) are scarce and contradictory. Recently it has been reported, that rural women in Ethiopia (20) showed a decrease in BMR per unit body weight of about 13% during the pre-harvest season, while rural women in Benin (27) and India (21) did not show statistically significant changes. To our knowledge it has not been reported in the

Figure 2. Seasonal changes in rainfall, in number of cases of respiratory infections and malaria and, in maize price in Dogbo, 1988.



literature that during seasons with low food intake energy balance was re-established through a curtailment of physical activity.

To obtain more knowledge on the effects of seasonal changes in food availability on human energy balance it is desirable to measure body weight, food intake and energy expenditure repeatedly throughout a one year cycle. In a pilot-study in southern-Benin among rural women we measured body weight, BMR, food intake and activity pattern. In this study we confirmed that measurements could be carried out with enough precision and accuracy in field conditions. It was investigated to what extent seasonality existed in southern-Benin. Since the present studies have been based upon the findings from the pilot-study, the main results will be discussed in the next paragraph.

1.3. Seasonal influences on the energy balance of rural Beninese women: a pilot-study

The study discussed in this paragraph (27) preceded the studies described in the following chapters.

The study area was the south-western part (Mono-province) of the Republic of Benin, West-Africa. Mean annual rainfall in this part of Benin is 850 mm (distributed over two rainy seasons), which is low compared to the rainfall in surrounding areas. The population consists mainly of subsistence farmers. Main crops are maize, cassava, oil palms and beans. Cultivation is done by men as well as women using hoes; the women usually cultivate their own fields. The main staple food maize is harvested twice a year, in December and July.

To measure seasonal changes in energy balance body weight of 130 rural women (characteristics are given in Table 2) was determined every two weeks throughout a one year cycle (December 1985-November 1986)(Weight study). The results of the body weight measurements are presented in Figure 3. Body

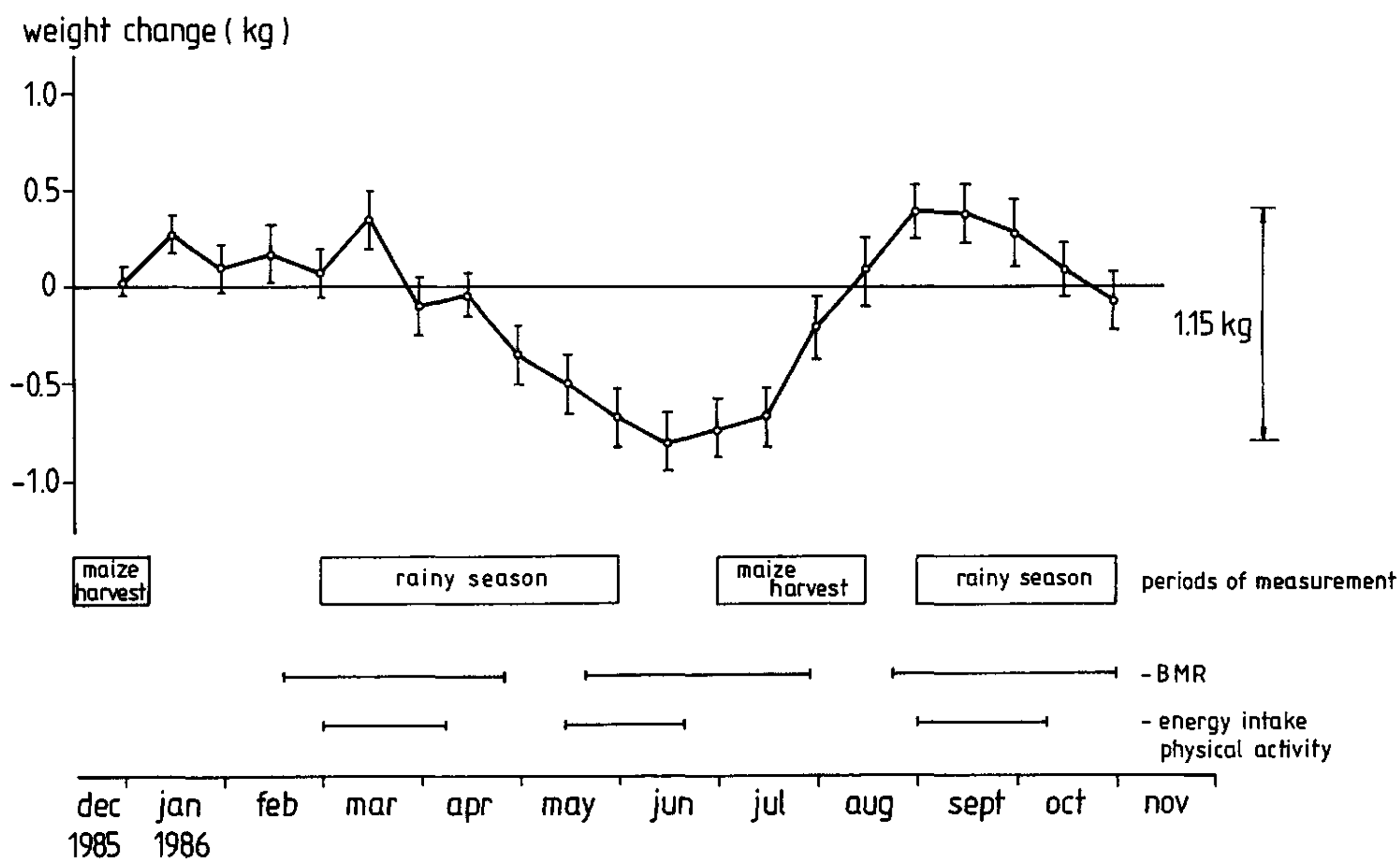


Figure 3. Seasonal body weight changes of rural Beninese women (n=130; expressed as means ± s.e.m) (From reference 27).

Table 2. Physical characteristics of the women [a]

	Weight study	BMR study	Energy intake & Activity study
Number	130	17	18
Age (y)	33.2±5.5	32.8±5.1	34.2±6.8
Weight (kg)[b]	50.4±6.4	51.7±7.4	52.6±6.6
Height (cm)	157.0±5.7	156.4±6.5	159.3±6.6
BMI (kg/m^2)[bc]	20.4±2.3	21.1±2.0	20.8±2.9

a) Means ± SD.

b) At the start of the study in December 1985.

c) BMI: body mass index ($weight/height^2$).

weight remained at about the same level from January to March (post-harvest), after which weight decreased from April to May, to reach the lowest level in June (pre-harvest). Body weight increased again during the post-harvest season in August and September, and the difference between the lowest weight level in June and the heighest weight level in August was 1.2±1.3 kg. Seasonal body weight changes were not uniform for all women. While thin women with a body mass index (BMI) less than 18 hardly showed seasonal weight changes, fatter women with a BMI>23 showed a marked weight loss during the pre-harvest period (Figure 4).

BMR was measured in 17 women (selected from the women who participated in the weight study; characteristics in Table 2) in three different seasons (see Figure 3 for periods of measurement). Measurements were made in a small field laboratory by open circuit indirect calorimetry using the Douglas bag technique. Body weight changes of these women (BMR study) were comparable to the weight changes of the 130 women (weight study). BMR did not change in the three different seasons and remained at a level of about 1330 kcal/day (Table 3) (a 5% decrease in BMR would have been detected with a

Figure 4. Seasonal body weight changes of women with a BMI<18 (n=21) and of women with a BMI>23 (n=17)(From reference 27).

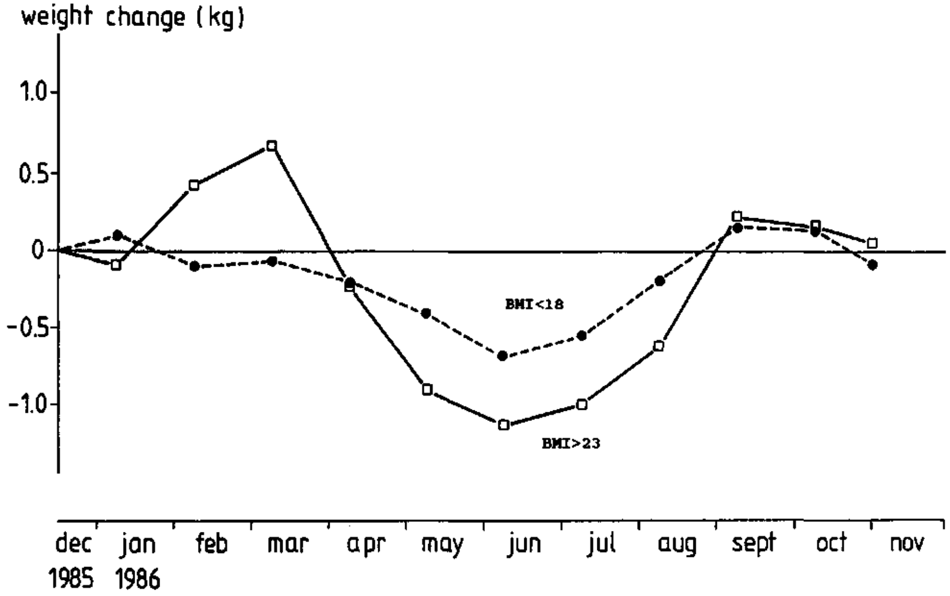


Table 3. BMR and energy intake in two different groups of women in three different seasons [a]

WOMEN	VARIABLE	SEASON		
		Mar-Apr	Jun-Jul	Sep-Oct
BMR study	<u>BMR</u>			
(n=17)	kcal/day	1328±168	1337±175	1335±152
	cal/kg/min	18.1±3.2	18.4±3.2	18.0±2.8
Energy	<u>Energy intake</u>			
intake study	kcal/day	1882±384	1558±219[b]	1661±342
(n=18)	kcal/kg/day	36.2±7.6	30.5±5.8[b]	31.9±7.1

a) Means ± SD.

b) Energy intake in June-July significantly different from intake in March-April (p<0.01).

Table 4. Daily activity pattern of 18 women in three different seasons (expressed as percentage of 24 hours) [a]

ACTIVITY	SEASON		
	Mar-Apr	Jun-Jul	Sep-Oct
Sleeping, resting, sitting	61.0±5.7	67.0±7.4[b]	61.9±8.2
Light domestic work[c]	21.0±7.1	17.9±6.6	19.9±6.2
Moderately heavy work[d]	3.6±2.6	5.9±4.2	4.4±4.8
Eating	3.0±1.2	2.7±0.7	2.4±0.6
Walking	4.7±4.1	4.2±4.8	4.2±3.6
Agricultural work	6.7±7.0	2.3±4.0	7.3±4.9

a) Means ± SD.
b) Different from values in the other seasons, p<0.01
c) Such as: cooking, tending children, washing dishes.
d) Such as: washing clothes, fetching water, gathering fire wood.

probability of 90%; p=0.05). BMR per kg body weight averaged 18.2 cal/day.

Daily energy intake and activity pattern were measured during the same periods in 18 women (also selected from women from weight study; characteristics in Table 2). Whole day food intakes were measured using the precise weighed food intake method during four consecutive days in each season. The daily activity pattern was studied by recording the time spent on six categories of activities (minute to minute registration). Measurement of food intake as well as activity recordings were done by trained local assistants well known by the community. Energy intake (Table 3) as well as activity pattern (Table 4) showed large seasonal variations. During the pre-harvest season (May-June) daily energy intake was about 300 kcal lower than in March-April. Daily energy expenditure was calculated from the daily activity pattern using published energy costs (7) for each activity category. Level of energy expenditure in

May-June was 0.09 times the BMR, or 120 kcal, lower than in March-April.

It was concluded that the Beninese women arrived at a new level of energy expenditure during the pre-harvest season mainly by loosing body weight. A metabolic adaptation in the form of a decreased BMR per unit body weight was not found. Although total energy expenditure in May-June was slightly lower than in March-April, it was not possible to conclude that the reduced energy intake was the reason for the change in activity pattern. Within the population large differences in seasonal weight loss existed between individuals. 'Fat' women showed marked seasonal weight changes, while thin women did not do so. The 'fatter' women apparently lost body weight to regain energy balance. In thin women other adaptation mechanisms might play a role. The available data on energy balance however were insufficient to test whether different individuals use different adaptation mechanisms.

1.4. Aims of the present studies.

On basis of the findings from the above described pilot study on energy balance in relation to seasonality in food availability a number of questions were formulated for further studies:

- What is the difference in seasonal weight loss of populations who live in areas with one and two rainy seasons?
- Is the level of seasonal weight loss influenced by body size?

Individuals seem to use different mechanisms of adaptation to decrease energy expenditure during periods when food availability is limited:

- Do some individuals decrease energy expenditure by increasing metabolic efficiency?
- Do some individuals decrease energy expenditure by changing their physical activity pattern?

With the intention to answer these questions a number of studies were carried out from November 1987 to November 1989. The backgrounds and findings of these studies are presented in this thesis. Chapters 2 to 5 are written as articles which will be submitted to international journals and they describe the following subjects. In chapter 2 the results are described of longitudinal weight studies carried out in two different climatological zones in the Republic of Benin. In chapter 3 the results of BMR measurements in different groups of rural Beninese women during different seasons of the year are reported. In chapter 4 measurements on seasonal changes in activity pattern and physical activity level in relation to energy intake are presented. In chapter 5 seasonal changes in body composition assessed by skinfold measurements, bioelectrical impedance measurements and D_2O dilution technique are presented. The combined results of the studies will be discussed in chapter 6.

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CHAPTER 2.

PRE-HARVEST WEIGHT LOSS AND BODY MASS INDEX OF RURAL BENINESE POPULATIONS

JW Schultink MSc, JMA van Raaij PhD, JGAJ Hautvast MD

ABSTRACT

Body weight measurements were carried out every two weeks during several consecutive seasons among Beninese subsistence farmers who live in two different climatological zones. Pre-harvest weight loss in the two zones was compared, and the relation between body mass index (BMI) and pre-harvest weight loss examined. Pre-harvest weight loss in Dogbo (two rainy seasons) was 2.2$\pm$1.3 kg ($p<0.001$) for men ($n=110$) and 1.8$\pm$1.7 kg ($p<0.001$) for women ($n=82$). Pre-harvest weight loss in Manta (one rainy season) was 3.2$\pm$1.9 kg ($p<0.001$) for men ($n=37$) and 2.5$\pm$2.1 kg ($p<0.001$) for women ($n=34$). Pre-harvest weight loss in Manta was larger than it was in Dogbo ($p<0.05$). BMI during the pre-harvest season decreased significantly for all subjects ($p<0.01$). Correlationship existed between pre-harvest weight loss and BMI for Manta men ($r=0.41$; $p<0.01$) and women ($r=0.38$; $p<0.01$) and Dogbo women ($r=0.28$; $p<0.01$), suggesting that fat people loose more weight than thin people. During the pre-harvest season 5-10% of the people have a BMI lower than 17, which may constitute a risk to health.

Key words: pre-harvest weight loss, body mass index, subsistence farmers, distribution of rainfall.

INTRODUCTION

Food availability for and physical activity pattern of rural populations from developing countries are both subject to seasonal fluctuations (1-4). These seasonal fluctuations are directly linked with the amount and the distribution of yearly rainfall, since water is the major limiting factor determining vegetal growth in tropical countries. At the end of the rainy season just before the main staple food harvest the food supplies of small scale farmers often diminish, which results in a decreased food intake. During the pre-harvest seasons an inadequacy of food availability may coincide with an increased quantity of field work (2,4). The combination of a decreased food intake and a higher labour demand may bring people into a state of negative energy balance causing a loss of body weight. A good indication of seasonal changes in energy balance can therefore be obtained by serial measurements of body weight during several consecutive seasons.

The magnitude of most observed average weight loss of adults during the pre-harvest period is from 1 to 3 kg, corresponding to 2-5% of the body weight (5). One could wonder whether such modest weight losses will have any negative consequences for health or physical capacity. However, within populations, the between-individual variation in pre-harvest weight losses can be large and some individuals may loose substantial amounts of body weight (2). Indication exists that between-individual variation in pre-harvest weight loss is related to body size (as can be indicated by body mass index)(6-8), but the reason for this relation is still unclear. If between-individual variation in pre-harvest weight loss would be related to body size, then it would be possible to identify at-risk individuals with the help of simple anthropometric criteria.

In the present study we carried out longitudinal measurements of body weight among rural populations in two different climatological zones in the Republic of Benin to investigate the differences in pre-harvest weight loss occurring in the two areas. Furthermore the relation between body mass index and pre-harvest weight loss was studied.

SUBJECTS AND METHODS

Study area

The study was carried out in the districts of Dogbo and of Manta, which are situated in different provinces of the Republic of Benin. Dogbo lies in the Mono province in the south west of Benin at about 70 km from the coast. Manta lies in the Atacora province in the north west of Benin at a distance of about 500 km from the coast.

Rainfall in Dogbo is mainly distributed over two rainy seasons (Table 1). The population of the villages under study (about 1100 inhabitants in each village) consists largely of small scale farmers who cultivate maize, cassava, beans and oil palms as main crops. Cultivation is done by men as well as women using hoes. The women cultivate their own fields, and also work on the fields of their husbands when necessary. Bimodal distribution of yearly rainfall permits two harvests a year of the main crops (Table 1). Sowing of maize is done in March and September, weeding in April and October. Cassava is planted in September and harvested from November to February.

