FOOD AND NUTRITION INSECURITY IN NORTHERN BENIN: IMPACT ON GROWTH PERFORMANCE OF CHILDREN AND ON YEAR TO YEAR NUTRITIONAL STATUS OF ADULTS

E. A. D. ATEGBO

Promotor : Dr. J.G.A.J. Hautvast
Hoogleraar in de leer van de voeding
en de voedselbereiding

Co-promotor: Dr. Ir. J.M.A. van Raaij
Universitair hoofddocent bij de vakgroep
Humane Voeding

Eric-Alain D. ATEGBO

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PROPOSITIONS

I

The magnitude of the stress created on energy balance of rural farmers by seasonal variations in food availability, even under unimodal climatic conditions, is too limited to involve metabolic adaptation as an energy sparing mechanism (In this thesis).

II

The transitory food and nutrition insecurity experienced by rural populations of developing countries as a consequence of seasonal variations in rainfall, results in a depressed growth velocity for children (In this thesis).

III

Among subsistence female farmers, changes in activity pattern during pre-harvest seasons result in an increased energy expenditure rather than in a decreased energy output (In this thesis)

IV

Although the average body weight loss experienced by Beninese subsistence farmers living in an area characterized by a unimodal climate was limited, large inter-individual variations were observed (In this thesis)..

V

Coping with uncertainty in food supply does not limit itself to meeting particular nutritional and health criteria. It also implies being happy and feeling secure about food. (De Garine I. & Harisson GA. Coping with uncertainty in food supply. Clarendon Press. Oxford 1988)

VI

Despite international nutrition guidelines, relief programmes often fail to provide the minimum Recommended Dietary Allowances (RDA) of essential micronutrients such as vitamin A, thiamine, niacin, vitamin C, iron and folic acid (Toole MJ. Lancet 1992;339:1214-6).

VII

Social facilitation has a causal influence on eating which increases food intake (Reed M. & Castro JM. Physiology and Behaviour 1992;52:749-54).

VIII

Promoting breastfeeding when countries undergo change will allow women to retain valuable traditional practices while adopting important western ones, such as modern methods of contraception and employment outside the home.
(Alan Berg & Susan Brems. World Bank Technical paper No 102,1989)

IX

The term "Structural adjustment with a human face" is misleading, since it results in a drastic reduction of the budget devoted to health and education, and in a tremendous loss of job opportunities.

X

Democracy is a prerequisite for sustainable socio-economic development, but democracy alone can not improve the economical situation in the Third World countries.

Propositions belong to the thesis of Eric-Alain D. Ategbo entitled "Food and nutrition insecurity in northern Benin: impact of growth performance of children and on year to year nutritional status of adults".

Wageningen, The Netherlands, 21 June 1993.

Samuel reçoit ceci en hommage posthume

Elisabeth, ceci est le couronnement de tes efforts

Bless the Lord, O my soul, and forget not all his benefits. Ps 103 vers 2.

ABSTRACT

The purpose of the study was to examine the consequences of a substantial nutritional stress, created by an unimodal climate on the energy balance of adults and on children's growth. Coping strategies of adults, at an individual level, with the seasonal fluctuations in food availability were also considered.

Body weight was measured during three consecutive years among members of subsistence households. Weight changes occur between pre and post-harvest periods. Size of weight loss was moderate and comparable to weight loss reported for farmers in areas with less substantial seasonal fluctuations in food availability. The year to year repeatability of seasonal weight change may be mainly influenced by factors which are not regulated by rainfall pattern. Among children aged 2 to 9 years, growth performances were depressed during pre-harvest periods. Growth velocities attained during post-harvest periods can not be considered as catch up growth. When compared with the reference, growth velocities slowed down with increasing age. Prevalence of stunting was high and stable at about 30%.

Resting metabolic rate, activity pattern, energy cost of cycling and food intake were measured during two consecutive years in a subgroup of 45 women. Resting metabolic rate and energy cost of cycling were stable throughout the year. Changes in activity pattern result in increased energy expenditure in pre-harvest periods. Energy, protein and iron intakes were adequate to cover the yearly needs. However, the bio-availability of iron in the local diet needs further study. Intake of retinol equivalents was below the recommended dietary allowance during pre- and post-harvest periods, and it is unknown whether the excessive intake during the intermediate period can produce adequate body stores for the whole year's needs.

It is concluded that the stress on energy balance created by an unimodal climate may result in a modest weight change and does not necessarily result in metabolic or behavioural adaptation. However, the present study suggests that the growth of children is substantially depressed by the seasonal food shortage.

CONTENT

PREFACE

Since 1983, there has been a university cooperation programme between the Faculty of Agricultural Sciences of the National University of Benin and two Dutch universities: the Wageningen Agricultural University and the State University of Utrecht, financed by the Netherlands Organisation for International Cooperation in Higher Education (NUFFIC). The main aim of this cooperation project was to build and to strengthen a Department of Human Nutrition and Food Sciences in Benin. In this perspective, a training programme was set up to provide well-trained local staff members to this young institution. The present thesis is a partial achievement of this goal.

Due to the cooperation project between Benin and the Netherlands, it was possible for me to undertake the present training. This was possible with the financial support from the Dutch government through the NUFFIC. I am very grateful to the Dutch government who made everything possible.

The research programme is part of a EC-STD funded multicenter study with the following main researchers: Professor Dr A Ferro-Luzzi (Rome) as the coordinator, Professor Dr JGVA Durnin (Glasgow), Professor Dr PS Shetty (Bangalore) and Professor Dr JGAJ Hautvast (Wageningen). The Wageningen STD team consists of Professor Dr JGAJ Hautvast, Dr Ir JMA van Raaij and Dr AP den Hartog. The study in Benin was principally carried out by two PhD students, one of them being Ir MJ van Liere and the other one is the author of this thesis. We both share the research topic of *Seasonal fluctuations in food availability in rural households in northern Benin.* However, each of us studied the population from a different perspective.

Professor Dr JGAJ Hautvast gave me the opportunity to carry out this research in his department. I gratefully acknowledge the confidence he had in the young generation, and I thank him for the stimulating discussions we had together in the Netherlands and in Benin. His visit in the field was a moral booster.

Dr Ir JMA van Raaij, you supervised my work in an excellent way. Together we had very useful brain storming sessions and discussions. Your visits to Benin were really useful. We worked a lot, but we also had social activities which made me feel at ease every time we got together and this has surely contributed much to the fine working conditions we both experienced. I would like to thank you for everything.

Dr AM N'Diaye and Dr MC Nago believed in my capabilities and recruited me as a staff member of the university. That was where everything started. Moreover, they

show continuous interest in the training of the young staff of our institution. I would like to show them my gratitude.

I want to thank Dr Ir FLHA de Koning for our fine, fruitful collaboration and the interest he showed in the study. More than a colleague, you are a friend. I would like to take this opportunity to express my recognition.

The International Course in Food Sciences and Nutrition (ICFSN) of the International Agricultural Center of Wageningen was an intermediate step in between Benin and the Department of Human Nutrition. In this course, I learned a lot from a friendly staff and I would like to thank Dr Ir F van der Haar, Ir T van der Briel and Ir W Klaver for their advice, their willingness to help me whenever it was necessary and the good times we spent together.

I am very much indebted to the staff of the Department of Human Nutrition of Wageningen Agricultural University for every single thing everyone did to help me during the preparation, data analyses and reporting phase of this study. I would like to assure you that you succeeded in making me feel at home here in Wageningen.

I would also like to thank the Central Service Department of the Biotechnion for the drawing of figures and photography.

Despite the enormity of the task, the field work went smoothly and according to plan. The credit for this goes to all those who were actively involved in the study and I enjoyed working with them.

- The personnel of the Department of Nutrition and Food Sciences in Benin: Celestin Ayité, Lyne Mahouekpo, Cyriaque Hinson and Génerose Dalodé.
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- The Beninese field workers: Kouaro T Josephine, Boki A Paulette, Yaconkou N'Tieta, N'Tcha Tempa, Bagri Pierrette and N'Tia Loreen.

I found here and fit in a West african family. With the members of this family I shared a lot of experiences. As a member of this family I would like to mention:

- Thiendou, Coumba, Baba, M'baké and Djibi. You are just wonderful.
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Next to my African family, I also have a Dutch family. I would like to mention Marylou, Annelies, Pauline, Fré, Jupie and Frida. With you I did not feel an outsider and this was very important in determining how everything went. Dank U.

A special word goes to my colleague and friend Marti. Together, we shared the difficulties of carrying out research in a very remote area. I will not forget our long meetings with our fieldworkers in order to have everything under control. Your contagious enthusiasm was very helpful. Together, we also shared the tough task of analyzing data and writing articles. I would like to thank you for all that. I wish you all the best.