Table 1. Some characteristics of the study area

	Dogbo district	Manta district
Villages under study	5	2
Yearly rainfall	1000-1100 mm	1100-1200 mm
Rainy seasons:		
Number	2	1
Period	March-May, September-October	June-September
Main harvests:		
Number	2	1
Period	July, December	October-December
Main food crops	maize	sorghum, millet, fonio

Manta has only one rainy season, but annual rainfall is about the same as in Dogbo (Table 1). The population of Manta also consists mainly of subsistence farmers, and men as well as women cultivate the fields using a hoe. The main crops sorghum, millet and fonio are harvested once a year in October and November. Sowing is done in April and May, and weeding from June to August.

Study design and subjects

In Dogbo the measurements of body weight were carried out from January 1988 to November 1989 (with a break from October to December 1988, when no measurements were made) covering the pre-harvest periods (May-June) of two subsequent years. In Manta the measurements of body weight were carried out from February 1988 to March 1989, covering one pre-harvest period (August-September). During the whole study period the weighing was carried out every two weeks.

In Dogbo 150 men and 150 women were selected (30 of each sexe out of each of the 5 villages) and in Manta 50 men and 50 women, using the following criteria. The subjects had to be between 20 and 45 y. The women had to be non-pregnant, and had to have two to five children (the youngest child at least nine months old). All subjects had to have farming as their main occupation. When women became pregnant during the observation period, data collection was continued but the results of these women were not used in the present analysis. When a subject was not present at four non-successive weighing sessions (or more), or at two successive weighing sessions during one year, his/her data were excluded from the analysis. A data set covering the whole period of measurement was obtained for 110 men and 82 women from Dogbo, and for 37 men and 34 women from Manta. Some characteristics of the subjects are presented in Table 2.

Measurements

Every two weeks body weight was measured between 7.00 and 8.00 a.m. at a central place in each village using SECA

Table 2. Characteristics of subjects[a]

	Dogbo district		Manta district	
	Men	Women	Men	Women
Number	110	82	37	34
Age(y)	34.6±7.1	32.8±5.8	34.8±8.0	31.0±8.0
Weight(kg)[b]	59.1±8.3	52.0±9.3	61.9±6.8	51.3±7.3
Height(cm)	170.6±7.1	158.0±6.0	169.0±7.0	158.0±5.0
BMI(kg/m^2)[c]	20.1±2.3	20.8±3.4	21.4±1.9	20.6±2.7

a) Means ± SD.
b) Weight at the start of the study (January 1988 for the Dogbo study, and February 1988 for the Manta study).
c) BMI: body mass index ($weight/height^2$) at the start of the study.

platform spring balances. The balances were attached to wooden boards and were placed on a horizontal surface. Before each weighing session the balances were checked, and calibrated if necessary, using calibration weights of 40.0 and 60.0 kg. The subjects were wearing a minimum of clothing and body weight was measured to the nearest 100 g (no correction was made for the clothing which weighed at most about 300 g). Height was measured with the subjects standing on a horizontal surface against a vertically placed wooden board with the heels together, chin chucked in and stretched upwards to full extent and the head in a Frankfurt plane. The heels, buttocks and shoulders were in contact with the wooden board to which a flexibel metal tape had been fixed.

Statistics

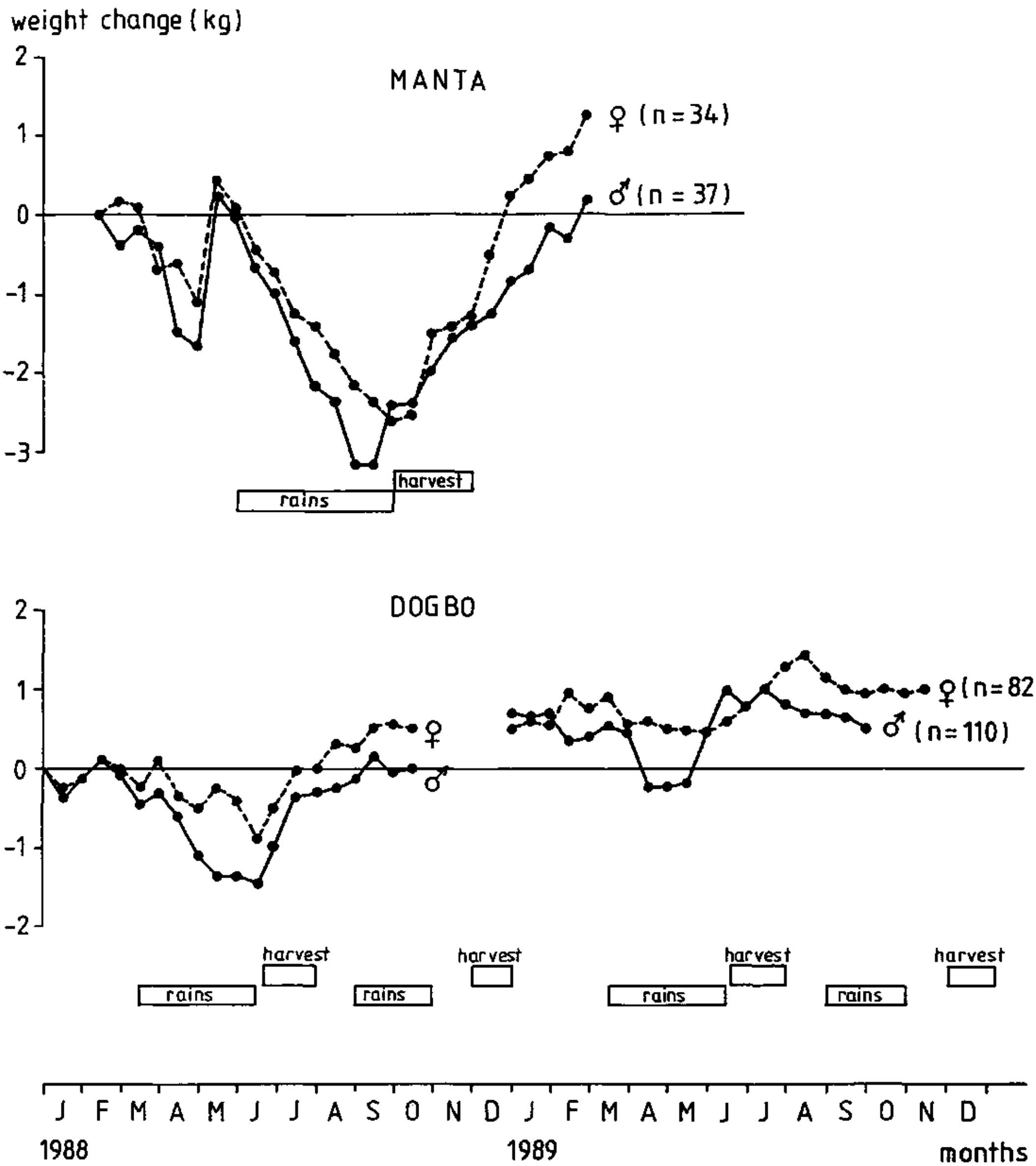
Differences in body weight between post-harvest and pre-harvest seasons were tested using Wilcoxon's matched-pairs signed-ranks test (6), the same test was used to compare pre-harvest weight losses of 1988 and 1989 in Dogbo subjects (within subjects). Differences between mean pre-harvest weight losses between subjects of Manta and Dogbo subjects were tested using a Mann-Whitney test (6). Differences in body mass index between different seasons were tested using a paired t-test (6). The body mass index of different groups was compared using an unpaired t-test (6).

RESULTS

The results of the longitudinal body weight measurements of Dogbo and Manta subjects are shown in Figure 1. For Dogbo men and women body weight remained relatively stable from January to March 1988 (post-harvest season), after which body weight decreased gradually until the middle of June (pre-harvest season) (1.5$\pm$1.7 kg for men, $p<0.001$; and 0.9$\pm$2.1 kg for women, $p<0.001$). Body weight increased rapidly from the middle of June to the middle of July to arrive at about the same level as it had during the post-harvest season in January-March. From the middle of July until the end of September (post-harvest season) body weight increased further, and at the end of September body weight of men and women was respectively 1.6$\pm$1.7 kg ($p<0.001$) and 1.4$\pm$1.7 kg ($p<0.001$) higher than in the middle of June. In January 1989 body weight was significantly higher than in January 1988 for men (0.7$\pm$2.2 kg, $p<0.01$) as well as for women (0.5$\pm$1.9 kg, $p<0.01$). The pattern of the seasonal weight fluctuations in 1989 was similar to the pattern of 1988 except that the weight fluctuations were less pronounced and that the increase in weight during the harvest period started one month earlier (middle of May).

In Manta, body weight decreased from March until the end of April (1.7$\pm$1.3 kg for men, $p<0.001$; 1.1$\pm$1.5 kg for women, $p<0.001$), but then increased again, and in the second half of May weight values were similar to the values in February. Subsequently a loss of body weight occurred from the end of May until September (pre-harvest season) for men (3.2$\pm$2.0 kg,

Figure 1. Seasonal weight changes of rural men and women in two areas in the Republic of Benin.



p<0.001) as well as for women (2.6±2.1 kg, p<0.001). From September to February (harvest and post-harvest season) a large increase in body weight occurred for men (3.4±2.3 kg, p<0.001) and for women (3.8±1.7 kg, p<0.001).

Individual pre-harvest weight loss of Dogbo subjects was calculated as the difference between the mean value of the two highest successive weight recordings in January-February and the mean value of the two lowest successive weight recordings in May-June. The mean of the individual pre-harvest weight losses for Dogbo men was 2.2±1.3 kg (p<0.001) in 1988 and 1.5±1.4 kg (p<0.001) in 1989, and for Dogbo women 1.8±1.7 kg (p<0.001) in 1988 and 1.1±1.4 kg (p<0.001) in 1989. The individual pre-harvest weight losses of both men and women in 1989 were significantly lower than in 1988 (p<0.01). The correlation between the individual pre-harvest weight loss in 1988 and the individual pre-harvest weight loss in 1989 was 0.05 (not significant, n=110) for men, and 0.23 (p<0.05, n=82) for women.

The individual pre-harvest weight loss of the Manta subjects was calculated as the difference between the mean value of the two highest successive weight recordings in February-March and the mean value of the two lowest successive weight recordings in August-September. The mean of the pre-harvest weight losses were 3.2±1.9 kg (p<0.001) for Manta men, and 2.5±2.1 kg (p<0.001) for Manta women. In 1988 the mean pre-harvest weight loss of Manta subjects was significantly larger than that of Dogbo subjects (difference: 1.0 kg for men; p<0.01, and 0.7 kg for women; p<0.05). The distribution of individual pre-harvest weight losses of Dogbo and Manta subjects is shown in Figure 2.

In Table 3 body mass index (BMI) values in post- and pre-harvest seasons are presented. For both men and women from Dogbo and Manta BMI during the pre-harvest season was significantly lower than BMI during the post-harvest seasons (Table 3). BMI of Dogbo men was lower than BMI of Manta men, except in the pre-harvest season, when BMI was about the same.

Correlation existed between individual pre-harvest

Figure 2. Distribution of individual seasonal weight changes.

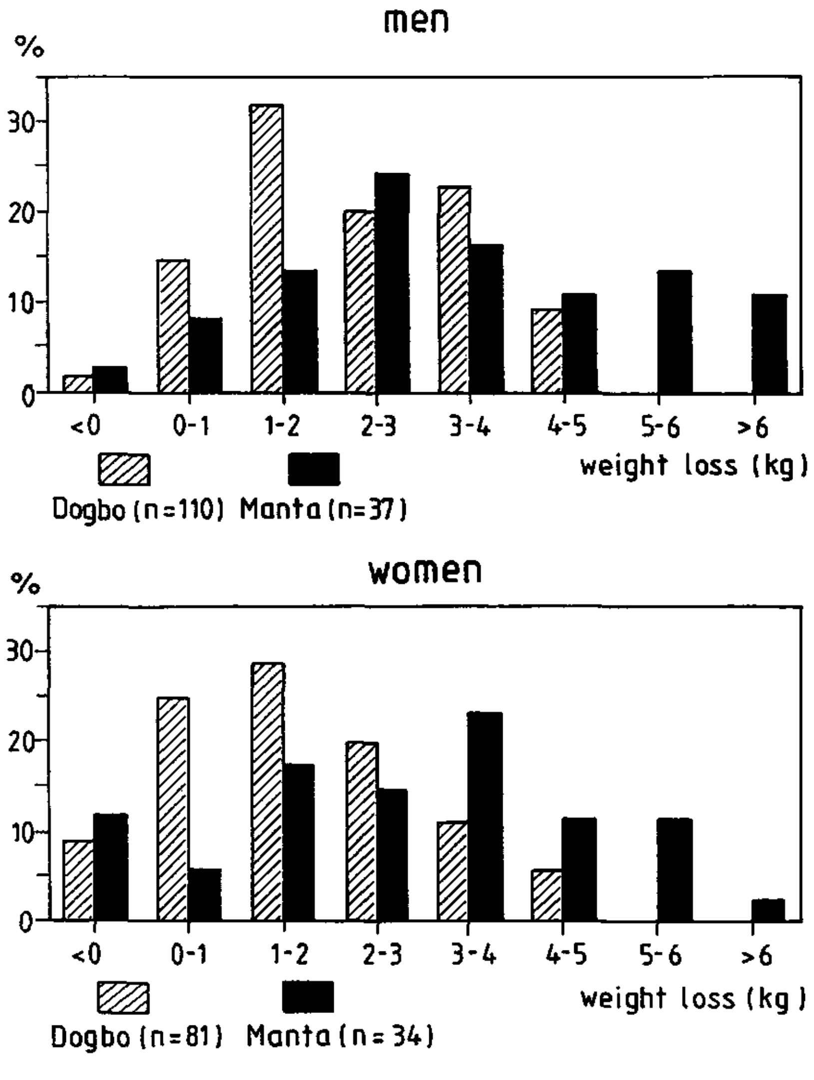


Table 3. Body mass index in three different seasons

	Men			Women		
Season[a]	BMI[b]	BMI<18 (%)	BMI<17 (%)	BMI[b]	BMI<18 (%)	BMI<17 (%)
DOGBO						
post-harvest	20.3±2.4[c]	16.1	3.8	20.8±3.5	17.6	8.8
pre-harvest	19.9±2.3[d]	18.7	7.5	20.5±3.2[d]	15.1	8.8
post-harvest	20.3±2.3[c]	13.2	3.8	20.9±3.4	13.8	5.0
MANTA						
post-harvest	21.4±1.9	2.9	0.0	20.6±2.7	7.4	0.0
pre-harvest	20.2±2.3[d]	5.9	5.9	19.5±2.6[d]	33.3	14.8
post-harvest	21.5±1.9	2.9	0.0	20.8±2.5	7.4	0.0

a) Dogbo: post-harvest seasons are February and September, pre-harvest season is June (all in 1988).
Manta: post-harvest seasons are February 1988 and February 1989, pre-harvest season is September 1988.

b) BMI: body mass index (weight/height^2) calculated using mean weights in above mentioned months, and expressed as means±SD.

c) Different from Manta men ($p<0.01$).

d) Different from values in post-harvest seasons ($p<0.01$).

weight loss in 1988 and BMI (at the start of the study) for Manta men ($r=0.41$; $p<0.01$), Manta women ($r=0.38$; $p<0.01$), and for Dogbo women ($r=0.28$; $p<0.01$). For Dogbo men no correlation was found.

DISCUSSION

The present study was carried out in two areas which have about the same amount of annual rainfall, but with a different distribution. There was no reason to suppose that an extra-ordinary pre-harvest food shortage had occurred during the study period in either of the two study areas, therefore the seasonal weight changes reported here are assumed to reflect a normal situation.

In Dogbo as well as in Manta body weight decreased significantly during the pre-harvest season. Body weight of Dogbo men during the pre-harvest season in May-June 1988 was 1.5±1.7 kg lower than during the post-harvest season in January-February 1988, for women the reduction in body weight was 0.9±2.1 kg (Figure 1). This decrease represents about 2.0-2.5% of the body weight during the post-harvest season, which is comparable with decreases in body weight reported for other rural African populations who live in areas with two rainy seasons (6,7,10). As is clearly shown in Figure 1 with the Dogbo subjects, the amount of pre-harvest weight loss as well as the months during which it occurs may vary from one year to another. For Manta subjects the difference in body weight between the post-harvest season in February-March and the pre-harvest season in August-September was 3.2±2.0 kg for men and 2.6±2.1 kg for women, representing about 6% of the body weight during the post-harvest season. Similar values have been reported for a nomadic population from Niger where weight loss during the hungry season was 3.1±2.1 kg for men (5.3% of body weight) and 2.4±2.7 kg for women (4.6% of body weight)(11). Smaller body weight losses during the pre-harvest season have been reported for other rural African populations who live in areas with one rainy season, the values vary from 0.7 kg for women to 2.8 kg for men (12-16).

The variation in pre-harvest weight loss between individuals is large. In Manta it ranged from a small weight loss of less than 1 kg to a weight loss of more than 6 kg, while in Dogbo the maximum weight loss was up to about 5 kg. In Manta 35% of the men and 27% of the women lost more than 4 kg during the pre-harvest season, while for Dogbo men and women these figures were 9% and 6% respectively. Mean pre-harvest weight loss in Manta was significantly larger than in Dogbo.