To my colleagues Dossa Romain, Tangni Emmanuel, Rock Mongbo, Simplice Vodouhè and Rigobert Tossou, for the time we shared in Wageningen. I wish you a lot of success.

Wageningen, June 1993 Eric-Alain D ATEGBO

CHAPTER 1

GENERAL INTRODUCTION

In developing countries, rural areas in which food production is exclusively rainfed often experience periods of food scarcity which are usually called the "hungry seasons" (1-5). Duration and severity of the hungry season are mainly related to rainfall pattern (3,4). Food shortage usually occurs during the rainy season, a period of intensive agricultural labour, when food stocks are almost depleted (2,3,6). As a result, households of small scale farmers, engaged in a subsistence farming system are subject to seasonal fluctuations in food availability (1-4). Seasonal fluctuations in food availability may determine a human being's health and his socio-economic performance. Seasonal food shortage may also influence children's growth pattern, and may therefore be considered as a socio-economic and public health issue. However, the phenomenon is recurrent and people usually take actions to alter the effects of the seasonal food shortage. Actions may be taken at the community level or at the household level. Beside those strategies worked out before the establishment of the hungry season, some adjustments are usually made at the individual level in order to cope with the fluctuations in food availability. These measures are used in a later stage when compared to strategies, and are summarized by the term "adaptations".

Recently, studies on the effects of seasonal variations in food availability on many facets of life such as energy intake, energy expenditure, nutritional status, activity pattern and child growth performance have received a lot of attention (5-23). However, they are not conclusive about the type of adaptations used by people in free living situations to cope with seasonal food shortages, and the extent to which those adaptations can be used remains unclear. The mild climatic conditions experienced by most regions where studies have been carried out was used as an explanation for the lack of evidence for either metabolic or behavioural adaptation to overcome seasonal food shortage. So far, very little is known about areas with more substantial seasonal stress.

In this chapter, the influence of seasonal food shortage on energy balance will be discussed and the adaptive processes used by individuals to cope with this phenomenon will be considered as well. Next, the consequences of seasonal variation in energy expenditure and the effects of seasonality on children's growth performance will be discussed followed by the issue of food and nutrition security in rural areas of developing countries. Finally, the study and its objectives will be presented.

Seasonality and energy balance

In the subsistence farming system of developing countries, rainfall pattern determines agricultural fieldwork and harvest periods as well as post-harvest periods. Food availability and human energy expenditure, therefore depend on the rainfall pattern.

Generally, after the harvest the staple crop is stocked and this stock has to provide food until the next harvest. However, food supply may diminish during the period just before the harvest, resulting in a lowered food intake during the period of intensive agricultural fieldwork. Studies focusing on seasonal variations in food intake of African and Asian farmers (5-12) confirmed that the level of daily energy intake changes throughout the different seasons. Especially during pre-harvest seasons, energy intake may be lower (6,10,11,23) than the maintenance requirement estimated as 1.4 x BMR (Basal Metabolic Rate) by a joint FAO/WHO/UNU Expert Consultation (24).

In contrast with food intake, agricultural work is at its peak during rainy season. In this period, fields have to be prepared, crops sown and farms maintained. Recent studies on seasonal variations in activity pattern of rural populations (5,9,10,13-16), all confirm that energy expenditure during the rainy season is higher than during the slack period, the dry season after the harvest.

If the periods of food shortage match with periods of heavy work and periods of food abundance with periods of relative rest, people experience a succession of negative and positive energy balances. This results in a seasonal variation in the energy balance. Energy balance is usually defined as the difference between food energy intake (metabolisable energy) and energy expenditure. The daily energy expenditure composes of three components: basal metabolic rate (BMR), dietary induced thermogenesis (DIT) and work induced thermogenesis (WIT). The BMR can be defined as the rate of energy expenditure at complete rest, without any physical activity and measured under strictly standardized conditions (lying down, shortly after being awake, in thermoneutral state, 12-14 hours after the last meal, emotionally undisturbed, without any disease or fever). BMR is the major component of daily energy expenditure and covers about 50-60% of the total daily energy expenditure in an average adult individual. The dietary induced thermogenesis (DIT) is the increase of energy expenditure above BMR in response to food ingestion. The level of DIT depends on the amount and the type of the food ingested, and amounts to about 10% of daily energy intake. The WIT represents the amount of energy expended for physical activities. The 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.

In each season, the body may use different adaptive processes to adjust energy expenditure to the level of intake.

Adaptation in energy expenditure: definition and mechanism

Keys et al (25) stated years ago: "It might seem entirely reasonable that the energetic processes of the body diminish in intensity as the exogenous food supply is reduced...it is reasonable in the sense that a wise man reduces his expenditure when his income is cut". In their work on the biology of human starvation, "adaptation" was defined as a "useful adjustment to altered circumstances".

Waterlow (26) restricts the term adaptation to those physiologically-determined changes that maintain relative constancy within a definable range. This physiological adaptation would be characterized by four attributes: (a) energy adaptation is an integration; (b) it maintains a steady state; (c) the steady state is within a preferred range; (d) the adaptation is usually reversible if the environment changes (26).

A working definition in the context of nutrition is given by the Expert Committee of the FAO/WHO/UNU in its 1985 report (24): " 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". In this definition, the words "new" and "different" are carefully chosen. The former refers to short-term adaptation as occurs in nutritional balance studies. The latter is appropriate only when long-term adaptations are involved. However, the borderline between the short-term and the long-term is not specified. According to Waterlow (27), a discrepancy in energy intake and energy expenditure may lead to three types of adaptations: biological adaptation, behavioural adaptation and metabolic adaptation.

Biological adaptation

Biological adaptation is operationalized by an alteration in body size and/or in body composition (27). Reduced food intake and increased labour result in a mobilisation of body energy stores to fill the gap, thus in a body weight reduction. Average weight loss due to seasonal fluctuations in food availability is known to vary on average from 1 to 3 kg, corresponding to 2-5% of body weight (7). Large between-individual variations have been reported with respect to seasonal weight changes. Some subjects may lose a substantial amount of body weight, up to 7 kg or more (2,8). It has also been reported that pre-harvest weight loss is related to body size (1,8,9). Reported weight losses as a response to seasonal changes in food availability are moderate but it is still unclear what the situation will be under more substantial seasonal stress. A reduction of body weight or a change in body composition seems to be the most widely used adaptative mechanism. When an individual is in negative energy balance, energy will be mobilized from the body stores, resulting in a reduction in body weight and a change in body composition. To produce energy, free fatty acids mobilized from the body stores are transduced into the citric acid cycle, producing ATP, in variable quantities, depending on the chain length and degree of unsaturation of each acid (28). As a consequence of the body weight loss, BMR and WIT will be lowered because there is less tissue to maintain and to move, and total energy expenditure will be decreased. It is unclear so far, whether there is a limit to body weight loss as a response to food shortage or whether the process of losing weight may continue indefinitely, until a new energy balance is established.

Behavioural adaptation

A behavioural adaptation means modification of activity pattern (27). This type of adaptation is logical, it is feasible, and it is widely believed to occur in real life. It is also the one of the three adaptive responses with potentially the largest social and public health implication (29). In real life, the mechanism that can be called upon to restore energy equilibrium by adjusting energy output, may operate either by cutting out entire blocks of specific tasks, by reducing the time allocated to various activities, by slowing down the pace, or by diminishing the intensity at which those activities are carried out.

In spite of the fact that this behavioural adaptation potentially might be the most powerful one, direct evidence of reduced physical activity in response to low energy intake is scarce (30).

<u>Metabolic adaptation</u>

Metabolic adaptation includes mechanisms which increase the efficiency of energy metabolism. Best documented evidence of metabolic adaptation is the reduction of BMR per unit body weight associated with a large reduction in response to a prolonged substantial fall in energy intake (25). According to Waterlow (27), there are several possibilities reflecting modification of metabolic efficiency, to account for this additional fall in BMR: (a) decreased work of the heart, (b) decreased rate of protein turnover, (c) decreased sodium pump activity, (d) alterations in metabolic pathways, (e) increased yield of ATP per unit oxygen used, (f) decreased substrate cycling, (g) increased efficiency in energy transduction.

It is obvious that the absolute energy cost of absorbing and processing nutrients decreases when intake is reduced. On average, DIT accounts for a daily energy expenditure of approximately 10% of the caloric intake. It is still unknown whether the thermic response to a meal decreases, stays the same or increases after weight reduction; results on this topic are contradictory (31-33). If a negative energy balance does result in a decrease of the thermic response to feeding, it might be a mechanism to increase metabolic efficiency.

The mechanisms by which the metabolic rate is altered in response to a change in energy, may be mediated by change in hormone metabolism. The available evidence indicates that suppression of T3-serum levels and sympathetic activity occurs in human beings as well as in animals during periods of caloric restriction (34-36).

Reduction in the total amount of physical activity as well as adjustment in the rate of doing work may be involved, and the metabolic efficiency could be increased by performing some physical activities in an energetically less costly way. According to Gaesser (37) and Whipp (38), phosphorylative-coupling and contraction-coupling efficiencies are determining factors in muscular contraction efficiency.

Seasonal variations in energy expenditure: its impact

The day to day life of rural households in developing countries is to a large extent determined by the rainfall pattern. During the rainy season, a lot of work has to be done and the rainy seasons are considered as the busiest periods for farmers (13-17). Unfortunately, this busy period coincides with the period when food intake is low (6,10,11,23). The consequence of such inadequate balance between food intake and energy expenditure is a reduction in body weight (11,12,16). The functional impact of seasonal body weight reduction is still not well documented. It has been reported that a reduction in physical work capacity and a deterioration of endurance and therefore deterioration of productivity may be attributed to stress in energy intake (39). So far, it is not known whether the magnitude of energy stress created by the seasonal food shortage is large enough to result in a reduction of productivity. If this is the case, the phenomenon of seasonal food shortage will have an important economic dimension. Other outcomes of the seasonal variations in rainfall are increased morbidity rate and temporary deterioration of the social network. It has also been reported that the outcome of pregnancy may be influenced by seasonality.

Seasonality and children's growth performance

As members of rural households, children are also exposed to the adverse effects of seasonal cycling in food availability. During the hungry season, children as well as adults experience stress in their food intake (40). This stress in food intake results in a deterioration in their growth performance. Growth velocity is depressed during the hungry season and again reaches again a higher rate during the post-harvest season (17,18). It has also been reported that the outcomes of the seasonal variation in food intake on children are a reduced physical work activity, a slow sexual maturation and a delay in the adolescence growth spurt (39,41).

The hungry period is always coupled with the rainy season. The prevalence of infectious diseases has been reported to be highest during the rainy season (7). In this particular period, the prevalence of water born diseases is at its highest level. The situation of children during the rainy season is worsened by the fact that mothers are required to work for long hours outside the compound, resulting in less care for the children (20,42). The children's nutritional situation is then highly influenced by seasonality. The mechanism by which children's nutritional status is influenced by seasonal variation in rainfall pattern is complex, and is mainly determined by the combined effects of reduced food intake because of seasonal food scarcity and infections due to the deterioration of hygiene and sanitation. However, the group of children may be considered as a rather heterogenous one as far as age classes are concerned and hardly anything is known about the extent to which each age group experiences the seasonal fluctuations in food availability.

Food and nutrition security in rural areas of developing countries

Food security is defined as insured access by all people at all times to enough food for an active and healthy life (44-46). Food security entails four conditions: (a) ensure adequate food production; (b) ensure that households have access to food; (c) ensure a stability on the market and a stable relation between income and food prices; (d) ensure adequate quality of food, from the point of view of appreciation by the consumer (local food habits) (47).

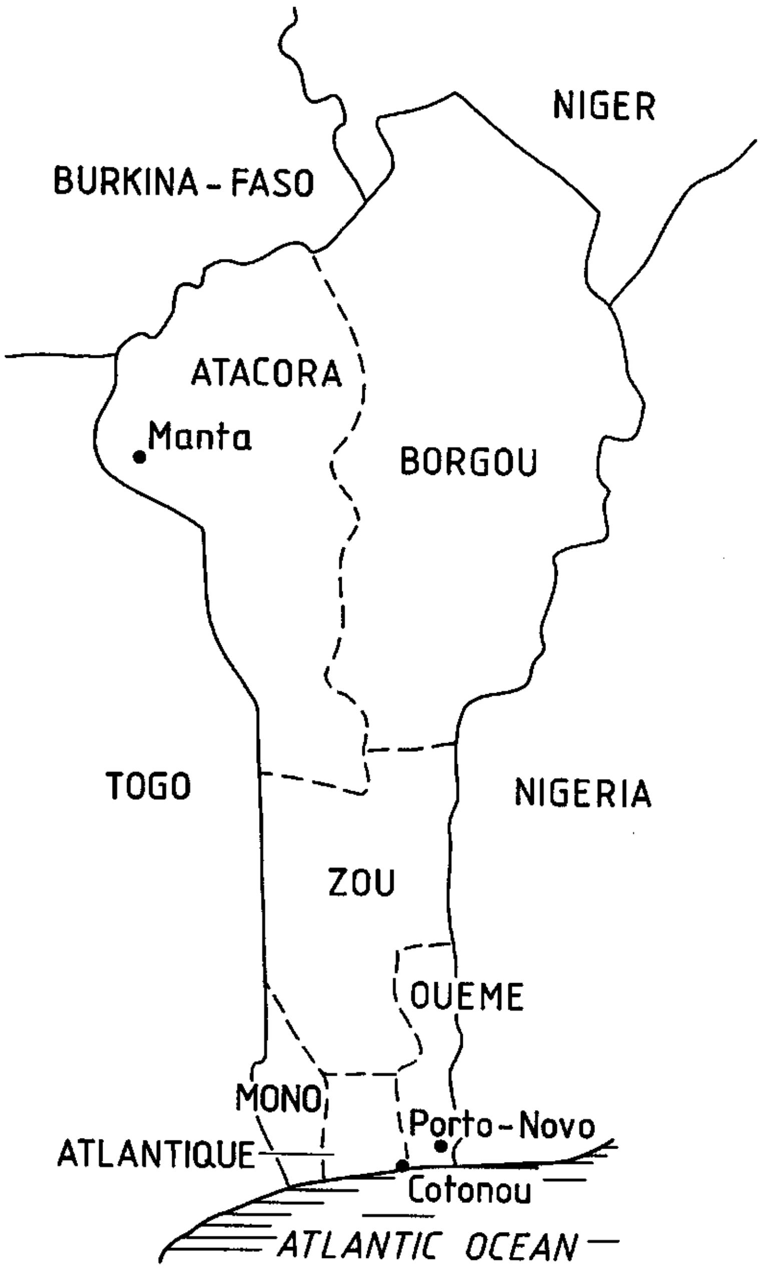
In rural areas of developing countries where agricultural production is determined by rainfall, adequacy of food production seems difficult to ensure since farmers can not influence rainfall. In case of inadequate production, redistribution of food between areas of abundance and zones of shortage may be considered as a solution. This option needs sound infrastructure to run fine. However, in rural areas of poor countries, infrastructure is minimal and roads are not always usable for cars during rainy seasons. Farmers of poor countries are generally small holders engaged in subsistence farming (2). They are little or not involved in income generating activities (2). Poor quality of food stores, can not ensure stable availability and this results in fluctuations in food prices. Therefore, access to food for rural farmers can be limited, exposing populations to food insecurity, which is defined as lack of access by all people at all times to enough food for an active life (46). However, this should be seen as transitory, since the situation may be reversed during the dry season, after harvest. Transitory food insecurity due to seasonality is most severe in Sub-Saharan Africa (46).

Food security does not take into account food quality, the concept of nutrition security does. Along with ensuring access to adequate quantities of food, nutrition security must ensure adequate quality, safety of food and water, and also consider specific nutrition needs of individuals (46). Unfortunately, seasonal variations in food availability and diseases on one hand and poor sanitation encountered in poor rural areas on the other hand (20,48), indicate that safety of food and water, proper intra-household food distribution and adequate diet composition may not be guaranteed in periods when food availability is limited. In this period, the population or part of it may face nutrition insecurity.

The study and its objectives

Between 1985 and 1987, a multicentre study was carried out with an objective to investigate seasonal influences on human energy balance. This study was a joint venture between the National Institute of Nutrition in Rome, The University of Glasgow and the Wageningen Agricultural University and nutrition institutions in Ethiopia, India, Benin, Nepal and Zimbabwe (11,12,23). These studies have reported weight changes ranging from 1 to 3% of the average body weight and failed to point out clearly whether metabolic and behavioural adaptations were used as response to seasonal food shortage. These situations were explained by the fact that studies were performed in areas showing low to moderate seasonal stress. It was then decided to investigate this topic in a more substantial way. More than the previous studies, the present research was carried out for more than one agricultural cycle to have a global view of the phenomemon and its repeatability from year to year. More attention is also given to the energy cost of standardized physical activity. Moreover, the present study also implies a socio-economic dimension, the purpose of which was to study on the same group the strategies used at the community or at the household level to cope with the seasonal food shortage. Results on the household's coping strategies will be presented in a separate dissertation. Results which are presented in this thesis are related to the anthropometric measurements and to adaptive processes used at the individual level to overcome seasonal food shortage. The study described here was carried out in the north-western region of the Republic of Benin (Figure 1), West Africa (43). The overall objective of this study was to investigate the extent to which food shortage occurs and which type of adaptive processes may be used at the individual level in order to cope with seasonal food shortage, in an unimodal

FIGURE 1: The Republic of Benin with an indication of the study area: Manta



climatic area, and to identify the effects of seasonal shortage on children's growth performance.