Body weight losses during the pre-harvest season were reflected in BMI, which also decreased significantly during the pre-harvest season in Manta as well as in Dogbo. The lower limit of an acceptable range for BMI as mentioned by the FAO/WHO/UNU (17) is 20.1 for men and 18.7 for women. BMI of Dogbo men during the pre-harvest season was only 19.9. The BMI of Manta subjects, who show larger pre-harvest weight losses than Dogbo subjects, stays above the lower limit of the acceptable range.

BMI and pre-harvest weight loss in 1988 were statistically significantly correlated for Manta men and women and Dogbo women, which suggests that the fatter people loose more body weight during the hungry season than the leaner people. This finding is in line with results obtained in other seasonality studies (6-8).

James ea.(18) proposed to classify chronic energy deficiency in adults using the BMI. They argumented that a BMI>18.5 is compatible with good health and physical capacity, but that a BMI<17 constitutes a substantial risk to health. As is shown in Table 3 the number of subjects having a BMI<17 rises during the pre-harvest season (except for the Dogbo women). During the post-harvest season in February all subjects in Manta had a BMI>17, while during the pre-harvest season in August 15% of the women and 6% of the men had a BMI<17. Also in Dogbo, where pre-harvest weight loss is smaller than in Manta, about 8% of the people had a BMI<17 during the pre-harvest season.

From the present study it can be concluded that the distribution of rainfall is a more important factor influencing pre-harvest weight loss than the yearly amount of rainfall. Especially in the area of Manta with one rainy season pre-harvest weight loss was large. The largest pre-harvest weight losses seem to be experienced by the fatter individuals in a community, who can better afford to loose body tissue without negative consequences for their health.

This phenomenon cannot be explained by the findings obtained in the present study, and needs further research. For an important part of the population pre-harvest weight loss may have negative concequences for health and physical capacity considering the low BMI which decreases to less than 17 during the pre-harvest season in not less than 5-15% of the people studied.

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CHAPTER 3.

SEASONAL WEIGHT LOSS AND METABOLIC ADAPTATION IN RURAL BENINESE WOMEN : THE RELATION WITH BODY MASS INDEX

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ABSTRACT

Large variation in seasonal weight loss between individuals exists in rural communities in developing countries. Therefore it was investigated whether some individuals change metabolic efficiency, and through that prevent large body weight losses during the pre-harvest season. Basal metabolic rate (BMR), energy intake (EI) and physical activity level (PAL) of rural Beninese women were measured in three seasons. Groups of subjects were: women with body mass index BMI<18 (n=18) and BMI>23 (n=16), and women who had shown small (n=18) and large (n=15) pre-harvest weight loss. All groups of subjects decreased energy intake during the pre-harvest season with 160-260 kcal/day. PAL did not show significant seasonal changes in any of the four groups. Only subjects with BMI<18 decreased BMR during the pre-harvest season with 0.7 ± 1.6 cal/kg/min ($p<0.05$), next to a decrease of 0.8 ± 1.4 kg ($p<0.05$) in body weight. Very thin women with a BMI<17 (n=5) decreased BMR expressed per unit body weight by 12% during pre-harvest season, suggesting that a change in metabolic efficiency only occurs when weight loss affects health and physical capacity.

Key words: Seasonal changes in basal metabolic rate and body weight in relation to body mass index.

INTRODUCTION

Rural populations in developing countries often experience important seasonal changes in food availability (1-3). In peasant communities a period of food shortage usually occurs at the end of the rainy season just before the main food harvest. Therefore, during the pre-harvest season people may come into a state of negative energy balance (energy intake minus energy expenditure) resulting into a loss of body weight. Pre-harvest weight loss of rural populations usually corresponds to 2-5% of the body weight (4). However, within the same community, the variation between individuals in pre-harvest weight loss is large, which is possibly related to body mass index (5,6). A large between-individual variation in pre-harvest weight loss suggests that not all individuals experience the same seasonal food shortage, or that individuals may change their energy expenditure to different levels.

When during the pre-harvest period body weight is lost energy expenditure is decreased because of a lowered metabolic rate (less body tissue causes a lower metabolic rate). Another way to decrease energy expenditure is by changing physical activity pattern, or by changing metabolic efficiency without changing weight or activity. A change in activity pattern is an effective mechanism but it is reported that farmer populations rather have to increase energy expenditure during the pre-harvest season due to a higher agricultural labour demand (7,8). The possibility of a change in metabolic efficiency is known to exist (9), but it is unclear whether it can occur in individuals who are not changing body weight and who experience relatively small decreases in energy intake.

The aim of the present study was to investigate whether pre-harvest weight losses are only related to reductions in energy intake or also to reductions in energy expenditure caused by an increase in metabolic efficiency. This question was studied by measuring body weight, BMR, energy intake and energy expenditure in different seasons in two groups of women with a different body mass index, and in two groups of women who showed a difference in pre-harvest weight loss in a previous year.

SUBJECTS AND METHODS

Study area

The study was carried out in five villages in the rural district of Dogbo in the south-western region (Mono province) of the Republic of Benin, West Africa. The district is situated at 70 km from the coast at an altitude of 80 m above sea level. Each of the research villages has about 1100 inhabitants who are subsistence farmers. Mean annual rainfall is 1050 mm, which is mainly distributed over two rainy seasons: a long rainy season from March to May, and a short rainy season from September to October. The main food crops are maize, cassava, oil palms and beans. Cultivation is done by men as well as women using hoes; the women cultivate their own fields. The staple food maize is harvested twice a year in July and in December. Sewing of maize is carried out in March and in September. Weeding is mainly carried out in April and in October. Women usually do the housekeeping, take care of the children, prepare food, gather fire wood and fetch water. Almost all women have some small money earning activities such as selling meals and snacks, palm oil and cassava meal.

Study design and subjects

At the start of the study in December 1987 body weight, height and skeletal diameters were measured of 150 women from the five research villages (30 out of each village). Body mass index (BMI) was calculated from their weight and height. Subsequently, body weight of all women was measured every two weeks until October 1988. For each woman pre-harvest weight loss was calculated as the difference between the mean value of the two highest successive weight recordings in January-February (post-harvest season) and the mean value of the two lowest successive weight recordings in May-June (pre-harvest season).

In December 1987 40 women (BMI group) were selected out of the total group of 150 women on basis of their initial BMI : 20 women with a BMI<18 and 20 women with a BMI>23. In these women basal metabolic rate (BMR), upper arm circumference and skinfold thicknesses, food intake and physical activity level were measured in three different seasons: January-February 1988 (post-harvest), May-June 1988 (pre-harvest), August-September 1988 (post-harvest) (Figure 1).

In December 1988 another group of 40 women (weight loss group) was selected out of the whole group of 150 women on basis of their pre-harvest weight loss in 1988: 20 women with a small pre-harvest weight loss (<0.7 kg) and 20 women with a larger pre-harvest weight loss (>1.5 kg). In these women the same measurements were carried out according to the same procedures as for the BMI group. The measurements took place in comparable seasons but one year later on: January-February 1989, May-June 1989, September-October 1989. In addition body weight was measured every two weeks from January 1989 to November 1989.

All 80 selected women had farming as their main occupation, they were aged 20 to 45 y, had two to five children and the age of the youngest child was at least nine months (these criteria were used to select the whole group of 150 women). At the beginning of the study all women were non-pregnant. The data of women who became pregnant during the study period were excluded from present analysis. Due to reasons of pregnancy, illness and moving, a complete data set covering the whole study period became available from 18 women with a BMI<18, from 16 women with a BMI>23, from 18 women with small pre-harvest weight loss and from 15 women with larger pre-harvest weight loss. More characteristics of the women are given in Table 1.

<u>Body weight and anthropometry</u>

The two-weekly body weight measurements took place in

Table 1. Characteristics of subjects[a]

	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
Age(y)	41.3±10.2	39.3±8.3	32.1±3.9	31.6±6.8
Weight(kg)[c]	44.0±5.1	64.0±7.5	48.7±5.5	53.4±7.1
Height(cm)	159.0±7.0	157.0±5.0	157.0±6.0	159.0±6.5
BMI(kg/m^2)[bc]	17.2±1.0	25.8±2.4	19.7±1.5	21.3±2.5
Sum wrist diameter(cm)	9.9±0.8	10.2±0.6	9.6±0.9	10.1±0.8
Sum knee diameter(cm)	16.1±1.0	16.6±1.1	16.2±0.9	17.4±1.0
Shoulder diameter(cm)	33.6±2.1	34.4±1.7	33.6±2.0	34.4±1.9

a) Means ± SD.
b) BMI: body mass index (weight/height^2).
c) Start of study: December 1987 for BMI group, January 1989 for pre-harvest weight loss group.

the villages between 7.00 and 8.30 a.m. using SECA platform spring balances who were attached to a solid wooden board. The balances were placed on a horizontal level and were checked before each weighing with calibration weights of 40.0 and 60.0 kg. The women were wearing a minimum of clothing and body weight was measured to the nearest 100 g (no correction was made for clothing which weighed at most about 300 g). Measurements were made by trained local assistants. Height was measured with the women standing on a horizontal surface against a wall with the heels together, chin chucked in and stretched upwards to full extent and the head in a Frankfurt plane. The heels, buttocks and shoulders were in contact with the wall to which a flexibel metal tape had been fixed. Readings were made to the nearest 0.5 cm. Skeletal diameters

were measured using a Holtain skeletal anthropometer. Upper arm circumference was measured midway between the tip of the shoulder and the elbow, with the arm hanging loosely by the side , using a flexibel metal tape.
Skinfold thicknesses (biceps, triceps, sub-scapular and supra-iliaca) were measured in triplicate using a Holtain caliper (Holtain Ltd, Briberian, UK) at the same moment as the BMR measurements. The 4 skinfolds equation of Durnin and Womersley (10) was used to estimate body fat percentage.

Basal metabolic rate (BMR)

BMR was measured in three successive seasons in each year (see Figure 1) by the same method. In each season BMR was measured on two days within the same week (one day between the two days of measurement). BMR measurements were carried out in a small field laboratory, where body weight was measured at the same time. The subjects were transported to the laboratory by car at about 7.30 a.m., having been asked not to work or eat beforehand. After lying down quietly for 30 minutes, BMR was measured by open circuit indirect calorimetry, using the Douglas bag technique. The women wore nose clips and breathed through a respiratory valve. Expired air was collected for three times 10 minutes with intervals of 2 minutes between each collection. The volume of the expired air was measured with a precision wet-type gas meter (Schlumberger Meterfabriek BV, Dordrecht, The Netherlands). Oxygen concentration was measured in samples of expired air with a paramagnetic Servomex oxygen analyser (Type OA 570; Taylor Instrument Analytics Ltd., Crowborough, Sussex, United Kingdom). The oxygen analyser was calibrated with outside air and 100% nitrogen, and checked against a calibration gas of known composition. Metabolic rate was calculated using Weir's equation (11). Room temperature at the time of measurement varied from 26-31°C (habitual range for these women) and air pressure ranged between 754 and 764 mm Hg.

Since BMR was measured in triplicate on two days, six measurements were made of each woman in each season. In the differences between the three measurements within the same day (average values being 0.92, 0.93, 0.93 kcal/min for the first, second and third measurement respectively), or between the two days (0.92 and 0.93 kcal/min for the first and second day respectively). Therefore, for each woman in each period the average of the six measurements (or in case a value was missing the average of the remaining measurements) was used for further analysis. In the three seasons in 1989 there was again no difference between the two days (0.93 and 0.93 kcal/min respectively), but there existed a small but statistically significant difference between the three measurements within the same day (0.94, 0.93, 0.93 kcal/min, for the first, second and third measurement respectively). There was no evidence for a difference between the second and third measurement, but the first measurement was statistically significantly higher than the other two measurements. Again the average of six measurements was used for further analyses. But in case one measurement value was missing, the missing value was estimated using a model accounting for systematically higher values of the first measurement compared to the second and third measurement, assuming no difference between the second and third measurement and between the two days of measurement. The reproducibility of the BMR measurements as based on triplicate measurements (ignoring the small systematical differences in 1989) was 6.0% (CV) in 1988 and 6.1% (CV) in 1989.

Food intake

Food intake was determined for each subject in the same season as BMR during four consecutive days in each season. The time interval between measurement of BMR and the measurement of food intake in the same subject was maximally two weeks. Food intake was measured using the observed precise weighing record method (12). All food was weighed before and after cooking, as well as the subject's portion of it, to the nearest g using a digital balance (Soehnle Type 8000) for weights up to 1 kg. Weights above 1 kg were weighed to the nearest 25 g on a mechanical balance (Soehnle Type 1201). The measurements were carried out by local assistants who were well known in the villages, and who stayed with the subjects from 7.30 a.m. until the time the subjects had eaten their dinner (usually around 8.00 p.m.). Foodstuffs which were eaten when the assistants were not present were determined using the recall method. To calculate energy intake, appropriate food composition tables were used (13,14). Energy intake for each subject in each season was obtained by calculating the average intake of four consecutive days.

Physical activity level

Physical activity level (15) (PAL) was measured on the same days as the food intake. PAL was calculated on basis of recorded daily physical activity patterns. Recording was done by the local assistants using minute to minute registration (16). It was explained emphatically to the subjects that they should continue to carry out their habitual daily tasks while the assistants were present. The recall method was used to determine activities carried out when the assistants were not present. For the sake of simplicity physical activities were divided into eight categories:

1. sleeping and resting activities (sleeping, sitting quietly, standing quietly, light work in sitting position),
2. light activity (taking care of children, washing dishes, cleaning house),
3. moderate activity (sweeping, washing clothes),
4. heavy activity (gathering fire wood, fetching water),
5. preparation of food,
6. eating,
7. walking,
8. doing field work (clearing the field, using the hoe, harvesting).

For each day the number of minutes spent on each activity category was calculated and the results were averaged over the four day period in each season. The PAL was calculated for each women in each period using estimated energy costs of each category of activities, based on values published by the FAO/WHO/UNU (17). These energy costs are expressed as a multiple of BMR , and are respectively: 1.2xBMR, 2.2xBMR, 3.2xBMR, 4.1xBMR, 1.8xBMR, 1.5xBMR, 3.0xBMR, 3.5xBMR.

Statistical analysis

Differences in body weight and body fat mass between post- and pre-harvest seasons were tested using Wilcoxon's matched-paires signed-ranks test (18). To determine statistically significant seasonal changes in BMR, energy intake and physical activity level, analysis of variance for repeated measurements was used (MANOVA in SPSS/PC+ V2.0)(19). When MANOVA revealed significant F-values ($p<0.05$) a paired t-test was used to compare values of the different seasons. Differences between average values (BMR, energy intake, PAL) of two groups of subjects were tested by unpaired t-tests (18).

RESULTS

Body weight and anthropometry

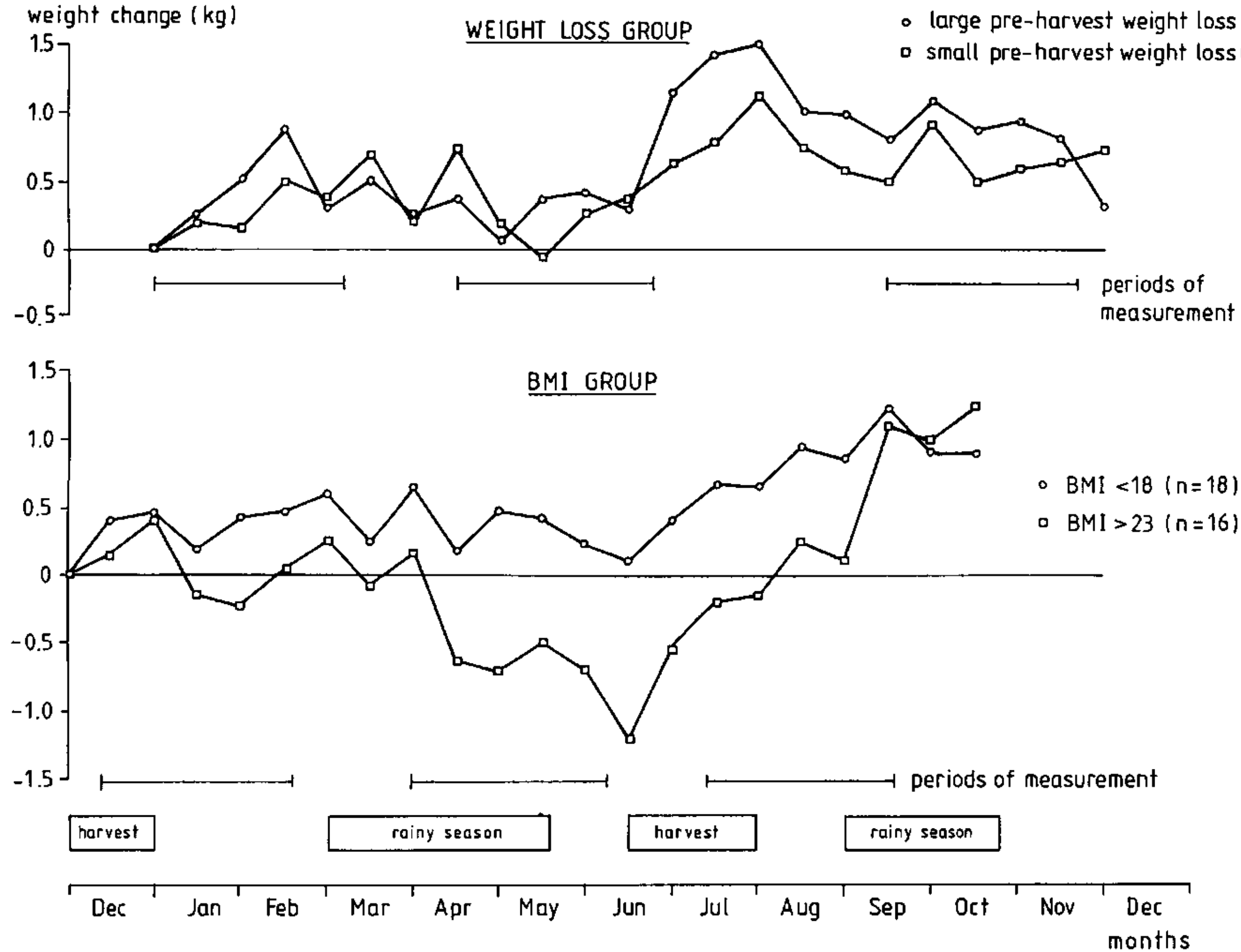
Results of the measurements of body weight, body fat and upperarmcircumference are presented in Table 2. For women with a BMI<18 body weight in May-June (pre-harvest) was 0.8 ± 1.4 kg ($p<0.05$) lower than in January-February (post-harvest), for women with a BMI>23 the decrease was 1.7 ± 3.2 kg ($p<0.08$). Fat mass and upperarmcircumference of women with a BMI<18 did not show significant changes. Fat mass of women with a BMI>23 in May-June (pre-harvest) was 1.6 ± 1.9 kg ($p<0.01$) lower than in January-February (post-harvest). Women who had shown small pre-harvest weight loss did not change their body weight significantly during the three seasons of measurement. Body weight of subjects who had shown large pre-harvest weight loss increased by 0.6 ± 0.8 kg ($p<0.05$) in August-October (post-