The overall objective was split up into the following specific objectives:

- **To describe seasonal effects in energy balance under unimodal climatic conditions.**
- **To analyse eventual adaptive processes at the individual level in response to seasonal food shortage.**
- **To study the effects of seasonal food shortage on children, with special attention to growth performance.**
- **To study which are the specific vulnerable groups who are annually exposed to the seasonal food shortage.**

To provide adequate answers to these questions, the present study was designed and was carried out from July 1989 to May 1992.

Chapter 2 to 6 are written as articles which will be submitted for publication in international journals and they deal with the following topics. Chapter 2 presents the results of a longitudinal weight study carried out during 3 consecutive years on rural men and women in villages of the north-western Benin. In Chapter 3, results of the effects of seasonal food shortage on children's growth performance are presented.
In Chapter 4, the question of metabolic adaptation is considered. Chapter 5 is devoted to the behavioural adaptation issue and Chapter 6 is dealing with the seasonal variation in energy and nutrients intake as well as food products use. The overall results of the study will be discussed in Chapter 7.

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CHAPTER 2

SURPRISINGLY LOW BODY WEIGHT FLUCTUATIONS IN RURAL BENINESE PEOPLE LIVING UNDER UNIMODAL CLIMATIC CONDITIONS: A 32 MONTH FOLLOW-UP STUDY

Eric-Alain D Ategbo, Marti J van Liere, Joop MA van Raaij, Frans LHA de Koning, Joseph GAJ Hautvast

ABSTRACT

Body weight of Beninese subsistence farmers and their wives living in an unimodal climate was measured over 3 consecutive years. Pre-harvest weight losses for men were about 6.4% and 4.8% of their average weight in 1990 and 1991 respectively. For women pre-harvest weight losses were 5.4% and 4.9% of their average weight in 1990 and 1991 respectively. Weak but significant associations were found between post-harvest weight gain and preceding pre-harvest weight loss, between year to year post-harvest gains and between year to year pre-harvest losses. In pre-harvest seasons, 6 to 10% of the subjects had a Body Mass Index (BMI) between 16.0 and 18.5 but only 2 to 5% had a BMI between 16.0 and 17.0 This study suggests that despite the substantial seasonal stress, the size of weight change remains moderate. Further, the same subjects may experience seasonal stress to the same extent every year.

KEYWORDS: pre-harvest weight loss, post-harvest weight gain, body mass index, unimodal climate.

INTRODUCTION

In developing countries, rural areas in which food production is exclusively rainfed, often experience periods of food scarcity which are usually called the "hungry seasons" (1-5). Duration and magnitude of the hungry season are mainly related to rainfall pattern (3,4). One of the consequences of seasonal food shortages is seasonal weight change (1,6). Reported average body weight losses due to seasonal variation in food availability vary from 1 to 3 kg, corresponding to 2 to 5% of average body weight (7). The modesty of the change in body weight was explained by the fact that most of the reported studies were performed under conditions of mild seasonal variations in food availability (3,7-9). The effects on body weight of seasonal fluctuations in food availability generated by a climate with only one rainy season a year, are not known. Moreover, knowledge about the repeatability of the seasonal weight change is limited. The present study, carried out on male and female subsistence farmers living in an area characterized by only one harvest a year, was designed to investigate the extent to which seasonal body weight changes occur in an unimodal climatic condition and the repeatability of this event from year to year. Findings are based on a longitudinal study on men and women of a rural population in the north-western part of the republic of Benin over a period of almost three consecutive years.

SUBJECTS AND METHODS

Study area

The present study was performed in five villages of the commune of Manta, situated in the ATACORA province, in the north-western part of the Republic of Benin. Manta is located at an altitude of 240 meters above sea level, between two mountain-ranges of about 500 meters altitude (10). Infrastructure in the study area is minimal. During rainy seasons when rainfall is at its peak, roads linking the research area to the province capital are almost inaccessible for cars. Study villages are within a radius of 10 km from the central village Koutangou of the commune of Manta. Altogether about 4,000 inhabitants are living in the five villages in the study area, nearly all are subsistence farmers.

Manta has an average annual rainfall of about 1300 mm, which is spread over one season, from May to September (Figure 1). Average daily temperature varies between 26 and 36°C with lowest temperature in the middle of the rainy season and highest temperature at the end of the dry season. Relative humidity varies between 80% during rainy season and 20% during dry season. The lowest humidity level is observed in December and January when the Harmattan, a dry and cool wind from the Sahara, is blowing.

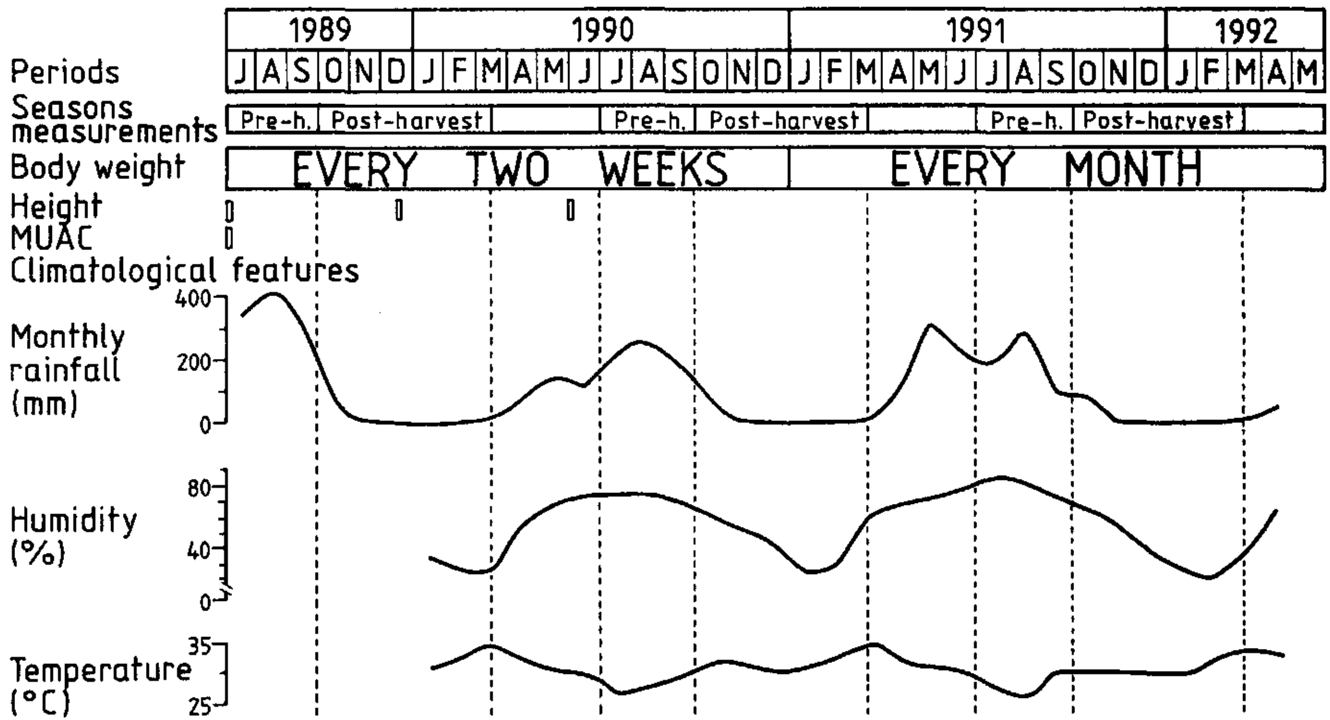
Food prices collected at the local market show a similar trend as the rainfall pattern. The price of sorghum, one of the staple foods, reaches its highest value in the middle of the rainy season and its lowest value in the dry season, during the harvest. The local health center attendance rate reaches its peak in the rainy season due to higher prevalence of infectious diseases in that period. There is however, a considerable drop in attendance rate during the dry season, reaching its lowest level at the end of the dry season, just before the rains begin.

Study design and subjects

Anthropometric measurements were carried out during three consecutive years, covering three pre-harvest and post-harvest periods (Figure 1). During the first 18 months of the study, body weight was measured every two weeks. This measurement frequency was reduced to once a month during the last 15 months of the study. Height was measured three times throughout the first year and mid-upper-arm circumference was measured at the start of the study (Figure 1).