Table 2. Body weight and body composition in three different seasons[a]

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
Weight(kg)	44.9±5.0[c]	65.0±7.7	48.8±5.5	53.5±7.0
Fatpercentage(%)	20.3±4.8	32.8±4.3[d]	24.4±4.9[c]	25.8±6.3
Fatmass(kg)	9.1±2.3	21.5±4.5[d]	12.0±2.3[c]	14.1±5.2
Armcircumference (cm)	23.7±1.6	32.0±2.9	26.4±2.5	27.2±2.6
BMI[b]	17.6±1.0[c]	26.2±2.4[c]	19.6±1.6	21.1±2.7
MAY-JUN (pre-harvest)				
Weight(kg)	44.1±4.9	63.3±7.3	49.0±5.0	53.3±7.0
Fatpercentage(%)	19.7±4.8	31.2±4.5	25.2±4.9	26.2±5.0
Fatmass(kg)	8.6±2.3	19.9±4.6	12.4±3.2	14.2±4.2
Armcircumference (cm)	24.1±1.9	31.5±2.5	26.4±2.3	26.6±2.2
BMI[b]	17.3±1.1	25.5±2.5	19.7±1.4	21.0±2.6
AUG-OCT (post-harvest)				
Weight(kg)	44.3±4.9	63.6±7.4	49.3±4.5	53.9±7.0[c]
Fatpercentage(%)	NM	NM	25.4±4.7	27.5±5.4[de]
Fatmass(kg)	NM	NM	12.6±3.0	15.0±4.6[de]
Armcircumference(cm)	NM	NM	26.3±2.2	27.1±2.5
BMI[b]	17.3±1.1	25.8±2.5	19.8±1.4	21.2±2.6[c]

a) Means ± SD; NM means : not measured.
b) BMI: body mass index (weight/height^2).
c) Different from value in May-June ($p<0.05$).
d) Different from value in May-June ($p<0.01$).
e) Different from value in January-February ($p<0.01$).

Figuur 1. Body weight changes throughout a one year cycle of four groups of rural Beninese women.



harvest), their fat mass also increased significantly.

Changes in body weight in relation to the three seasons of measurement are shown in Figure 1.

Energy intake and physical activity level (PAL)

Results of energy intake measurements are presented in Table 3. Energy intake of all four groups of women was lower during the pre-harvest season in May-June than during the post-harvest seasons in January-February. However, only subjects with a BMI<18 and subjects who had shown large pre-harvest weight loss showed statistically significant seasonal changes in energy intake. Energy intake during the pre-harvest season in May-June of subjects with BMI<18 was 231±375 kcal/day (p<0.05) lower than the intake during the post-harvest season in January-February. The energy intake in August-October (post-harvest) of subjects who had shown large pre-harvest weight loss was 357±449 kcal/day lower than the intake in January-February (p<0.05). Energy intake expressed per unit body weight of the four groups showed large differences. During the pre-harvest season the intake of subjects with a BMI<18 is 9 cal/kg/day higher (p<0.01) than the intake of subjects with a BMI>23.

PAL during the three seasons is shown in Table 3. There occurred no statistically significant seasonal changes in PAL in any of the four groups of subjects. The lowest PAL was 1.66xBMR of subjects with BMI>23 during the post-harvest season in January-February. This value was significantly lower than the level of 1.74xBMR of subjects with BMI<18 in the same season (p<0.05).

Basal metabolic rate (BMR)

Results of the BMR measurements are presented in Table 4. Subjects with a BMI<18 showed statistically significant seasonal changes in BMR. This was not so for the other three groups of subjects. BMR of subjects with BMI<18 during the pre-harvest season in May-June was lower (p<0.05) than the values in the other two seasons. The decrease remains

Table 3. Energy intake and physical activity level in three different seasons[a]

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
Energy intake:				
kcal/day	1890±468	2071±554	1940±514	1986±568
$kcal.kg^{-1}.day^{-1}$	43±12	33±9	40±10	37±12
PAL[c]				
xBMR	1.74±0.12	1.66±0.11	1.73±0.13	1.73±0.16
MAY-JUN (pre-harvest)				
Energy intake				
kcal/day	1660±286[de]	1808±459	1784±367	1748±495[d]
$kcal.kg^{-1}.day^{-1}$	38±7[de]	29±7	37±8	33±10[d]
PAL[c]				
xBMR	1.73±0.08	1.70±0.14	1.73±0.12	1.74±0.10
AUG-OCT (post-harvest)				
Energy intake				
kcal/day	1861±377	1903±356	1923±391	1629±403[d]
$kcal.kg^{-1}.day^{-1}$	42±10	30±5	39±8	30±7[d]
PAL[c]				
xBMR	1.76±0.09	1.73±0.15	1.78±0.15	1.78±0.11

Legends Table 3:

a) Means ± SD.

b) Body mass index ($weight/height^2$).

c) Physical activity level: total daily energy requirement expressed as ratio of BMR.

d) Different from value in January-February ($p<0.05$).

e) Different from value in August-October ($p<0.05$).

Table 4. BMR in three different seasons[a].

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
BMR				
kcal/day	1234±137	1461±128	1297±150	1392±143
kcal/min	0.86±0.09	1.01±0.09	0.90±0.10	0.97±0.10
$cal.kg^{-1}.min^{-1}$	19.3±1.6	15.8±1.9	18.6±2.3	18.4±2.4
$cal.kgFFM^{-1}.min^{-1}$	24.2±1.8	23.6±2.3	24.6±2.6	24.6±2.5
MAY-JUN (pre-harvest)				
BMR				
kcal/day	1182±156[c]	1444±120	1311±157	1323±172
kcal/min	0.82±0.11[c]	1.00±0.08	0.91±0.11	0.96±0.09
$cal.kg^{-1}.min^{-1}$	18.8±1.1[c]	16.0±2.0	18.8±2.2	18.3±1.5
$cal.kgFFM^{-1}.min^{-1}$	23.4±2.0	23.3±1.9	24.9±2.9	24.6±1.3
AUG-OCT (post-harvest)				
BMR				
kcal/day	1231±148	1459±138	1323±172	1348±142
kcal/min	0.85±0.10	1.01±0.10	0.92±0.12	0.94±0.10
$cal.kg^{-1}.min^{-1}$	19.5±1.9	16.1±2.3	18.8±2.3	17.6±1.6
$cal.kgFFM^{-1}.min^{-1}$	NM	NM	25.1±2.3	24.2±1.4

Legends Table 4:

a) Means ± SD; NM means: not measured.

b) BMI: body mass index (weight/height^2).

c) Different from values in post-harvest seasons in January-February and August-October ($p<0.05$).

statistically significant when BMR is expressed per unit body weight. BMR in May-June (pre-harvest) is 0.7±1.6 cal/kg/min lower ($p<0.05$) than in August-October (post-harvest). BMR per unit fat free mass in May-June was not statistically significantly lower than in January-February ($p=0.11$).
BMR of subjects with a BMI>23 of 15.8±1.9 cal/kg/min (post-harvest, January-February) was significantly lower ($p<0.01$) than the value of 19.3±1.6 cal/kg/min of subjects with BMI<18 in the same season, the difference is no longer significant when BMR is expressed per unit fat free mass.

DISCUSSION

Normally during the pre-harvest season, if food intake is decreased, body weight is lost in order to lower energy expenditure. Some groups of individuals within a rural community hardly loose weight (5), therefore we wanted to investigate whether some individuals change metabolic efficiency in order to decrease energy expenditure and through that prevent large body weight losses during the pre-harvest season. The necessity to decrease energy expenditure would only exist if energy intake during the pre-harvest season decreases markedly compared to the energy intake during post-harvest seasons. In the present study energy intake of all four groups of women during the pre-harvest season in May-June was lower than energy intake during the post-harvest season in January-February, although this decrease was statistically significant in only two groups. The fall in energy intake between the post- and pre-harvest season ranged from about 160 kcal/day to 260 kcal/day. This decrease in energy intake during the pre-harvest season is comparable with results from other studies among rural African women in Senegal (20), Ethiopia (6) and Gambia (21) where decreases in energy intake during the pre-harvest season were reported ranging from 130 kcal/day to 400 kcal/day. Energy intake expressed per unit body weight of Ethiopian women during the pre-harvest season was 40 kcal/kg/day (6) compared to a lower value of 34 kcal/kg/day which is about the average of all four groups of subjects in the present study during the pre-harvest season.

When the level of energy intake falls below the level of energy expenditure during a prolonged period of time, energy expenditure might be reduced by changing the activity pattern. Although energy intake decreased during the pre-harvest season in the present study, physical activity level did not change significantly during the different seasons throughout the year in any of the four groups. Since it was our intention only to investigate whether seasonal changes in physical activity level would occur, no comparison will be made here between the energy intake and the physical activity level.

Considering the fall in energy intake and the unchanged energy expenditure a loss in body weight would be expected during the pre-harvest season. The group of subjects with a BMI>23 showed a decrease in body weight during the pre-harvest season in May-June consisting mainly of fat mass. Also subjects with a BMI<18 decreased body weight during the pre-harvest season. Subjects who had shown small pre-harvest weight loss in the previous year experienced no significant weight change which corresponds with the non-significant changes in energy intake. Subjects who had shown large pre-harvest weight loss in the previous year did not decrease their weight significantly during the pre-harvest season but weight increased markedly during the post-harvest period in August-October.

BMR values in the present study vary from about 16 cal/kg/min (BMI>23) to 20 cal/kg/min (BMI<18). They are comparable with BMR values reported for other rural women in Africa, which are: Ethiopian women 20 cal/kg/min (6), Gambian women 19 cal/kg/min (22), Beninese women 18 cal/kg/min (5). A predicted BMR for subjects with small pre-harvest weight loss using the FAO/WHO/UNU equations (17) and their body weight in January-February is 1250 kcal/day. Our measured value of 1297 kcal/day is 104 per cent of the predicted value. When BMR is expressed per unit fat free mass the values are about 23 to 25

Table 5. BMR, energy intake and physical activity level in three different seasons of women with a BMI<17[ab]

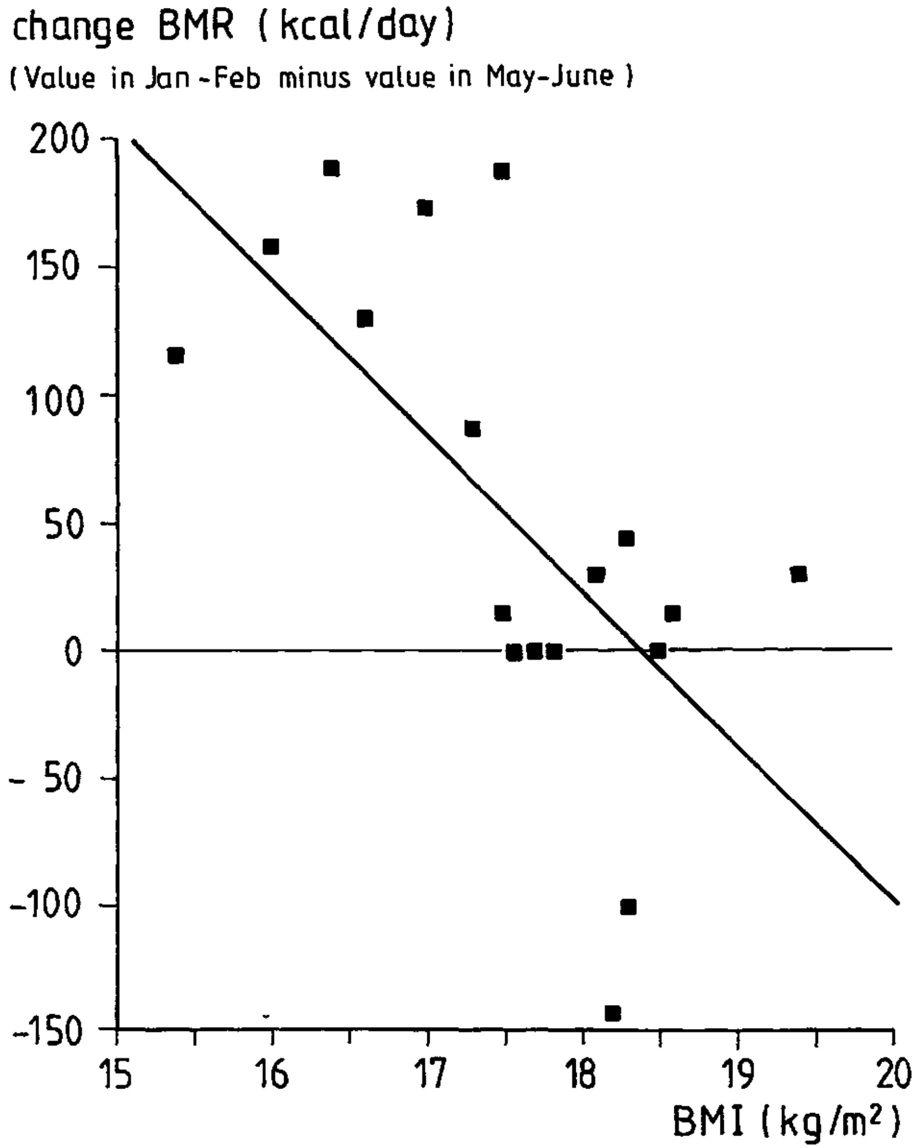
Variable	Season		
	Jan-Feb Post-harvest	May-June Pre-harvest	Aug-Oct Post-harvest
Number of women	5	5	5
BMR			
(kcal/day)	1215±147	1064±133[cd]	1188±120
(kcal/min)	0.84±0.10	0.74±0.09[cd]	0.82±0.08
($cal.kg^{-1}min^{-1}$)	20.8±1.2	18.4±1.0[cd]	20.3±1.8
($cal.kgFFM^{-1}.min^{-1}$)	24.8±1.5	22.1±1.5[c]	NM
Energy intake			
(kcal/day)	2056±422	1603±361[c]	1846±448
PAL[e]			
(xBMR)	1.70±0.11	1.70±0.06	1.78±0.08

a) Means ± SD; NM means not measured.
b) BMI: body mass index ($weight/height^2$).
c) Different from value in January-February ($p<0.05$).
d) Different from value in August-October ($p<0.05$).
e) Physical activity level: total daily energy requirement expressed as ratio of BMR.

cal/min and are comparable with reported values for Gambian women of 23 cal/min (23).

Only lean women with a BMI<18 changed their BMR statistically significantly throughout the year. BMR of these lean women was 4.3 per cent lower during the pre-harvest season than BMR during the other two seasons. This decrease was not only caused by a loss of body weight. The decrease in BMR expressed per unit body weight during the pre-harvest season is still about 3 per cent, which represents a statistically significant seasonal change. Within the group of women with a BMI<18 a correlation existed between BMI and the

Figure 2. Relation between body mass index (BMI) and the decrease in BMR for women with a BMI<18. The decrease in BMR (kcal/day) is calculated as: the value in the post-harvest season minus the value in the pre-harvest season. r=0.64 (p<0.01); y=1112-60.4*x.



decrease in BMR (Figure 2). Very thin women with a BMI<17 showed a large reduction in BMR during the pre-harvest season (Table 5). BMR of these very thin women changed from 20.8±1.2 cal/kg/min in the post-harvest season to 18.4±1.0 cal/kg/min in the pre-harvest season, which is a 12 per cent decrease. This change in BMR between the post-harvest and the pre-harvest season represents a daily saving in energy expenditure of 150 kcal/day, covering about 30 per cent of the fall in energy intake. Metabolic adaptation during the pre-harvest period has also been reported for lean rural Ethiopian women with a BMI of 18.4±1.6 (6). Daily energy intake of these women dropped from 2210 kcal/day to 2045 kcal/day while their BMR decreased from 20.8 cal/kg/min to 18.8 cal/kg/min in the same period, which is equal to the decrease in BMR in the women with a BMI<17 in the present study. In a previous study among rural Beninese women (BMI 21.1±2.0) energy intake during the pre-harvest season decreased with about 300 kcal/day compared to the post-harvest season and arrived at a level of 1560 kcal/day (5). This large seasonal change to a low level of energy intake did not provoke a change in BMR, nor a change in physical activity level.