The study started with a sample of 214 women and 198 men. The women were selected using the following criteria: age between 18 and 45 years, non-pregnant and non-lactating, mother of at least one child, and farming as main occupation. Once a woman was selected, her husband was automatically included in the sample. Some households were headed by women due to widowhood or because husbands had moved to the city. For this reason, women contributed slightly more to the sample size than men. When women became pregnant during the study period, data collection was continued but

FIGURE 1: Study design and climatological features of the Manta area



*) MUAC means mid upper arm circumference

results of these subjects were excluded from present analysis. A data set covering the whole period of measurement was obtained from a subgroup of 139 men and 114 women. Some characteristics of the subjects are given in Table 1.

TABLE 1: Anthropometric characteristics of subjects*

	Women		Men	
	All	Subgroup†	All	Subgroup†
Number	214	114	198	139
Age (years)	36.0±5.5	35.8±5.6	49.0 ±7.8	49.2±7.3
Weight (kg)	49.9±5.2	49.6±5.2	57.9±6.6	57.8±6.6
Height (cm)	158.7±5.7	158.4±5.6	169.0±5.8	169.3±5.9
Body Mass Index(kg/m^2)	19.5±1.8	19.4±1.7	20.3±1.8	20.2±1.9
M U A C‡ (cm)	20.0±1.8	20.1±1.8	32.3±2.2	32.1±2.0

*) Means ± SD; Characteristics as measured at the start of the study.
†) Subgroup of subjects on which complete data set is available.
‡) Mid upper arm circumference.

Measurements

Body weight was measured between 6.30 and 7.30 am at a central place of the village or, when houses were too spread out in a given village, measurements were held on two consecutive days at two different locations. Two days before the weighing session, a brief reminder was distributed to the participants. Measurements were done using 3 SECA platform spring balances (SECA, type 725; Vogel und Halke Mess-Und Wiege-Techniek, Hamburg, Germany). These scales were fixed on wooden boards and were placed on a horizontal surface. Before each weighing session, scales were calibrated, using calibration weights of either 40, 50 or 60 kg. To weigh a person, a balance calibrated with a weight closest to the weight of the subject was used. Care was taken to make the floor as flat as possible and to place the scale in such a position that it could not be moved. Subjects were wearing a minimum of clothing and body weight was measured to the nearest 0.5 kg.

Height was measured with the subject standing on a horizontal surface against a vertically placed metal board with heels together, chin chucked in and body stretched upwards to full extent and the head in a Frankfurt plane. Heels, buttocks and shoulders were in contact with the metal board to which a flexible metal tape had been fixed. Readings were made to the nearest 0.5 cm. Individual's height was calculated as the mean of the three measurements performed throughout the first study year.

Derived quantities

From height and body weight measurements, body mass index (BMI) was calculated as the ratio of body weight (kg) and squared height (m^2).

Pre-harvest weight loss was calculated as the difference between the highest recorded weight of the subject after the previous harvest and the lowest recorded weight before the next harvest.

Post-harvest weight gain was calculated as the difference between the highest body weight of the individual attained after the harvest and the lowest weight displayed by the subject shortly before the same harvest.

In addition to pre-harvest and post-harvest weight changes, body weight of subjects were compared with the average body weight of the subjects over two years period (January 1990 - December 1991).

Statistics

The Wilcoxon-Mann-Whitney test (11,12) was used to compare differences in pre-harvest weight losses as well as in post-harvest weight gains between men and women.

To compare body weight in the post-harvest and the pre-harvest seasons and to study the year-to-year variability in post-harvest weight gain as well as in pre-harvest weight loss, Wilcoxon 's matched pairs signed-rank test (11,12) was used. Spearman's correlation coefficient was used to study the year-to-year association of pre-harvest weight losses and that of post-harvest weight gains. The same type of measure of association was used to study the relationship between post-harvest weight gain and the previous pre-harvest weight loss. Spearman's correlation coefficient was also used to study the association between average BMI calculated over two years and the pre-harvest weight losses.

RESULTS

The variation of the mean body weight and of the mean monthly weight changes are shown in Figures 2 and 3 respectively. For all men and women, body weight decreased substantially during pre-harvest seasons from about July onwards, to reach its lowest level around September-October. Body weight increased rapidly in the harvest seasons from a minimum in October to a maximum in March.

Pre-harvest weight loss has been observed twice during the study period (Table 2). In 1990, the observed pre-harvest weight loss among men was on average 3.9 ± 2.1 kg (6.4 ± 3.2 % of their average body weight over 1990), while women showed a significantly lower ($p<0.01$) weight loss of 2.8 ± 2.4 kg (5.4 ± 4.6% of their average body weight over 1990). In 1991, the pre-harvest weight loss observed among men was on average 2.9 ± 1.9 kg (4.8 ± 3.0% of average body weight over 1991) and 2.5 ± 2.2 kg (4.9 ± 4.1% over 1991) for women. In men pre-harvest weight loss of 1990 was significantly higher ($p<0.05$) than pre-harvest weight loss observed in 1991.

Post- harvest weight gains were measured three times. During the first post-harvest period in 1989, men as well as women showed large weight gains reaching 4.8 ± 2.8 kg and 2.8 ± 2.6 kg (Table 2). Weight gain for men was significantly higher ($p<0.05$) than for women. For both men and women, the gain in 1989 was significantly larger ($p<0.01$) than in 1990 and 1991. In 1990 and 1991, the men showed post-harvest weight gains of 1.8 ± 1.8 kg and 1.7 ± 1.3 kg respectively, while women showed post-harvest weight gains of 1.8 ± 2.6 kg and 1.4 ± 2.2 kg respectively (Table 2). For men as well as for women the weight gains of 1990 and 1991 were not significantly different. For both men and women the post-harvest weight gains of 1990 and 1991 were significantly lower ($p<0.05$) than the preceding pre-harvest weight losses.

There was a weak but significant association ($p<0.01$) between the pre-harvest weight losses of 1990 and 1991 for both men and women (men $r=0.325$; women $r=0.343$). Similar strengths of association were found in post-harvest weight gains between 1989 and 1990 and between 1990 and 1991 (men $r=0.483$ and $r=0.322$;

FIGURE 2: Seasonal weight changes among adults in Manta as compared with a mean value averaged over 2 complete calendar years (January 1990-December 1991)

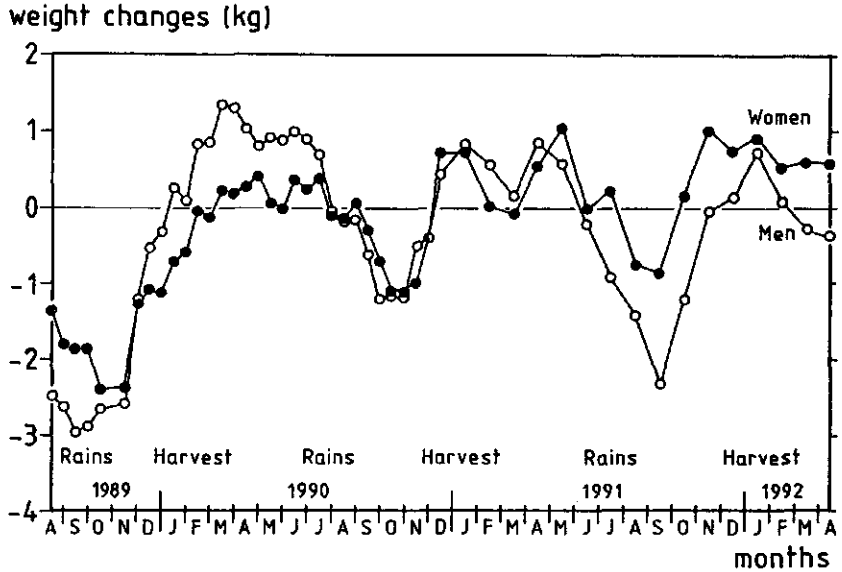


FIGURE 3: Absolute weight among subgroups of men (139) and women (114) with complete data set, in Manta over 3 consecutive years

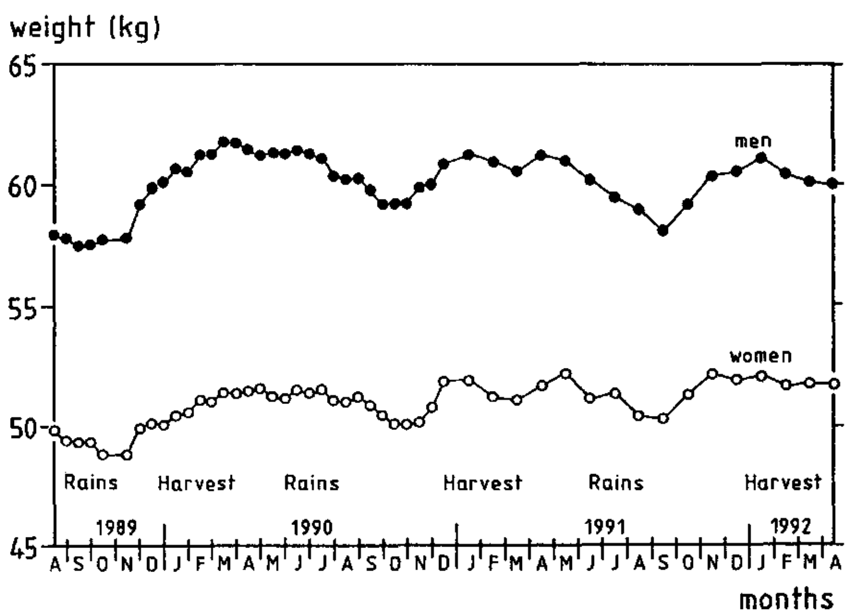


TABLE 2: Pre-harvest weight losses and post-harvest weight gains in adults in Manta*

	Women		Men	
	(n)	(kg)	(n)	(kg)
Post-harvest gain 1989	172	$2.8 \pm 2.6^{\dagger\ddagger\S}$	174	$4.8 \pm 2.8^{\dagger\S}$
Post-harvest gain 1990	135	$1.8 \pm 2.6^{\dagger\P}$	166	$1.8 \pm 1.8^{\dagger\P}$
Post-harvest gain 1991	114	$1.4\ 2.1^{\dagger\P}$	139	$1.7 \pm 1.3^{\dagger\P}$
Pre-harvest loss 1990	135	$2.8 \pm 2.4^{\dagger\ddagger}$	166	$3.9 \pm 2.1^{\dagger\|}$
Pre-harvest loss 1991	114	$2.5 \pm 2.2^{\dagger}$	139	$2.9 \pm 1.8^{\dagger}$

*) Means ± SD
†) Significantly different from 0 ($p<0.05$)
‡) Significantly different from value observed for men ($p<0.01$)
§) Significantly different from post-harvest gain of 1990 and 1991 ($p<0.01$)
‖) Significantly different from pre-harvest loss of 1991 ($p<0.05$)
¶) Significantly different from preceding pre-harvest weight loss ($p<0.05$)

women $r=0.256$ and $r = 0.346$). For both men and women significant associations ($p<0.001$ for men; $p<0.05$ for women) were found between post-harvest weight gain and the preceding pre-harvest weight loss. In 1990, correlation coefficients were 0.419 and 0.335 for men and women respectively and in 1991 they were 0.509 for men and 0.299 for women.

In Table 3, the distribution of the BMI is given for the various pre- and post-harvest seasons throughout the study. In none of the seasons was a BMI below 16 found. During pre-harvest seasons, 6-10 % of the subjects had a BMI between 16.0 and 18.5, but only 2 to 5 % had a BMI between 16.0 and 17.0. The average BMI over two complete years was calculated (21.1 ± 1.9 for men and 20.2 ± 1.8 for women). There was no association between BMI of individuals and their pre-harvest weight losses for 1990 (men $r = 0.105$; women $r = 0.100$) or their pre-harvest weight losses for 1991 (men $r = -0.116$; women $r = 0.122$).

TABLE 3: Body Mass Index (BMI) distribution of adults in Manta throughout different seasons*

	Body Mass Index (kg / m^2)			
	16.0-16.9	17.0-18.4	18.5-24.9	>25
		%		
MEN				
Post-harvest 1989	0.7	5.1	91.4	2.8
Post-harvest 1990	0.0	4.8	93.2	2.0
Post-harvest 1991	0.0	4.6	94.1	1.1
Pre-harvest 1989	4.5	5.4	89.2	0.9
Pre-harvest 1990	2.1	5.7	90.3	0.9
Pre-harvest 1991	3.2	6.3	89.5	1.0
WOMEN				
Post-harvest 1989	0.9	1.8	95.5	1.8
Post-harvest 1990	1.1	3.1	93.8	2.0
Post-harvest 1991	1.1	2.2	95.7	1.0
Pre-harvest 1989	5.2	3.4	90.4	1.0
Pre-harvest 1990	2.9	3.8	91.3	2.0
Pre-harvest 1991	3.1	3.1	92.8	1.0

*) No BMI below 16 was observed.

DISCUSSION

Mean pre-harvest body weight loss in 1990 was 3.9 kg for men and 2.8 kg for women corresponding to 6 and 5 % of their average body weight. Pre-harvest weight losses in 1991 were less pronounced. These decreases of body weight were higher than those reported for women living in a rural community in the southern part of Benin (1,2) and for other rural African populations who live in areas with two rainy seasons and who have two harvests per year (3,14). However, similar body weight losses (2.5-4 kg) during pre-harvest season were observed among other rural African populations, living under similar climatic conditions (2,15-19). The magnitude of pre-harvest weight loss in our research area, may seem rather modest since our results are in line with 5% body weight loss reported for areas with two harvests a year. However, in interpreting pre-harvest weight loss data, it is important to take into account the cropping pattern. Under an unimodal climate, the hungry period was expected to be longer than under a bimodal climate. Although Manta has an unimodal climate, a rather short "hungry period" has been observed, because farmers in Manta produce some short cycle crops such as early beans, early millet, maize and hungry rice, which can be harvested early, shortening the length of the hungry period to 8 to 10 weeks. This is as short as the hungry period reported for the South of Benin which has a bimodal climate (2).

A modest gender difference in body weight losses emerges from the analysis, women tending to have slightly smaller weight losses. This finding is in line with Schultink's (2) observation on the same population and is also similar to what was reported for farmer communities in other African countries (16,18-20). The explanation of this gender difference may be found in the fact that there is probably a difference in the level of energy expenditure. In rural areas, men are usually engaged in heavy physical activities, while women are engaged in activities that are time consuming but at a lower energy cost. From the pre-harvest weight losses observed in both groups, we could not find any significant difference between the two years for women, while for men weight loss during the pre-harvest season of 1990 was significantly larger ($p < 0.05$) than that of 1991. This gender difference may be explained by changes in activity pattern. Failure of the harvest of the hungry rice may explain this difference. Harvesting hungry rice is a task exclusively performed by men. Poor harvest of hungry rice in 1991 allowed men to work less, when compared to the previous year. This finding would suggest that the amount of pre-harvest weight loss may be influenced by the occurrence of any single event which can influence energy expenditure, food crop production as well as social events having implications for food availability (funerals, weddings and other ceremonies).

The between-individual variation in pre-harvest weight loss was large. It ranged from a non-significant weight loss of less than 1 kg to a weight loss of more than 5 kg. 36 % of men and 24 % of women showed weight loss of more than 4 kg during the pre-harvest seasons. A similar distribution of body weight losses was observed by Schultink (2) in the same population two years before.

The unique aspect of this study is that it was performed during 3 consecutive years. The duration of the study provided opportunity for studying the year-to-year consistency in seasonal weight changes. The significant associations found between year-to-year pre-harvest weight losses, between year-to-year post-harvest weight gains and between post-harvest weight gain and the preceding pre-harvest weight loss suggest that the same subjects tend to experience each year, comparable seasonal stress. This finding means that seasonal weight changes observed among a given population follow a certain pattern determined by the distribution of some variables among the population. Variables such as socio-economic status of the household, hygiene and sanitation level might play a certain role. Further research is needed to identify the determinant of body weight losses or weight gains in various seasons.

James (21) and Ferro-Luzzi (22) propose to classify the degree of chronic energy deficiency in adults using BMI. The lower limit of the acceptable range for BMI as mentioned by the FAO/WHO/UNU is 20.1 for men and 18.7 for women (23). The BMI of subjects in Manta during pre-harvest seasons was 20.3 ± 1.8 and 19.5 ± 1.8 for men and women respectively. These mean values obtained in a period where people have their lowest body weight, were still higher than the lowest level of BMI compatible with good health and desirable physical activity (21,23). When BMI values were studied in the light of the suggested level of 17 which constitutes a substantial risk to health (21), only few subjects fall below this threshold. From the distribution shown in Table 3, no subject shows a BMI below 16. This may be an indication of a too low cut off point for people living under normal circumstances. About 5% of men and 3.5% of women had a BMI less than 18.5 during post-harvest seasons, while during pre-harvest seasons 8 to 10 % of men and 6 to 8% of women were below 18.5. This proportion of individuals may be exposed to increase morbidity. Therefore they constitute a group at risk which needs attention. Contrary to what was previously reported (1,8,9), we did not observe any association between body size (BMI) and pre-harvest weight loss in our study population. Our data can not support the evidence that fat people can afford to loose more weight than lean people.