Sukhatme and Margen (24) postulated that individuals can change their metabolic efficiency at all times in response to a sustained change in energy intake without changing body energy stores or physical activity. The results obtained in the present study do not support this hypothesis. Only thin women with a low BMI increased their metabolic efficiency next to a loss of body weight, while women with larger body energy stores only decreased body weight in response to a moderate reduction in energy intake. However, there are limits to the amount of weight which an individual can loose if good health is to be maintained. It is argumented that a BMI below 17 constitutes a risk to health and could lead to an impaired physical capacity (25). During periods when food availability is modestly restricted, as may occur during pre-harvest seasons in developing countries, the present results suggest that individuals do not change their physical activity level but decrease their body weight in order to re-establish energy balance. However, if a loss of body weight would represent a danger to health and an impairment to physical capacity, which is probably the case with BMI's lower than 17, a metabolic adaptation occurs to lower energy expenditure.

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CHAPTER 4.

INFLUENCES OF SEASONAL FOOD SHORTAGE ON DAILY ACTIVITY PATTERN AND PHYSICAL ACTIVITY LEVEL OF RURAL BENINESE WOMEN

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ABSTRACT

Large variation in seasonal weight loss between individuals exists within rural communities in developing countries. It was investigated whether some individuals change activity pattern to decrease energy expenditure and through that prevent large body weight loss during the pre-harvest season, by measuring energy intake (EI), activity pattern and physical activity level (PAL) in three seasons. Subjects were women with body mass index BMI<18 (n=18) and >23 (n=16), and women who had shown small (n=18) and large (n=15) pre-harvest weight loss in a previous year. Generally about 60% of a day was spent on resting activities, 10-16% of a day on food preparation and 10-12% on walking. Activity pattern showed seasonal changes but PAL remained at about 1.7 times BMR throughout the year in all four groups. EI during pre-harvest season decreased to a level of about 1.3-1.4 times BMR, but this value may be an underestimation. It can not be concluded whether changes in activity pattern are made conciously.

Key words: Seasonal food shortage and daily activity pattern

INTRODUCTION

To estimate energy requirement of rural populations in developing countries, accurate data of the habitual daily activity pattern are necessary. These data have to be gathered during different seasons throughout the year because the daily activity pattern shows seasonal changes due to a varying agricultural workload. Especially during the pre-harvest season, when food availabilty may be limited, the agricultural workload of subsistence farmers is believed to be high (1-3). The combination of a low food availability and a high agricultural workload may bring people into a state of negative energy balance (energy intake minus energy expenditure) resulting in a loss of body weight. Within such a community the variation between individuals in weight loss during the pre-harvest season is large, which suggests that not all individuals experience the same seasonal food shortage, or that they change their energy expenditure to different levels. This large variation between individuals in pre-harvest weight loss is possibly related to body mass index (4,5).

Most important ways to decrease energy expenditure when energy balance is negative are by reducing body weight (decreased metabolic rate), or by changing the physical activity pattern in order to regain energy balance. However, the changes in physical activity pattern may not always be socially or economically acceptable or allowable, and can therefore have negative consequences. A loss of body weight has only negative consequences when weight gets below a certain level (6). Especially data of the energy expenditure and activity pattern of rural women are scarce, and they do not always show seasonal changes (4,5,7-9).

The aim of the present study was to investigate daily activity pattern in different seasons, the from that arising energy expenditure, and their relation to pre-harvest weight loss. Furthermore energy expenditure and energy intake were compared. Measurements were carried out in three different seasons in two groups of rural Beninese women with a large difference in body mass index, and in two groups of women who showed a difference in pre-harvest weight loss in a previous year.

SUBJECTS AND METHODS

Study area

The study was carried out in five villages in the rural district of Dogbo in the south-western region (Mono Province) of the Republic of Benin in West-Africa. The district is situated at 70 km from the coast at an altitude of 80 m above sea-level and has a population density of about 150 inhabitants per km^2. Each of the research villages had about 1100 inhabitants who were subsistence farmers. Mean annual rainfall is 1050 mm, which is mainly distributed over two rainy seasons: a long rainy season from March to May, and a short rainy season from September to October (Table 1). The main crops are maize, cassava, oil palm, beans, groundnuts and for the men cotton. Cultivation is done by men as well as women using hoes; the women usually cultivate their own fields. The most important agricultural activities are presented in Table 1.

Women's activities are: doing the housekeeping, taking care of children, preparing food, gathering fire wood and fetching water. Almost all women visit the main district market, which takes place every four days, to earn money by selling home made foodstuffs or agricultural products. To get to the market some women had to walk about 12 km. On market days the fields were normally not cultivated.

The main staple food maize is eaten one or two times a day as a thick porridge with a sauce of which red palm oil, peppers, onion and small dried fish are the main ingredients. Sometimes green leafy vegetables are added to the sauce. Meat and eggs are eaten infrequently. Dried cassava meal is often used to make a porridge, or it is eaten in a dry form together with groundnuts.

Study design and subjects

At the start of the study in December 1987 body weight and height were measured of 150 women from the five research villages (30 out of each village), and body mass index (BMI)

Table 1. Agricultural calendar and time of measurements[a]

MONTH	SEASON	ACTIVITY	MEASUREMENTS[a]
Jan			X
Feb		harvest cassava	X
Mar	rains	reclaiming land, sowing maize	
Apr	rains	sowing maize and groundnut, weeding	
May	rains	harvest cassava, sowing beans	X
Jun		harvest maize, sowing cotton	X
Jul		harvest maize and groundnut, sowing cotton	
Aug		harvest beans, sowing groundnut	X
Sep	rains	sowing maize and beans, planting cassava	X
Oct	rains	weeding	X
Nov		harvest maize, cassava, beans, groundnut	
Dec		harvest maize, cassava, cotton, groundnut	

a) Measurements include: activity pattern, food intake, BMR.

was calculated from their weight and height for each women. Subsequently body weight of all women was measured every two weeks until October 1988. For each woman pre-harvest weight loss was calculated as the difference between the mean value of the two highest successive weight recordings in January-February (post-harvest) and the mean value of the two lowest successive weight recordings in May-June (pre-harvest).

In December 1987 40 women (BMI group) were selected out of the total group group of 150 women on basis of their initial BMI: 20 women with a BMI<18 and 20 women with a BMI>23. In these women physical activity pattern, food intake and basal metabolic rate (BMR) were measured in three different seasons: January-February 1988 (post-harvest), May-June 1988 (pre-harvest) and August-September 1988 (post-harvest) (Table 1).

In December 1988 another group of 40 women (weight loss group) was selected out of the whole group of 150 women on basis of their weight loss in 1988: 20 women with a small pre-harvest weight loss (<0.7 kg) and 20 women with a large pre-harvest weight loss (>1.5 kg). In these women the same measurements were carried out according to the same procedures as for the BMI group. The measurements took place in comparable seasons but one year later on: January-February 1989, May-June 1989, September-October 1989 (Table 1).

All 80 women had farming as their main occupation, they were aged 20 to 45 y, had two to five children and the age of the youngest child was at least nine months (these criteria were used to select the whole group of 150 women). At the beginning of the study all women were non-pregnant. The data of women who became pregnant during the study period were excluded from present analysis. Due to reasons of pregnancy, illness and moving, a complete data set covering the whole study period became available from 18 women with a BMI<18, from 16 women with a BMI>23, from 18 women with small pre-harvest weight loss and from 15 women with large pre-harvest weight loss. Some characteristics of the subjects are presented in Table 2.

Body weight

Weighing was carried out between 7.00-8.00 a.m. using SECA platform spring balances which were checked before each weighing using weights of 40.0 and 60.0 kg. The women were wearing a minimum of clothing and body weight was measured to the nearest 100 g (no correction was made for clothing). The results of the two-weekly weighing programme are presented elsewhere (10). In the present study body weight during a season was calculated as the mean value of the weight recording immediately before the measurement of food intake and activity pattern and the weight recording immediately afterwards.

Activity pattern and total daily energy expenditure

A subject's daily activity pattern was recorded using

Table 2. Characteristics of subjects[a]

	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
Age (y)	41.3±10.2	39.3±8.3	32.1±3.9	31.6±6.8
Weight (kg)[c]	44.0±5.1	64.0±7.5	48.7±5.5	53.4±7.1
Height (cm)	159.0±7.0	157.0±5.0	157.0±6.0	159.0±6.5
BMI (kg/m^2)[bc]	17.2±1.0	25.8±2.4	19.7±1.5	21.3±2.5
Fatpercentage[cd]	20.3±4.8	32.8±4.3	25.1±4.8	26.3±5.8
Upperarmcircumf.(cm)	23.7±1.6	32.0±2.9	26.4±2.3	27.2±2.6

a) Means ± SD.
b) BMI: body mass index (weight/height^2).
c) Start of the study: December 1987 for BMI group, January 1989 for pre-harvest weight loss group.
d) Estimated by measuring four skinfolds (biceps, triceps, subscapular, suprailiac) and using Durnin and Womersley equation (10).

minute-to-minute registration (12) in each season during four consecutive days (which contained always a market day). Recording was done by the local assistants who were specially trained for the purpose and who worked under close supervision of the first author. The assistants were well known in the villages and stayed with the subjects from 7.30 a.m. until the time the subjects had eaten their dinner (ususally around 8.00 p.m.). Activities carried out while the assistants were not present were estimated using the recall method. It was explained emphatically to the subjects that they should continue to carry out their habitual daily tasks during the presence of the assistants. For the sake of simplicity daily activities were divided into eight categories (Table 3). For

Table 3. Activity pattern study: classification of daily activities and gross energy expenditure in specified categories[a]

Activity category	Examples	Energy expenditure xBMR
1. Resting	Sleeping, lying, sitting quietly, very light sitting activity	1.2
2. Light	Taking care of children, cleaning house, washing dishes, strolling	2.2
3. Moderate	Sweeping, washing clothes	3.2
4. Heavy	Gathering fire wood, fetching water	4.1
5. Preparing food	Cleaning vegetables, stirring, cutting ingredients	1.8
6. Eating		1.5
7. Walking	Walking at normal pace, walking with load,including going to the field	3.0
8. Field work	Sowing, weeding, harvesting	3.5

a) Energy expenditure values are derived from FAO/WHO/UNU (13). Only the energy cost of walking was obtained by own analysis (FAO/WHO/UNU value for walking at comparable speed is 2.85xBMR).

each day the number of minutes spent on each activity category was calculated, and the results were averaged over the four day period in each season. Total daily energy expenditure for each woman in each season was determined by calculating the physical activity level (PAL) (13). PAL was obtained by multiplying the time spent on each activity (expressed as percentage of 24 h divided by 100) with the corresponding energy costs (Table 3). The energy costs used in the present study are based on values published by FAO/WHO/UNU (14). Only

the energy cost of walking is based on own made measurements. Of 20 women energy cost of walking on a tredmill at 3.5 km/h, with and without load, at a horizontal level was measured by open circuit indirect calorimetry using the Douglas bag method (for methodology see BMR measurements). The 20 women were selected out of the group of 150 women and had an average weight and height of respectively :53.8±4.6 kg and 159.0±10.0 cm. The results for walking with and without load were respectively 2.8±0.4xBMR and 2.7±0.4xBMR.
Because sometimes actual walking speed of the women was higher, and the loads they carried were heavier, energy cost of walking was set at 3.0 times BMR (Table 3).

Food intake

Food intake was determined for each subject using the observed precise weighing record method (15). In each season measurements were made during the same four days as activity pattern was recorded, by the same assistants. All food was weighed before and after cooking, as well as the subject's portion of it, to the nearest g using a digital balance (Soehnle Type 8000) for weights up to 1 kg. Weights above 1 kg were measured to the nearest 25 g on a mechanical balance (Soehnle Type 1201). Foodstuffs which were eaten during the time the assistants were not present were determined using the recall method. To calculate energy intake appropriate food composition tables were used (16,17). There was no statistically significant systematical difference between the energy intake on the four days of measurement. For each subject in each season energy intake was calculted as the mean value of the intake on four consecutive days.

Basal metabolic rate (BMR)

The results of BMR measurements were used in the present study to express the energy intake of each subject in each season as a factor of BMR. BMR was measured by open circuit indirect calorimetry using the Douglass bag technique. Detailed descriptions of the methodology of the BMR measurements are given elsewhere (18).

Statistical analysis

To determine statistically significant seasonal changes in time allocated to different activities, in physical activity level and in energy intake analysis of variance for repeated measurements was used (MANOVA in SPSS/PC+, V2.0)(19). When MANOVA revealed significant F-values ($p<0.05$) a paired t-test was used to compare the values of the different seasons. Differences in body weight between post-harvest and pre-harvest seasons were tested using Wilcoxon's matched-pairs signed-ranks test (20). Differences in average values of physical activity level and energy intake between two groups of subjects were determined using an unpaired t-test.

RESULTS

Activity pattern

The daily activity pattern of the four groups of subjects in the three seasons of measurement are presented in Table 4. All groups spent most time of a day on resting activities. This varied from about 57% for subjects with a BMI<18 (Jan-Feb) to about 62% for subjects with a BMI>23 (Jan-Feb) ($p<0.05$). Other daily activities which demanded generally a lot of time are walking and the preparation of food. Generally, time devoted to field work was lower in January-February than during the other seasons. In all groups of subjects the time allocated to the different categories of activities showed statistically significant seasonal changes. The only group of subjects who changed the time allocated to resting activities throughout the year are subjects who had shown small pre-harvest weight loss. They spent $3.2\pm6.1\%$ of a day less ($p<0.05$) on resting activities in August-October than in January-February. Subjects with a BMI<18 and with BMI>23 devoted respectively $3.5\pm5.1\%$ and $3.7\pm7.0\%$ ($p<0.05$) of a day

Table 4. Daily activity pattern in three different seasons (time expressed as percentage of 24 h)[a]

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
1. Resting	57.1±5.8	62.3±6.3	61.6±6.4	60.1±6.8
2. Light work	6.3±4.4	5.7±2.6	6.5±5.2	5.5±3.5
3. Moderate work	3.4±1.7	4.2±3.8	3.2±1.8	3.0±1.9
4. Heavy work	2.8±2.9	2.3±2.0	3.8±2.9	3.8±3.2
5. Preparing food	15.6±5.4	13.7±5.6	11.0±2.8	13.5±5.9
6. Eating	2.9±0.8	2.7±1.0	2.4±0.8	2.4±0.7
7. Walking	10.1±4.4	8.9±3.9	10.0±4.0	9.9±4.7
8. Field work	2.0±4.3	0.3±0.6	1.5±2.5	1.8±2.0
MAY-JUN (pre-harvest)				
1. Resting	59.8±5.8	62.0±5.6	60.7±5.8	61.3±5.2
2. Light work	5.8±3.7	5.9±3.2	7.0±6.7	6.7±3.7[c]d
3. Moderate work	3.8±2.1	3.6±2.3[d]	3.0±1.4	3.0±2.5
4. Heavy work	1.8±1.3	1.6±1.6	2.1±2.1[c]	2.6±2.3
5. Preparing food	12.7±5.2[c]	11.2±3.6	10.9±3.5	11.4±4.9
6. Eating	2.6±0.8	2.5±0.9	2.4±0.8	2.6±1.0
7. Walking	11.3±2.8	11.0±4.5[c]	10.7±4.7	11.7±4.7[c]
8. Field work	2.3±2.9[d]	2.4±4.8[d]	3.4±4.1	3.6±3.6
AUG-OCT (post-harvest)				
1. Resting	58.5±4.7	61.5±6.4	58.4±5.2[c]	59.5±3.8
2. Light work	5.5±3.5	4.6±3.0	6.7±3.7	5.8±4.4
3. Moderate work	3.0±1.3	2.2±1.4[c]	2.8±1.4	2.4±1.2
4. Heavy work	1.8±1.4	1.6±1.8	3.3±2.9	2.9±2.0
5. Preparing food	12.1±4.1[c]	10.0±3.8[c]	11.5±3.5	10.9±5.1
6. Eating	2.8±0.6	2.8±1.0	2.6±0.9	2.2±0.9
7. Walking	10.9±3.2	12.2±6.2[c]	11.3±5.1	12.7±3.5[e]
8. Field work	5.0±5.4[c]	4.7±5.6[e]	3.6±5.3	3.3±3.9

Legend Table 4:

a) Means ± SD.

b) BMI: body mass index (weight/height^2).

c) Different from value in January-February ($p<0.05$).

d) Different from value in August-October ($p<0.05$).

e) Different from value in January-February ($p<0.01$).

more to the preparation of food during the post-harvest season in January-February than during the post-harvest season in August-October, while more time was spent on ($p<0.05$) agricultural activities in August-October. Subjects who had shown large pre-harvest weight loss devoted 2.8±2.8% of a day more to walking in September-October than in January-February ($p<0.05$). Subjects with a BMI>23 spent 3.3±6.3% more on walking in August-October than in January-February ($p<0.05$). The time devoted to heavy work changed statistically significant throughout the year for subjects who had shown small pre-harvest weight loss and for subjects with a BMI>23. Subjects with BMI>23 spent 2.0±2.8% of a day less ($p<0.05$) on moderate work in August-October than in January-February.