It can be concluded from the present study that the magnitude of pre-harvest weight loss observed in this study was limited. This may be explained by the cropping pattern strategy applied by farmers. Crop diversification proves then to be as important a factor as rainfall distribution in determining pre-harvest weight loss among rural populations of developing countries. The same subjects may experience each year a comparable seasonal stress. However, simple events such as changes in activity pattern and social events may influence the extent to which people experience the seasonal stress. There was no association between the magnitude of pre-harvest weight loss and subject's body size. For about 5 % of the population, pre-harvest BMI is between 16 and 17. This low level of BMI may constitute a substantial risk to health.

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CHAPTER 3

STRONG SEASONALITY IN GROWTH PERFORMANCE IN RURAL BENINESE CHILDREN: A 32 MONTH FOLLOW-UP STUDY IN THREE AGE COHORTS

Eric-Alain D Ategbo, Marti J van Liere, Joop MA van Raaij, Frans HLA de Koning, Joseph GAJ Hautvast

ABSTRACT

Body weight and height were measured over three consecutive years, using a mixed-longitudinal design, on children aged 2, 4 and 6 years at the start of the study. All are from subsistence farming households. Yearly growth rate is lower than that derived from the 50th percentile of the NCHS reference. From the age of 5, growth rate is even lower than that derived from the 3rd percentile of the NCHS reference. A seasonal pattern was observed in growth rate, with highest rate ($p < 0.05$) in post-harvest periods. However, even post-harvest growth rate is lower than expected from the 50th percentile of the NCHS population. The pre-harvest growth rate is determined by the growth rate of the preceding post-harvest season ($0.26 \leq r \leq 0.40$). Prevalence of stunting is high (28-36 %), while wasting was on a lower level (6-13 %). These proportions were comparable in all age cohorts.

KEYWORDS: Weight gain, height increment, growth rate, post-harvest, pre-harvest, children, wasting, stunting.

INTRODUCTION

Growth and development patterns of children do reflect both the "healthiness" and the socio-economic level of the environment (1). In rural areas of developing countries characterized by subsistence rainfed farming, significant seasonal variations have been reported in food availability, physical activity pattern and in the prevalence of infectious diseases (2-9). However, these studies mainly focused on adults and hardly anything is known about children (2,4,6,8). As other members of the household, children must also experience the effects of seasonal variations in food availability. The outcome of such stress on children's growth performance is unknown. Data on the growth pattern of children, regularly experiencing seasonal food shortage is scarce and so far, no study was designed to address this issue within a wide age range. It has been reported that during the wet season, infectious diseases are generally highly prevalent and this may impair both food intake and nutrients absorption (9-13). These may lead to a perturbation in growth pattern. The present study was designed to investigate the effects of seasonal food shortage on the growth performance of children aged 2 to 9 years and to provide on the one hand knowledge about the year to year repeatability of such events and on the other hand, a complete view of the population of children ranging from 2 to 9 years. Results presented and discussed in this paper are based on a mixed-longitudinal study carried out during 3 consecutive years in north-western Benin, on three cohorts of children living in a poor rural environment.

SUBJECTS AND METHODS

Study area

The study was carried out in five villages of the commune of Manta, situated in the ATACORA province, in the north-western region of the Republic of Benin. Manta is situated at about 70 km West of Natitingou, the provincial capital. Infrastructure in the region is minimal. Roads are bad and almost inaccessible during rainy seasons. In the central village of the commune of Manta, Koutangou, there is a primary school, a health center and a local rural development agency. However, the attendance rate at school is extremely low with less than 5% of children in the area attending school. Manta lies at an altitude of 240 meters above sea level, between two mountain-ranges of approximately 500 meters altitude. The total number of inhabitants of the 5 villages is about 4,000. Main occupation of the population is subsistence farming (14).

Average annual rainfall is about 1300 mm, spread over one season, from May to September. Average daily temperature varies between 26 and 36°C with the lowest temperatures during the rainy season and the highest temperatures at the end of the dry season. Relative humidity varies throughout seasons, fluctuating between 80 % during the rainy season and 20 % in December and January when the Harmattan, a dry cool wind from the Sahara is blowing.

From the age of about five years, children already start participating either in household or in productive activities and sometimes in both. In the household, it is children's responsibility to clean dishes, sweep the compound and to take care of younger children. As far as productive activities are concerned, children are involved in food production and animal raising. Children are in charge of protecting crops against animals (like birds, sheep and pigs), carrying part of the harvest back home and threshing after the harvest. Children may also help with weeding during the peak of the agricultural season. Children also have the task of raising small livestock by supplying water and animal feed.

Study design and subjects

A mixed longitudinal design was used to study the growth of three age cohorts over three consecutive agricultural cycles, each including a pre-harvest season and a post-harvest season. At the start of the study, children in the cohorts were aged 2, 4 and 6 years respectively (Figure 1). Children came from households which had been selected on the basis of the following criteria concerning the mother: aged 18 to 45 years, non-pregnant and non-lactating, mother of at least one child of 2,4 or 6 years of age, permanent resident in the study area and farming as main occupation.

The size of each cohort at the start of the study was 66, 87 and 68 children aged 2, 4 and 6 years respectively. Due to death, migration or illness, a data set covering the whole study period was finally obtained for 60 children of the 2-year cohort, 74 of the

4-year cohort and 63 of the 6-year cohort. Some anthropometric characteristics of the subjects at the start of the study are given in Table 1.

In all age cohorts, body weight was measured every two weeks for the first 18 months of the study, and afterwards the measurement frequency was reduced to once a month. Throughout the whole study period, height has been measured once a month for children of 2 and 4 years old and every 3 months for the 6 years cohort.

FIGURE 1: A mixed-longitudinal design

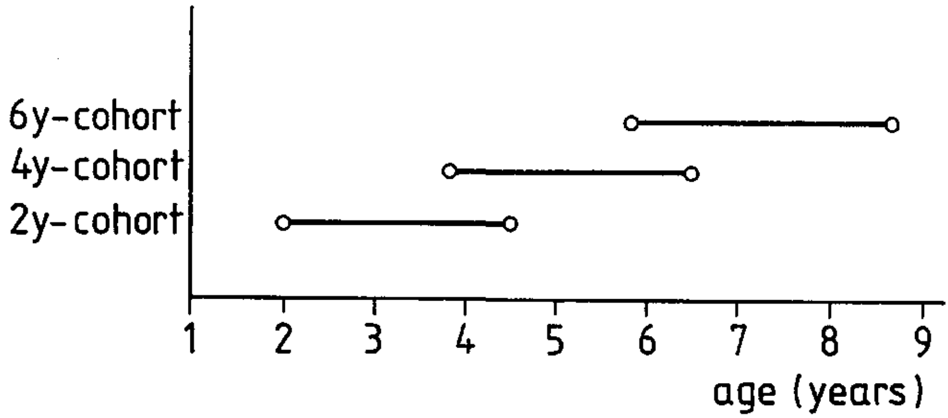


TABLE 1: Characteristics of children*

	2y cohort	4y cohort	6y cohort
Number	66	87	68
Age (months)	24 ± 3	48 ± 4	60 ± 3
Weight (kg)	10.4 ± 1.8	13.8 ± 1.9	16.3 ± 2.0
Height (cm)	82.5 ± 5.5	96.0 ± 7.0	107.5 ± 6.0
MUAC (cm)†	14.4 ± 1.3	14.8 ± 1.2	14.8 ± 1.0
Calf circumference (cm)	17.8 ± 1.7	19.4 ± 1.2	20.5 ± 2.1
Ratio boys / girls	25 / 41	39 / 48	43 / 25

*) Means values ± SD; characteristics measured at the start of the study
†) Mid-Upper-Arm Circumference

Measurements

Body weight was measured between 6.30 and 7.30 am at a central place of the village or, when houses were too far apart, measurements were done on two consecutive days at two different locations. For children less than 25 kg, a beam balance (Babies and toddlers scale model 625 T, CMS weighing equipment Ltd, London, England) precise to 5 grammes was used. A SECA platform spring balance precise to 0.5 kg was used for children heavier than 25 kg (Seca, type 725; Vogel und Halke Mess-Und-Wiege Techniek, Hamburg, Germany). The SECA balance was fixed to a wooden board and was placed on a horizontal surface. The beam balance was placed on a table. Before each measurement session, scales were calibrated using standard weights of 15 or 30 kg. Weights were read to the nearest 0.1 kg with the beam balance while readings were done to the nearest 0.5 kg with the spring balance. Children were measured wearing a minimum of clothing (no correction was made for clothing) in a sitting position on the CMS scale or standing on the SECA scale.

The height of 4 and 6 years old children was measured with the subject standing without shoes on a horizontal surface against a vertically placed metal board, with heels together, chin chucked in and body stretched upwards to full extent and head in the Frankfurt plane. Heels, buttocks and shoulders were in contact with the metal board to which a flexible metal tape was attached. Readings were made to the nearest 0.5 cm. For the 2-year cohort, length was measured in a supine position throughout the study period. Care was taken to maintain their head in an upright position, legs stretched to a full extent and feet at a right angle with the legs.