Physical activity level and energy intake

Results of the measurements of physical activity level (PAL) and energy intake are presented in Table 5. None of the groups of subjects showed statistically significant seasonal changes in PAL. Values of PAL ranged from about 1.7 times BMR to about 1.8 times BMR throughout the year. Subjects with a BMI>23 had the lowest PAL in January-February of 1.66±0.11 times BMR, while for subjects with a BMI<18 this was 1.74±0.12 times BMR ($p<0.05$) in the same season.

Energy intake of subjects with BMI<18 in May-June decreased with 231±375 kcal/day ($p<0.05$) compared to January-February . This intake in May-June is equal to 38±7 kcal/day when expressed per kg body weight and is higher than the intake of 29±7 kcal/kg/day ($p<0.05$) of the subjects with a

Table 5. Energy intake and physical activity level in three different seasons[a]

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
Weight (kg)	44.3±5.1	63.9±7.2	49.0±5.6	53.9±7.1
Energy intake				
kcal/day	1890±468	2071±554	1940±514	1986±568
kcal.kg^{-1}.day^{-1}	43±12	33±9	40±10	37±13
xBMR	1.55±0.41	1.44±0.42	1.50±0.36[c]	1.44±0.44[c]
PAL[d]				
xBMR	1.74±0.12	1.66±0.11	1.73±0.13	1.73±0.16
MAY-JUN (pre-harvest)				
Weight (kg)	44.3±5.0	62.9±7.1[e]	49.0±5.0	53.4±6.9[f]
Energy intake				
kcal/day	1660±286[ef]	1808±459	1784±367	1748±495[f]
kcal.kg^{-1}.day^{-1}	38±7[ef]	29±7	37±8	33±10[f]
xBMR	1.42±0.29[g]	1.27±0.38[g]	1.37±0.28[g]	1.27±0.37[g]
PAL[d]				
xBMR	1.73±0.08	1.70±0.14	1.73±0.12	1.74±0.10
AUG-OCT (post-harvest)				
Weight (kg)	45.1±5.2[f]	64.2±7.8	49.4±4.6	53.8±7.1
Energy intake				
kcal/day	1861±377	1903±356	1923±391	1629±403[f]
kcal.kg^{-1}.day^{-1}	42±10	30±5	39±8	31±8[f]
xBMR	1.54±0.38[c]	1.33±0.31[g]	1.47±0.34[g]	1.22±0.33[g]
PAL[d]				
xBMR	1.76±0.09	1.73±0.16	1.78±0.16	1.78±0.11

Legend Table 5:

a) Means ± SD.

b) BMI: body mass index (weight/height^2).

c) Different from PAL value in same season ($p<0.05$).

d) Physical activity level: total daily energy requirement expressed as ratio of BMR.

e) Different from value in August-October ($p<0.05$).

f) Different from value in January-February ($p<0.05$).

g) Different from PAL value in same season ($p<0.01$).

BMI>23 in the pre-harvest season. Energy intake during the post-harvest season in September-October of subjects who had shown large pre-harvest weight loss was 357±449 kcal/day lower ($p<0.05$) than the intake during the post-harvest season in January-February. Subjects who had shown small pre-harvest weight loss and subjects with BMI>23 did not experience statistically significant seasonal changes in energy intake.

The distributions of energy intake and PAL for all subjects combined are shown in Figure 1 and 2.

Information on the quality of the daily diet in a post- and a pre-harvest season is presented in Table 6. Protein intake of subjects with a BMI<18 and of subjects who had shown a large pre-harvest weight loss was respectively 12±14 g ($p<0.01$) and 10±14 g ($p<0.01$) lower during the pre-harvest season than during the post-harvest season. Percentage of energy derived from carbohydrates was about 65% in both seasons in all four groups of subjects. The major part of daily energy intake comes from maize (at least 40%).

DISCUSSION

The daily activity pattern of each of the four groups of rural Beninese women studied showed large similarities in the three seasons. All four groups of women had in common that

Table 6. Protein intake, percentage energy from protein and the proportion of energy from maize, cassava and beans in two different seasons[a]

Season	BMI group[b]		weight loss group (pre-harvest weight loss in previous year)	
	BMI<18 (n=18)	BMI>23 (n=16)	small (n=18)	large (n=15)
JAN-FEB (post-harvest)				
Protein:				
g/day	50±15	50±17	48±15	48±13
% energy	11±2	10±2	10±1	10±2
% energy from food:				
Maize	47±13	41±11	41±12	37±11
Cassava	9±4	11±7	15±8	17±10
Beans	5±3	5±3	9±6	11±8
MAY-JUN (pre-harvest)				
Protein:				
g/day	38±10[c]	43±12	41±8	38±13[c]
% energy	9±2[d]	9±2	9±1	9±2
% energy from food:				
Maize	42±12	40±12	42±14	43±13
Cassava	13±8	12±6	17±11	18±8
Beans	4±3	5±4	6±4	5±4

a) Means ± SD.

b) BMI: body mass index (weight/height^2).

c) Different from value in January-February ($p<0.01$).

d) Different from value in January-February ($p<0.05$).

they spent about 60% of a day on activities as sleeping, lying and sitting quietly in every season. The second most important activity category was the preparation of foodstuffs, to which 10-16% of a day was allocated. Walking took 10-12% of a day in each season. Similar results have been obtained among rural women in Ethiopia (5) and Burkina-Faso (8) where resting activities in the pre-harvest season took respectively 65% and 58% of a day. Food preparation by women in Ethiopia and Burkina-Faso took respectively 15% and 11% in the pre-harvest season. Another study among rural women in Benin gave comparable results (4). Generally little time was spent on agricultural activities. In August-October this was between 3-5% of a day equalling 43-72 minutes. This is only a small amount of time in comparison with women from Burkina-Faso (8) who spent 15.4% of a day on agricultural activities during the pre-harvest season. It has to be considered however, that the time allocation data in the present study are mean values over four days and that one of these days was a market day on which generally no field work was done. Time allocated to agricultural activities on non-market days was about 4-7%. Furthermore the size of the fields of the women was small (about 1 hectare) which means that not much time is needed to cultivate them.

The daily activity pattern of all four groups of women showed seasonal changes. During the post-harvest season in August-October women with a BMI<18 spent more time on field work but less time on food preparation than in January-February (post-harvest). Women with a BMI>23 spent more time on field work and walking but less time on house keeping in May-June (pre-harvest) than in January-February (post-harvest). Women who had shown small pre-harvest weight loss slightly increased time spent on field work in May-June while time spent on domestical activities decreased.

Although activity pattern showed seasonal changes, the resulting physical activity level did not change significantly throughout the year. All four groups had a physical activity level of about 1.7 times BMR, which is a moderate level

Figure 1. Distribution of energy intake in three different seasons (four groups combined, n=67; energy intake expressed as ratio of BMR).

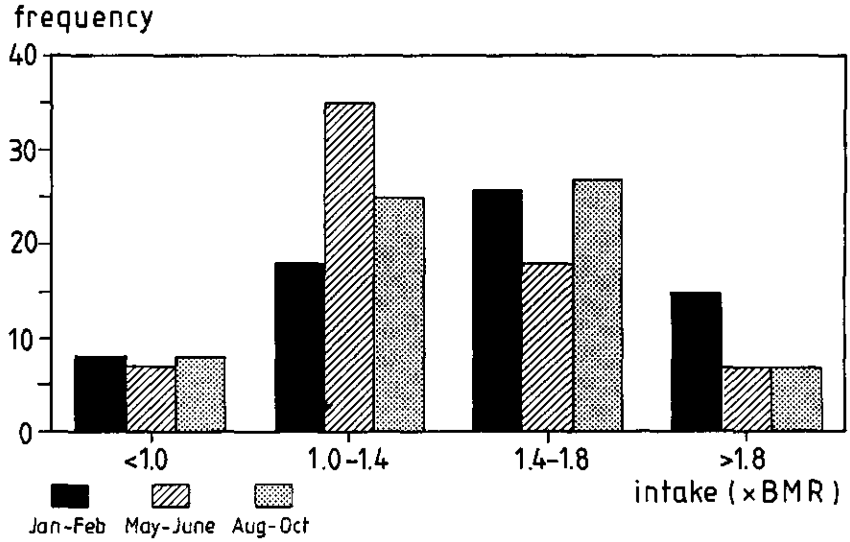
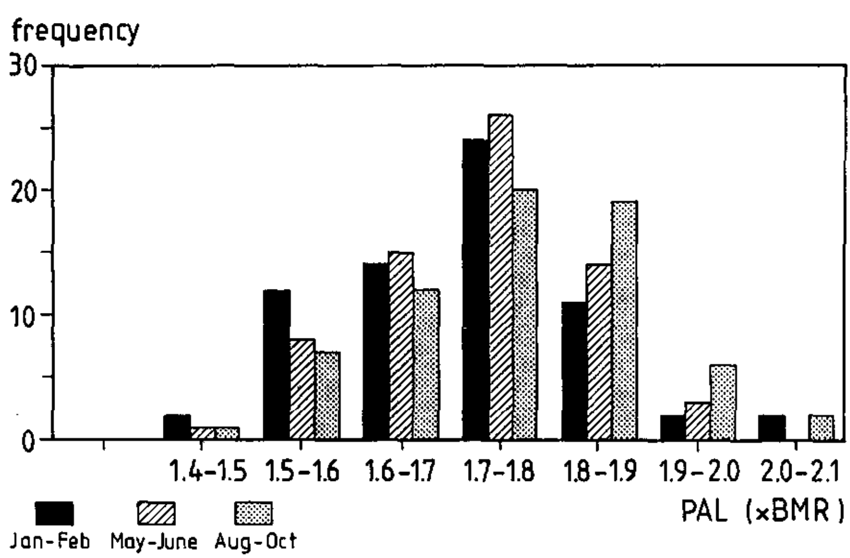


Figure 2. Distibition of physical activity level in three different seasons (four groups combined, n=67; physical activity level is total daily energy requirement expressed as ratio of BMR).



according to the FAO/WHO/UNU (14). Rural Ethiopian women (5) had a lower physical activity level of 1.47 times BMR, which also did not change throughout the year. Other studies did report seasonal changes in physical activity level of rural women. Physical activity level of Gambian women (7) was 1.7 times BMR during the post-harvest season while it was 2.0 times BMR during the pre-harvest season. Women from Burkina-Faso (9) also showed seasonal changes in physical activity level: 1.89 times BMR in dry season and 2.35 times BMR in rainy season.

When energy intake is compared with physical activity level it is found that the energy intake is lower than the physical activity level. This is especially so during the pre-harvest season in May-June. Only subjects with a BMI<18 had an energy intake during the pre-harvest season in May-June which was higher than 1.4 times the BMR which is considered as the maintenance requirement by the FAO/WHO/UNU (14). Comparable low levels of energy intake during the pre-harvest season have been reported for other rural African women (4,5,8,21,22).

Body weight of women with a BMI>23 and of women who had shown large pre-harvest weight loss in a previous year decreased during the pre-harvest season, which is to be expected with the negative energy balance during that season. Women with a BMI<18 and women who had shown a small pre-harvest weight loss in the previous year did not show a fall in body weight during the pre-harvest season, which is a conflict of evidence with the existing negative energy balance. During the post-harvest season in January-February (when there is supposed to be no food shortage) physical activity level is higher than the energy intake in all four groups although the difference does not reach statistical significance for women with a BMI<18 and for women with a BMI>23. This suggests that either energy intake has been underestimated or physical activity level has been overestimated. The estimation of energy expenditure using a technique as was done in the present study is reported to give comparable results with energy expenditure estimated by doubly labeled water (23). Also we had the impression that sometimes the women tended to stay a bit more in and around the house than they normally would when the assistants were present. This would result in slightly underestimated physical activity levels compared to the normal levels. Lawrence ea (24) have measured energy costs of common daily activities in Gambian women. If these energy cost values of Gambian women are used for our Beninese women comparable physical activity levels to the present values in January-February are obtained: 1.79 times BMR for women with BMI<18, 1.70 times BMR for women with BMI>23, and 1.76 times BMR for the women of the weight loss group. As is shown in Figure 1 seven to eight women had an energy intake which was lower than BMR in each season, while physical activity level of all women was higher than 1.4 times BMR. Considering that none of the women was ill during the days of measurement and that the values are mean values of four successive days, such a low intake is unlikely to represent the habitual intake of these women. Assuming no measurement errors, the women with these low intakes have probably eaten less (consiously or unconsiously) than they normally would during the presence of the assistants. If the energy intake values lower than BMR are not used, we arrive at a level of 1.57 ± 0.34 times BMR (all subjects, n=59) against a physical activity level of 1.70 ± 0.13 times BMR in January-February. This difference is still statistically significant, but less large (paired t-test, $p<0.05$). Considering the above mentioned arguments an underestimation of energy intake seems more likely than an overestimation of physical activity level. However, measured differences between seasons are likely to reflect the real situation considering the weight losses during the pre-harvest season which were found in subjects.

It can be concluded that in the present study no seasonal changes occurred in physical activity level although energy intake during the pre-harvest season in May-June decreased to a level of 1.4 times BMR and lower. The fact that women with a BMI<18 did not show a loss of body weight during the pre-harvest season while energy intake decreased with about 230 kcal/day can not be explained by the physical activity level because this did not decrease. A change in metabolic efficiency may play a role here. Daily activity pattern did change throughout the year. Generally one could say that when time spent on field work and walking increased, the time spent on household activities and food preparation decreased. It cannot be concluded that this is done conciously in order to lower energy expenditure. Whether a higher food intake could increase energy expenditure has been investigated but could not be proven (7,22). It has been stated that physical activity is regulated by social obligations, economic considerations and environmental constraints rather than by adaptive mechanisms (25). Considering the decrease in time spent on food preparation and household activities during the pre-harvest season, economic considerations may be the most important factor influencing the activity pattern when a food shortage exists. More research is needed on seasonal changes in activity pattern and its social and economic consequences because knowledge on this subject is limited.

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CHAPTER 5.

BODY COMPOSITION OF RURAL BENINESE WOMEN IN DIFFERENT SEASONS ASSESSED BY SKINFOLD AND BIOELECTRICAL IMPEDANCE MEASUREMENTS AND BY DEUTERIUM OXIDE DILUTION TECHNIQUE.

JW Schultink MSc, M Lawrence PhD, JMA van Raaij PhD, W Scottt PhD, JGAJ Hautvast MD.

ABSTRACT

Body composition of 24 rural Beninese women was assessed using skinfold and bioelectrical impedance (BIA) measurements and deuterium oxide (D_2O) dilution in the pre- and post-harvest seasons. The aim was to investigate whether these three methods gave comparable results in an African population when used in a field study. Fat mass assessed by D_2O dilution was 12.3±3.3 kg, by skinfold measurements 13.8±3.3 kg and by BIA 14.1±2.9 kg. Fat mass assessed by D_2O was significantly lower ($p<0.05$) than fat mass assessed by the other two methods. Body weight during the post-harvest season was 0.8±1.6 kg higher ($p<0.05$) than during the pre-harvest season. No significant changes in fat mass were measured, while fat free mass increased ($p<0.05$) as indicated by all three methods.

Key words: Body composition of rural African women in different seasons.

INTRODUCTION

Rural populations in developing countries often loose body weight during the pre-harvest season when food availability is limited. Reported pre-harvest weight losses for different rural populations from Africa and Asia range from 0.5 to 4.0 kg (1). Much less is known about seasonal changes in body composition. Knowledge of changes in body composition can provide additional information on seasonal fluctuations in nutritional status.

Data on changes in body composition are often obtained by measurement of skinfold thickness. This method is very suitable for use in field studies because the necessary skinfold calipers are relatively inexpensive, readily transportable and easy to use, and most studies in Africa on seasonal changes in body composition have used this (2-5). However, the commonly used equations of Durnin and Womersley (6) to assess body fat mass from skinfold thicknesses and body weight are based on measurements in a European population. It is not known whether such equations are appropriate for other populations, but there is evidence of between-population differences in the sub-cutaneous deposition of body fat that might affect their validity (7-9). Two other methods which are suitable for use in field conditions are the bioelectrical impedance method and the deuterium oxide dilution technique, which measures total body water and from which fat-free mass and fat mass can be calculated.

In the present study the fat mass of a group of rural Beninese women was estimated during pre- and post-harvest seasons using the skinfold method, bioelectrical impedance measurements and deuterium oxide dilution. The aim was to investigate whether the three methods gave the same assessment of the fat mass, and whether differences in body composition exist between seasons.

METHODS

Study area

The study was carried out in five villages in a southern region of the Republic of Benin in West-Africa. The study area can be characterised by an annual rainfall of about 1100 mm which is mainly distributed over two rainy seasons, a long rainy season from March to May and a short rainy season from September to October. The main food crop, maize, can be harvested twice a year: in July and in December. A period of relative food shortage occurs during the months of May and June (end of the rainy season, before the main harvest) resulting in a loss of body weight.

<u>Study design and subjects</u>

A group of 24 women was selected (on basis of willingness to participate) out of a group of 40 women who participated in a study in which basal metabolic rate and food intake were measured. Each woman was measured once during the pre-harvest season (May-June) and once during the post-harvest season (September-October).

All women were subsistence farmers and were aged between 20-45 years. They had two to five children, were non-pregnant and their youngest child was at least nine months old. Other characteristics are given in Table 1.

Table 1. Characteristics of subjects[a]

Number	24
Age (y)	34.4±5.6
Weight (cm)[b]	52.1±5.8
Height (cm)	159.9±5.5
BMI (kg/m^2)[bc]	20.3±1.6
Sum wrist diameter (cm)	9.8±0.9
Sum knee diameter (cm)	16.8±1.1
Shoulder diameter (cm)	34.2±1.7

a) Means ± SD.

b) Start of the study.

c) BMI: body mass index ($weight/height^2$).

Anthropometrical measurements

Body weight was measured using SECA platform spring balances, which were attached to wooden boards and placed on a horizontal surface. Before each weighing the balances were checked, and calibrated if necessary, using weights of 40.0 and 60.0 kg. Body weight was registered to the nearest 100 g, and the measured values were corrected for the minimum of clothing the subjects were wearing (estimated weight of clothing 300 g).
Biceps, triceps, sub-scapular and supra-iliaca skinfold thicknesses were measured in triplicate to the nearest mm using a Holtain skinfold caliper (Holtain Ltd.,Briberian, U.K.) (pressure 10 g/mm^2). Measurements were made on the left side of the body by the same person. Percentage fat was estimated using the equations of Durnin and Womersley (6) and fat mass calculated from these results and body weight.

Bioelectrical impedance

Bioelectrical impedance (BIA) was measured with the subject in a supine position with limbs away from the trunk as described by Lukaski (10) with a body composition analyser (RJL systems,Inc., BIA-101, Detroit, MI, USA). Measurements were made at about 9.00 a.m. and the subjects were asked not to eat beforehand. Fat-free mass was calculated using the following equation of Lukaski(11).
$FFM = 0.734\ Ht^2/R + 0.096Xc + 0.116Wt + 0.878G - 4.033$, in which Ht=height(cm), R=resistance, Xc=reactance, Wt=weight(kg), G=gender (1 for men, 0 for women). Fat mass was calculated as the difference between body weight and fat-free mass.

Deuterium oxide

Total body water (TBW) was measured using a deuterium oxide dilution technique (12,13). Women of one village were gathered in the morning at about 10 a.m. in one place where they stayed throughout the time of the experiment under supervision of a research assistant. They were asked not to eat anything before the measurement. We took a pre-dose sample of body water (1-2 mL of saliva) and then administered a carefully weighed dose of 15-20 g of a 20% D_2O solution (0.4 g of the solution per kg fat-free mass as estimated by skinfold measurements; about 0.1 g D_2O/kg body weight). After a 2h equilibration period the first post-dose saliva samples were taken, and after 3h a second post-dose saliva sample was taken. During the equilibration period the subjects neither ate nor drank. The increase in deuterium oxide level after dosing was calculated using the average of the 2h and 3h post dose saliva samples. Saliva samples were kept frozen at -20°C for storage. Analysis was carried out at Glasgow University, UK, by isotope ratio mass spectrometry (VG-Isogas, Middlewich, Cheshire, UK). Analytical precision, estimated as the mean difference between duplicate analysis of TBW was 0.9%. The deuterium dilution space was divided by 1.04 to correct for overestimation of TBW (14). Fat-free mass was defined as TBW/0.73 and the fat mass as the difference between body weight and fat-free mass.

Statistical analysis

To compare fat mass values as obtained by the three different methods, the results from each method in the pre-and post harvest seasons were pooled (48 values for each method). The agreement between two methods is shown by plotting the differences in fat mass against the mean fat mass as obtained by the two methods (15). Pearson correlation coefficient (16) was used to check for relationships between the differences in fat mass and the mean fat mass as estimated by two methods. Differences in average fat mass (obtained on basis of 48 values for each method) between the three methods were tested using paired t-test. Diffferences in body weight, fat mass and fat-free mass between pre- and post-harvest season were tested using Wilcoxon's matched-paires signed-ranks test (16).

Table 2. Fat mass and fat-free mass in pre- and post-harvest season obtained by D_2O dilution, skinfold and BIA measurements

	Pre-harvest (May-Jun)	Post-harvest (Sep-Oct)	Difference (post-harvest minus pre-harvest)
Number of subjects	24	24	24
Body weight (kg)	52.1±5.8	52.9±5.7	0.8±1.6[b]
Fat mass (kg)			
by D_2O method	12.4±3.4[c]	12.1±3.3[c]	-0.3±2.6
by skinfold method	13.6±3.2	14.0±3.5	0.4±1.3
by BIA method	14.1±3.0	14.1±2.9	0.0±1.4
Fat free mass (kg)			
by D_2O method	39.7±3.6[c]	40.8±4.1[c]	1.1±2.6[b]
by skinfold method	38.5±3.6	38.9±3.6	0.5±1.0[b]
by BIA method	38.0±3.5	38.8±3.8	0.8±1.6[b]

a) Means ± SD.

b) Difference between post-harvest and pre-harvest season is significant ($p<0.05$).

c) Value by D_2O method is different from values by other two methods ($p<0.01$).

RESULTS

Results are presented in Table 2. Fat mass as assessed by D_2O dilution was lower than the fat mass assessed by skinfold and BIA measurements. When the results of the measurements in the pre- and post-harvest seasons are pooled, mean fat mass (n=48) assessed by D_2O dilution was 12.3±3.3 kg, by skinfold measurements 13.8±3.3 kg and by BIA measurements 14.1±2.9 kg. The correlation between fat mass estimated by D_2O

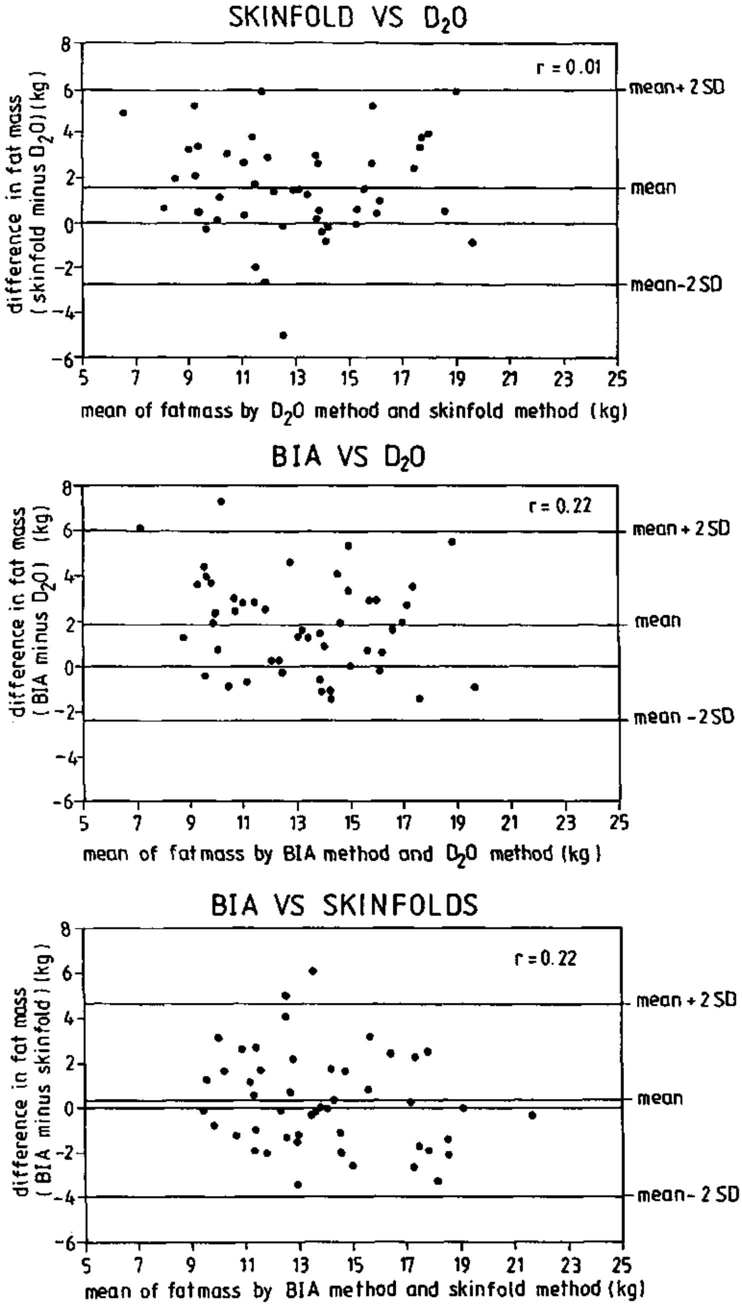
dilution and skinfolds was 0.79 ($n=48$; $p<0.001$), between the estimation by D_2O dilution and BIA 0.78 ($n=48$; $p<0.001$), and between the estimation by skinfolds and BIA 0.77 ($n=48$; $p<0.001$). The relationship between differences in fat mass and mean fat mass for pairs of methods are shown in Figure 1. No correlation existed between differences in fat mass and mean fat mass in any of the three comparisons (Figure 1). The difference in fat mass estimated by skinfold measurement and D_2O dilution was 1.5 ± 2.2 kg ($n=48$; $p<0.001$), by BIA measurement and D_2O dilution 1.8 ± 2.1 kg ($n=48$; $p<0.001$) and by BIA and skinfold measurement 0.3 ± 2.1 kg (NS).

Body weight during the post-harvest season was 0.8 ± 1.6 kg higher ($p<0.05$) than during the pre-harvest season. None of the three methods indicated that fat mass increased significantly during the post-harvest season. Fat-free mass did show a statistically significant ($p<0.05$) increase during the post-harvest season. The increase in fat-free mass was 0.5 ± 1.0 kg as assessed by skinfold measurements and 1.1 ± 2.6 kg as assessed by by D_2O dilution, the difference between these estimated increases is not statistically significant.

DISCUSSION

In this field study the fat mass of rural Beninese women estimated by D_2O dilution was on avarage 1.5 kg lower than that estimated by skinfold measurements. Comparable differences between these two methods have been reported in two other studies. In one study of 10 women from the United States fat mass estimated by D_2O dilution and skinfold measurements were respectively 11.9 kg and 13.0 kg (17). In another study of 45 black women (United States) no significant differences were found in fat mass estimated by D_2O dilution and by skinfold measurements when a Holtain caliper was used, but a significant difference of about 1.2 kg was found when a Lange caliper was used (fat mass by D_2O was less) (9). In comparing the results of the skinfold and the D_2O dilution methods it

Figure 1. Difference in fat mass vs mean fat mass as estimated by skinfold measurement and D_2O dilution, by BIA measurement and D_2O dilution and by BIA and skinfold measurement.



could be argued that the skinfold method overestimates the fat mass of Beninese women, perhaps because the equations of Durnin and Womersley (6) are inappropriate in this case. Zillikens and Conway report that black women (United States) have a different distribution of body fat from white women, but concluded there is no reason to use race specific skinfold equations (9). However fat distribution may also be affected by racial factors or by socio-economic, nutritional or environmental factors (9), and the Beninese women may well have a different body fat distribution compared to European women. The degree of hydration of the fat-free mass may vary among individuals (18), and it is possible that the water content of the fat-free mass may in Beninese women differ from the generally accepted figure of 73%. If instead of being 73% the water content of the fat-free mass were 74%, this would increase the estimated fat content of Beninese women by 0.5 kg, compared to the difference between methods of 1.5 kg.

In the present study fat mass assessed by D_2O dilution was also lower than fat mass assessed by BIA. This difference is not in line with results of a study in which the fat-free mass of obese subjects was assessed by D_2O dilution and BIA and where no significant difference was found (19). The difference between fat mass assessed by skinfold and BIA measurements was only 0.3 kg, which is comparable with results obtained in another study (20).

It can not be concluded from the present study which method most accurately assesses fat mass of Beninese women. When fat mass is expressed as a percentage of body weight a value of 24% is obtained for the D_2O dilution method and 26-27% for skinfold and BIA methods. The Beninese women had a body mass index (BMI) of 20.3 and these results may be compared with those of other studies in which the percentage fat of African women has been measured using the skinfold method. Ethiopian women (21) had a percentage fat of 21.0 (BMI 19.0), Gambian women (22) had a percentage fat of 18.7 (BMI 19.9) and women from Burkina-Faso (23) had a percentage fat of 19.3 (BMI 20.5). In comparison with these results the value of 26-27%

body fat by skinfolds for a BMI of 20.3 seems a little high.

Besides these differences in mean fat mass there were also considerable variations between individual results. This may be attributed to individual variations in the relationship between skinfold thicknesses and body fat, and by the degree of hydration of the fat-free mass. For human cadavers the water content of the fat-free mass is reported to vary from 71.6% to 74.8% (18). If this were the case in Beninese women, applying the factor 0.73 would result in individual errors in fat mass of as much as 0.9 kg. The fact that small changes in fluid balance result in relatively large differences in estimated fat mass estimations may also help to explain the large variation in fat mass within individuals from one season to another (-0.3 ± 2.6 kg). Fluid balance also influences BIA measurements (24), and this will contribute to errors in this method as well.

The rural Beninese women in this study showed significant seasonal changes in body composition. Body weight increased by 0.8 kg during the post-harvest season, similar to the increase in a larger group of Beninese women living in the same villages (25). Other rural Beninese women showed a decrease in body weight during the pre-harvest season of 1.2 kg (26). The increase in body weight during the post-harvest season seemed to consist mainly out of fat-free mass as indicated by all three methods. Similar results have been obtained elsewhere. Rural women from Zaire decreased body weight with 1.1 kg during the pre-harvest season while no significant changes occurred in triceps, biceps and sub-scapular skinfold thicknesses (3). Women from Senegal lost 1.7 kg of body weight while the sum of triceps, biceps and subscapular skinfolds only decreased 0.5 mm (2). Comparable results were obtained in other Beninese women (26). This indicates that seasonal body weight changes do not necessarily consist of only fat, but that fat-free mass also changes.

It can be concluded that in spite of the differences in estimated levels of fat mass between the three methods, they indicated a similar seasonal change in body composition.

Since, to our knowledge no information is available on seasonal changes in body composition of populations who experience large seasonal weight changes, more research is needed on this subject.

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CHAPTER 6.

GENERAL DISCUSSION

In this thesis the effects of seasonal changes in food availability on the energy balance and nutritional status of rural Beninese women were investigated. When human energy balance gets into a negative state, body's energy stores will be used. Therefore long-term serial measurements of body weight can provide a good indication of the yearly fluctuations in energy balance in a population. When body weight is lost, energy expenditure is decreased because of a lowered metabolic rate. Other ways to decrease energy expenditure would be by lowering physical activity, or by increasing metabolic efficiency (a lower metabolic rate without a change in weight or activity).

Seasonal changes in body weight and body composition

Body weight of subjects in Dogbo and in Manta was measured every two weeks during respectively a two year, and a one year period. Measurements of body weight were carried out more frequently than in most other studies on this subject (1-6), and a complete picture was obtained of the seasonal weight changes in the two study areas. The aim of the weight study (Chapter 2) was to investigate the difference between pre-harvest weight losses occurring in an area with one rainy season and in an area with two rainy seasons. In this study also the relation between body mass index (BMI) and pre-harvest weight loss was investigated.

Seasonal changes in body weight occurred in Dogbo as well as in Manta. In both areas body weight decreased significantly during the rainy season to arrive at a minimum level at the beginning of the harvest period. During the harvest period body weight increased again to arrive at a maximum level two to three months after the harvest period. Seasonal changes in body weight in Dogbo (two rainy seasons) were smaller than the weight changes in Manta (one rainy season). The decrease in body weight during the pre-harvest season in Dogbo is comparable to values reported for other rural African populations who live in areas with two rainy seasons (5-8). The decrease in body weight during the pre-harvest season in Manta was large, and only comparable to seasonal weight loss reported for a nomadic population (1).

An important question is whether seasonal weight losses have 'serious' consequences and should be worried about. Waterlow (9) states that changing energy expenditure by loosing body weight is only acceptable if good health and physical capacity will be maintained. In the present study we did not carry out measurements on physical capacity and health status. However, some remarks can be made on this subject on basis of measurements of BMI and body composition. Although body weight loss in Manta was larger than in Dogbo, it has to be considered that BMI of Manta men during the post-harvest seasons was larger than the BMI of Dogbo men. BMI's during the pre-harvest season arrived at about the same level. In Manta a significant correlation existed between BMI and pre-harvest weight loss. This suggests that the people with the larger body size experience the larger pre-harvest weight losses, which has also been reported in other studies (6-8). The measurements of body composition in a post-harvest and a pre-harvest season (Chapter 5) showed that seasonal weight changes do also consist of fat free mass. This indicates that seasonal weight loss is not only fat mass, and that physical capacity might be influenced due to a loss of muscle tissue during the pre-harvest season. During the pre-harvest season an important part of the population in Dogbo as well as in Manta have a BMI lower than 17, which is considered incompatible with good health and physical capacity (10). It can be concluded that although weight loss during the pre-harvest season is not necessarily harmful, it may have serious consequences for parts of the population.

Basal metabolic rate, activity pattern and physical activity level

Results of the pilot-study carried out among rural Beninese women (described in Chapter 1) showed that energy intake during the pre-harvest season was about 320 kcal/day lower than energy intake during the post-harvest season. However, BMR did not show seasonal changes. Variation in pre-harvest weight loss between individuals was large. This suggests that not all individuals experience the same seasonal food shortage, or that individuals may change their energy expenditure to different levels.

It was discussed in Chapter 3 whether pre-harvest weight losses are only related to decrases in energy intake or also to changes in energy expenditure caused by an increase in metabolic efficiency. This was studied in women with a BMI<18 and in women with a BMI>23 because different pre-harvest weight losses were found in the two groups of women. Furthermore women who had shown large or small pre-harvest weight losses in a previous year were studied (assuming that the same difference in weight loss would occur again).

The need to adapt the level of energy expenditure may exist if energy intake decreases markedly during the pre-harvest season. This happened in all four groups of women who were studied, although only statistically significantly in two groups (decrease of 160-260 kcal/day). It was observed that the level of energy intake was lower than the level of energy expenditure, even during the post-harvest season (difference of about 0.2-0.3 times BMR) (Chapter 4). Similar results have been obtained in other studies (11-13). However, it has to be kept in mind that energy intake and physical activity values should be regarded critically upon (14). It is possible that the measurements made in the present study underestimated the habitual energy intake of the women. However, the difference in energy intake between the post-harvest and the pre-harvest season is likely to reflect the true situation because the same methods to measure energy intake were used in the three seasons of measurement. Further it was found that changes in energy intake were reflected in changes in body weight and body composition. Women with a BMI>23 decreased energy intake during the pre-harvest season with 260 kcal/day and lost 1.6 kg of fat mass, and women with BMI<18 lost 0.8 kg of body weight consisting mainly of fat-free mass. Statistically significant changes in BMR expressed per unit body weight occurred only in the group of women with a BMI<18. Difference in BMR per unit body weight between the post-harvest and the pre-harvest season for the lean women (BMI<18) represented about 3 per cent of the mean value which can not be considered as physiologically significant. Only very thin women with a BMI<17 decreased BMR during the pre-harvest season in a physiological significant way through an increase of efficiency of about 12 per cent. This change in metabolic rate of 12 per cent is comparable to results obtained in Keys's study (15) and believed to be about maximally possible. The same change in metabolic rate is reported in a study with Ethiopian women (BMI=18.4)(8). The same kind of results have been reported by Shetty (17); BMR (per unit fat-free mass) of thin Indian men (BMI=16.6) was 13.8% lower than BMR of well fed counterparts (BMI=20.7). Waterlow (18) describes several mechanisms of how metabolic efficiency can be increased. On basis of the available data of the present study however, no conclusions can be made on this subject.

Next to a decrease in body weight and an increase in metabolic efficiency energy expenditure can be decreased by changing the physical activity pattern. In the present study physical activity pattern of the four groups of women showed seasonal changes. When the time spent on field work and walking (activities which consume a lot of energy) increased, often the time spent on household activities or food preparation decreased. It can not be concluded on basis of the available data that the women changed activity pattern consciously in order to decrease energy expenditure.
The changes in physical activity pattern did not bring about significant changes in physical activity level, in any of the four groups of women. An absence of significant seasonal

changes in energy expenditure has been reported previously (7,8), but this is not in line with a general point of view brought about by studies carried out in Burkina-Faso (19,20), Birma (21), The Gambia (12) and Iran (22) that energy expenditure shows large seasonal fluctuations. On basis of results obtained in the present study it may be concluded that seasonal changes in energy expenditure are probably not a determinant factor disturbing energy balance for all rural populations in developing countries.

Conclusions

- Pre-harvest weight losses in areas with one rainy season can be expected to be larger than pre-harvest weight losses in areas with two rainy seasons, even if the absolute amount of yearly rainfall is equal in the two areas.
- A loss of body weight during the pre-harvest season when food availability is low can not always be considered as only a loss of body fat which was stored during the post-harvest season when food availability was ample.
- People with larger body sizes (as indicated by a higher BMI) seem to loose more weight during the pre-harvest season than smaller people.
- It has to be considered that pre-harvest weight loss may have negative consequences for health and physical capacity for a part of a rural population.
- Within a population different ways are used to decrease energy expenditure in order to re-establish energy balance. A reduction of body weight is the most important way to decrease energy expenditure. An increase in metabolic efficiency seems only to occur in lean people because they can hardly afford to loose body weight.

Suggestions for further research

The present study was carried out in an area where seasonality was moderate. In areas where seasonality causes larger fluctuations in energy intake the necessity may exist for people to adapt energy expenditure to lower levels than observed in the study discussed in this thesis. In that case different kinds and magnitudes of adaptation might be used in order to regain energy balance. Therefore a follow-up study in such an area should be done and specific attention might be given to the following aspects:

- Seasonal weight losses seem to affect fat-free mass. What are the consequences for physical capacity if seasonal weight losses are large?
- What are health and social economic consequences of serious seasonal weight loss?
- The phenomenon of an increased metabolic efficiency should be studied in relation to BMI. Is it possible that women with BMI>18 also change metabolic efficiency?
- The energy cost of physical activities should be studied in different seasons in order to know whether changes in energy costs of activities occur.
- Finally there is a need for more information on household strategies which are developed to cope with seasonal food shortage.

The above mentioned topics are presently under study in an area in the north of Benin where large seasonal weight losses are found.

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SUMMARY

In developing countries food availability in rural areas may be limited during certain seasons. These seasonal changes in food availability can affect nutritional status and human health, and therefore they may have implications for social and economic planning policies. The aim of the studies described in this thesis was to investigate the effects of seasonal changes in food availability on the energy balance of rural Beninese populations.

In chapter 1 determinants of energy balance, the causes of seasonal cycling of food availability and the consequences for human energy metabolism are discussed. Three possible adaptive mechanisms in order to decrease energy expenditure when habitual energy intake is lowered are discussed: a loss of body weight, a change of physical activity and an increase of metabolic efficiency. Furthermore in Chapter 1 the results of a pilot study carried out in Benin among rural women are presented. Main findings of the pilot-study were that the women mainly lost weight as a reaction to a lowered food intake during the pre-harvest season. A decrease in BMR expressed per unit body mass was not found. Large variation existed between individuals in pre-harvest weight loss. 'Fat' women showed significant weight loss while lean women did not do so. The results of the pilot-study were used to formulate research questions which were at the basis of this thesis. These questions are also presented in Chapter 1.

In Chapter 2 the results of body weight measurements during several seasons among subsistence farmers who live in areas with one (Manta area) and two (Dogbo area) rainy seasons are presented. Pre-harvest weight loss in the two areas was compared and the relation between pre-harvest weight loss and body mass index (BMI) was examined. It was found that significant seasonal weight changes occur in both areas. Pre-harvest weight loss in Manta was larger than in Dogbo. Correlation existed between pre-harvest weight loss and BMI for Manta men, for Manta women and for Dogbo women suggesting

that the larger people experience larger pre-harvest weight losses. During the pre-harvest season 5-10% of the population have a BMI<17, which may constitute a risk to health.

In Chapter 3 and 4 the following research questions are dealt with. Within a population large differences in pre-harvest weight loss exist between individuals, which is possibly related to BMI. This suggests that not all individuals experience the same seasonal food shortage, or that they adapt their energy expenditure to different levels. It was investigated whether pre-harvest weight losses are only related to decreases in energy intake or may be influenced by changes in energy expenditure caused by an increased metabolic efficiency. Furthermore the relation between pre-harvest weight loss and daily activity pattern and physical activity level (PAL) was studied, by measuring basal metabolic rate (BMR), energy intake, physical activity pattern and PAL. Subjects were women from Dogbo with a BMI<18 (n=18), with a BMI>23 (n=16), women who had shown a small pre-harvest weight loss in a previous year (n=18) and women who had shown a large pre-harvest weight loss (n=15) in a previous year. All subjects had farming as main activity and were non-pregnant. The main findings were that energy intake during the pre-harvest season decreased in all four groups with 160-260 kcal/day to arrive at the low level of about 1.3-1.4 times BMR. The daily activity pattern showed seasonal changes in all four groups. However, the resulting PAL did not change throughout the year in any of the four groups, but stayed at a level of about 1.7 times BMR. PAL was also higher than energy intake during the post-harvest seasons, and it is discussed that the measured energy intake may have underestimated habitual energy intake of the women. Seasonal weight loss did not occur in women who had shown a small pre-harvest weight loss in a previous year. The other groups of women showed seasonal weight changes. Only BMR of women with a BMI<18 decreased statistically significantly with 3% during the pre-harvest season. This decrease was still significant when BMR was expressed per unit body weight. A physiologically significant decrease in BMR was experienced by five very thin women with a BMI<17 who decreased BMR with about 12% during the pre-harvest season. It was concluded that individuals use different adaptive mechanisms in order to decrease energy expenditure. Most important mechanism is by lowering body weight. Only lean people who can hardly afford to loose weight may increase metabolic efficiency.

Chapter 5 describes the results of a study in which body composition of 24 Beninese women was assessed in a pre-and post harvest season by skinfold and bioelectrical impedance measurements and by deuterium oxide dilution technique. Fat mass assessed by the deuterium oxide method was significantly lower (about 1.5 kg) than the assessed values by the two other methods. However, all three methods indicated that the increase in body weight of 0.8 kg between the pre- and post-harvest season was mainly due to an increase in fat-free mass. Fat mass did not change.

In chapter 6 the general discussion is given. The main findings of the studies are discussed and suggestions for further research are made. It is considered important to carry out a follow-up study in an area where seasonality causes larger fluctuations in energy intake.

SAMENVATTING

In ontwikkelingslanden kan de voedselbeschikbaarheid beperkt zijn gedurende bepaalde seizoenen van het jaar. Dit seizoensgebonden voedseltekort kan de voedingstoestand en de gezondheid van mensen beïnvloeden, en kan daarom sociaal-economische consequenties hebben. Het doel van de in dit proefschrift beschreven onderzoeken was de effecten van de seizoensfluctuaties in voedselbeschikbaarheid op de energiebalans van Beninese plattelandsvrouwen te bestuderen.

In hoofdstuk 1 worden de determinanten van de energiebalans besproken. Tevens wordt er wordt een kort overzicht gegeven van de oorzaken van de seizoensfluctuaties in voedselbeschikbaarheid en de mogelijke gevolgen voor de menselijke energiebalans. Er worden drie mogelijke adaptatiemechanismen besproken om de menselijke energiebesteding te verminderen als reactie op een daling in de gebruikelijke energie opname: een verlies van lichaamsgewicht, een verandering in fysieke activiteit en een verhoging van de metabole efficiëntie. Verder worden in hoofdstuk 1 de resultaten van een vooronderzoek, uitgevoerd in Benin, besproken. De belangrijkste resultaten van dit vooronderzoek waren dat vrouwen voornamelijk gewicht verloren als reactie op een daling in de energieopname gedurende het seizoen voorafgaand aan de oogst. Een daling in basaalmetabolisme uitgedrukt per kg lichaamsgewicht werd niet waargenomen. Er bestonden grote verschillen in de mate van seizoensgewichtsverlies tussen personen. 'Dikkere' vrouwen verloren een significante hoeveelheid gewicht in het seizoen voorafgaand aan de oogst, terwijl zo'n gewichtsverlies niet optrad bij 'dunne' vrouwen. De resultaten van het vooronderzoek zijn gebruikt om de vraagstellingen van dit proefschrift te formuleren. Deze vraagstellingen staan ook beschreven in hoofdstuk 1.

In hoofdstuk 2 staan de resultaten beschreven van een onderzoek naar de seizoensmatige gewichtsfluctuaties van Beninese plattelandsbevolkingen, die in een gebied met één

(Manta) respectievelijk twee (Dogbo) regenseizoenen wonen. Het gewichtsverlies gedurende het seizoen voorafgaand aan de oogst voorkomend in de twee gebieden is vergeleken, alsmede de relatie tussen het gewichtsverlies en de 'body mass index' (BMI; gewicht (kg)/lengte^2 (m)). In beide gebieden kwamen significante seizoensmatige gewichtsverliezen voor. Het seizoensmatige gewichtsverlies in Manta was groter dan het gewichtsverlies in Dogbo. Er bestond een significante correlatie tussen het gewichtsverlies gedurende het seizoen voorafgaand aan de oogst en de BMI voor de mannen en vrouwen van Manta, en voor de vrouwen van Dogbo. Dit suggereert dat de 'dikkere' mensen meer gewicht verliezen gedurende het seizoen voorafgaand aan de oogst dan 'dunne' mensen. Gedurende het seizoen voorafgaand aan de oogst daalt de BMI van 5-10% van de onderzoekspopulatie beneden de 17, wat een risico zou kunnen inhouden voor de gezondheid.

In hoofdstuk 3 en 4 zijn de volgende vragen onderzocht. Binnen een bevolkingsgroep bestaan grote verschillen in seizoensmatig gewichtsverlies tussen personen, wat mogelijk gerelateerd is aan BMI. Dit suggereert dat niet alle personen te maken hebben met een seizoensmatige daling in de voedselopneme, of dat personen hun energiebesteding op verschillende niveaus aanpassen. Er is onderzocht of seizoensmatige gewichtsverliezen alleen bepaald worden door een daling in de energie opname of mogelijkerwijs beïnvloed worden door een verandering in metabole efficiëntie. Verder werd de relatie bestudeerd tussen seizoensmatig gewichtsverlies en het fysieke activiteitenpatroon en de daaruit voortkomende energiebesteding. Hiervoor werden basaalmetabolisme, energie opname, activiteitenpatroon en energiebesteding gemeten in drie verschillende seizoenen. De proefpersonen waren vrouwen uit Dogbo met een BMI<18 (n=18), met een BMI>23 (n=16) en vrouwen die in een voorafgaand jaar kleine seizoensmatige gewichtsverliezen hadden (n=18) en vrouwen die grote seizoensmatige gewichtsverliezen hadden (n=15). Alle vrouwen bedreven voornamelijk de landbouw en geen van de vrouwen was zwanger. De energie opname in de 4 groepen vrouwen daalde in het seizoen voorafgaand aan de oogst met 160-260 kcal/dag tot een niveau van ongeveer 1,3 - 1,4 maal het basaalmetabolisme. Het dagelijkse activiteitenpatroon van de vrouwen vertoonde veranderingen gedurende de verschillende seizoenen. De resulterende energiebesteding veranderde echter niet gedurende de seizoenen, maar bleef op een niveau van ongeveer 1,7 maal de BMR. In alle seizoenen werd gevonden dat de energiebesteding hoger lag dan de energie opname. Er wordt besproken dat de gemeten energie opname mogelijk de werkelijke energie opname onderschat. Seizoensmatig gewichtsverlies kwam voor in alle groepen vrouwen, behalve in de groep die in het voorafgaande jaar weinig gewicht had verloren. Alleen het basaalmetabolisme van vrouwen met een BMI<18 daalde met 3% (statistisch significant) gedurende het seizoen voorafgaand aan de oogst. Deze daling bleef significant wanneer het basaalmetabolisme werd uitgedrukt per kg lichaamsgewicht. Een fysiologisch significante daling in basaalmetabolisme van 12% werd gevonden bij 5 erg dunne vrouwen met een BMI<17. Er is geconcludeerd dat personen verschillende adaptatiemechanismen gebruiken om hun energiebesteding te verminderen gedurende het seizoen voorafgaand aan de oogst. Het belangrijkste mechanmisme is een verlies van lichaamsgewicht. Een verhoging van de metabole efficiëntie kan optreden bij 'dunne' mensen die zich geen groot verlies van lichaamsgewicht kunnen veroorloven.

In hoofstuk 5 wordt een onderzoek besproken waarin de lichaamssamenstelling van 24 Beninese vrouwen is bepaald met huidplooidiktemetingen, met impedantiemetingen en met een deuteriumoxide oplossing in twee seizoenen. De hoeveelheid lichaamsvet bepaald met de deuteriumoxide methode was significant lager (ongeveer 1,5 kg) dan de bepaalde hoeveelheid met de andere methoden. Alle drie de methoden gaven echter aan dat de toename in lichaamsgewicht van 0,8 kg gedurende het seizoen na de oogst voornamelijk bestond uit vetvrije massa.

Hoofstuk 6 beslaat de algemene discussie. De voornaamste resultaten worden besproken en suggesties worden gegeven voor verder onderzoek. Het zou nuttig zijn om een vervolgonderozek uit te voeren in een gebied waar de voedselbeschikbaarheid sterker variëert met de seizoenen.

CURRICULUM VITAE

Jan Werner Schultink werd op 4 juli 1959 geboren te Emmen. In 1977 behaalde hij het atheneum-B diploma aan het Christelijk Atheneum te Arnhem. In datzelfde jaar begon hij zijn studie aan de toenmalige Landbouwhogeschool te Wageningen. In januari 1985 behaalde hij het doctoraalexamen met als hoofdvak Voedingsleer en als bijvakken Gezondheidsleer en Dierfysiologie. Van januari 1985 tot en met juli 1985 was hij werkzaam bij de International Course in Food Science and Nutrition. In september 1985 begon hij met de voorbereiding van een onderzoek naar de seizoensinvloeden op de energiebalans van Afrikaanse plattelandsvrouwen, waarvoor hij van oktober 1985 tot en met november 1986 in de Republiek Benin in West-Afrika verbleef. Van december 1986 tot en met april 1987 was hij bezig met de uitwerking van de resultaten van voornoemd onderzoek. Per 1 mei 1987 trad hij in dienst van de Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) en verrichtte met financiële steun van de Stichting voor Wetenschappelijk Onderzoek van de Tropen (WOTRO) het in dit proefschrift beschreven onderzoek. Vanaf oktober 1990 is hij werkzaam bij de Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in Duitsland.