Mid-upper-arm circumference (MUAC) was measured on the left side of the body mid way between the tip of the shoulder and the elbow with the subject's arm hanging freely along the body using a flexible non extensible tape. Readings were made to the nearest 0.1 cm.

Calf circumference was measured using a flexible non extensible tape with the subject sitting on a table and legs hanging freely. The maximal circumference was taken after several levels were tried. Readings were made to the nearest 0.1 cm.

Children's age was determined at the start of the study according to birth certificate, baptism certificate or based on major events which have occurred in the area during the previous years.

Data analysis and statistics

The velocities of weight and height gains were calculated as the difference between two consecutive measurements, adjusted for the length of the interval between measurements. For each individual the pre-harvest growth velocity was calculated as the mean velocity over the three months showing the smallest increments, while post-harvest velocities were calculated as the average velocity over the three months showing the greatest increments.

Following the guidelines of the World Health Organisation (WHO Working Group, 1986), Z-Scores of the parameters weight for height and height for age were used as indices of nutritional status, with the National Center for Health Statistics (NCHS)(15) population as the reference. Prevalence of wasting and of stunting were based on cut-off points of -2 Z-scores. Pre- and post-harvest Z-Scores were calculated for the same periods as defined above. To calculate pre- and post-harvest Z-Scores for each indicator the average age, height and weight over the concerned periodS were used.

Differences in mean growth rates between post-harvest and the following pre-harvest season, within the same age cohort were investigated using Student's paired t-test. The consistency in the year-to-year effects of seasonal variations in food availability on growth rate was studied by Pearson's correlation analysis (16,17).

RESULTS

Three cohorts of children aged 2, 4 and 6 years at the start of the study were followed up for a period of almost three years. After two years follow-up (August 1989 - August 1991), the average weight of the children of the 2y cohort, when they were 4 years old, reached almost the same level as the starting weight of the 4y cohort (13.9 ± 1.7 kg versus 13.8 ± 2.0 kg). The same was observed for the 4y cohort when compared with the 6y cohort (16.5 ± 2.1 kg versus 16.3 ± 2.0 kg). Also, when height was considered, after two years of follow-up, the 2y cohort reached the starting height of the 4y cohort (97.0 ± 5.6 cm versus 96.0 ± 7.0 cm). Likewise, the height of the 4y cohort, after two years , was comparable with the starting average height of the 6y cohort (107.0 ± 4.7 cm versus 107.5 ± 6.1 cm) (Figures 2 and 3).

FIGURE 2: Weight gain patterns of children from the NCHS reference population and of Manta's children aged 2 to 9 years

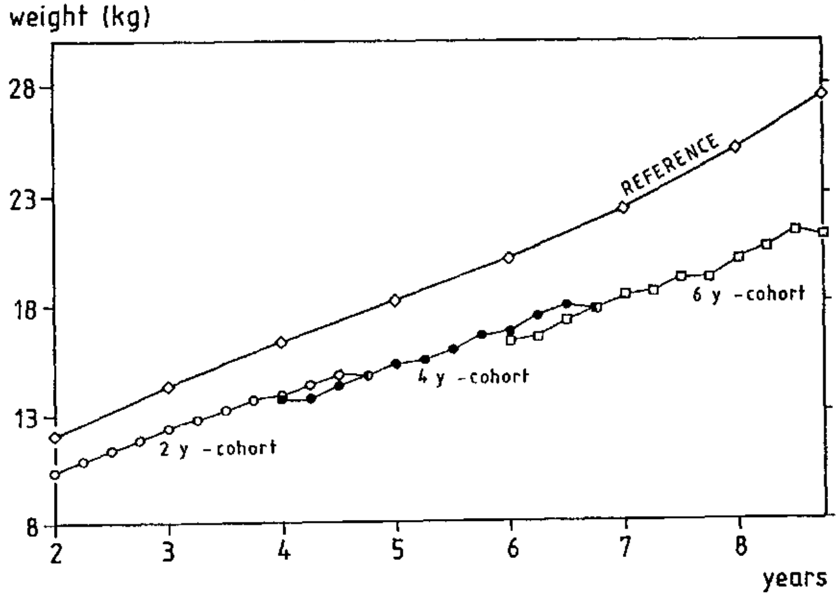
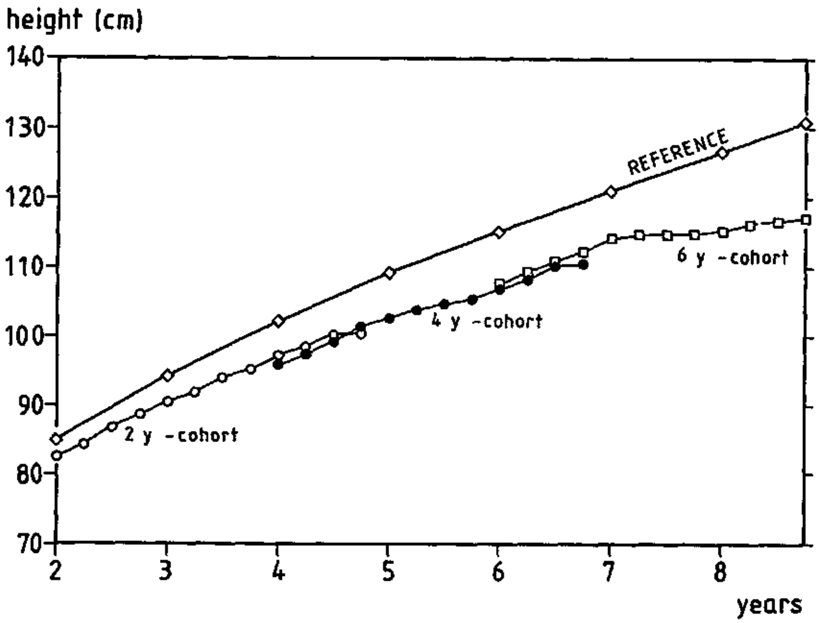


FIGURE 3: Height increment patterns of children from the NCHS reference population and of Manta's children aged 2 to 9 years



Weight gain attained over each year of life expressed as kg per year is shown in Table 2. For all ages, observed average weight gains were lower than expected gains derived from the 50th percentile of the NCHS reference (15). The observed weight gains for the 6 to 8 years old children were even lower than expected weight gains derived from the 3rd percentile. Height increase attained over each year of life expressed as cm per year is also shown in Table 2. In all age groups, the observed height increments were below the increments as derived from the 3rd percentile of the NCHS reference.

<u>**TABLE 2**</u>: Yearly gain in weight and height of children from Manta, North Benin*

	Year of life	Weight increment			Height increment		
		Manta	NCHS P3†	NCHS P50‡	Manta	NCHS P3†	NCHS P50‡
		kg / year			cm / year		
2y cohort							
	3	2.0(1.2)	1.5	2.3	7.0(2.1)	8.3	9.3
	4	1.5(0.9)	1.5	2.0	6.5(2.0)	7.1	7.8
4y cohort							
	5	1.5(1.0)	1.4	1.8	6.5(1.9)	6.2	6.9
	6	1.2(0.9)	1.4	1.9	4.5(1.7)	5.5	6.2
6y cohort							
	7	1.4(0.9)	1.5	2.2	4.0(1.9)	5.0	5.8
	8	1.1(1.0)	1.6	2.7	3.0(1.9)	4.7	5.5

*) Values observed in Manta are presented as means (standard deviations)
†) Weight or height increment as derived from the 3rd percentile of NCHS references (15)
‡) Weight or height increment as derived from the 50th percentile of NCHS references (15)

As shown in Figure 4, monthly weight gain fluctuates substantially throughout the year. Highest weight increments in all age cohorts were attained in March and lowest in October. Post-harvest weight gain was significantly higher ($p<0.05$) than pre-harvest weight gain. Growth rate was 170 g/month in March and 70 g/month in October for the 2y cohort. For the other 2 cohorts, weight increments were 140 and 130 g/month in March for the 4 and 6y cohorts respectively and 60 g/month in October for both age cohorts. Post-harvest weight gains for all ages were lower than that expected from the 50th percentile of the NCHS reference growth pattern. Pre-harvest weight gains were even lower than the growth rate derived from the 3rd percentile of NCHS reference (Table 3). Observed increase in height during post-harvest season was slightly higher than that observed in the following in pre-harvest season (Figure 5). However, this difference did not reach statistical significance. Height increases during post-harvest season for the 3rd and the 4th year of life were below the increments derived from the 50th percentile of the reference. For all ages, pre-harvest height increases were lower than that derived from the 3rd percentile of the reference (Table 3).

FIGURE 4: Monthly body weight increment of children from Manta, North Benin

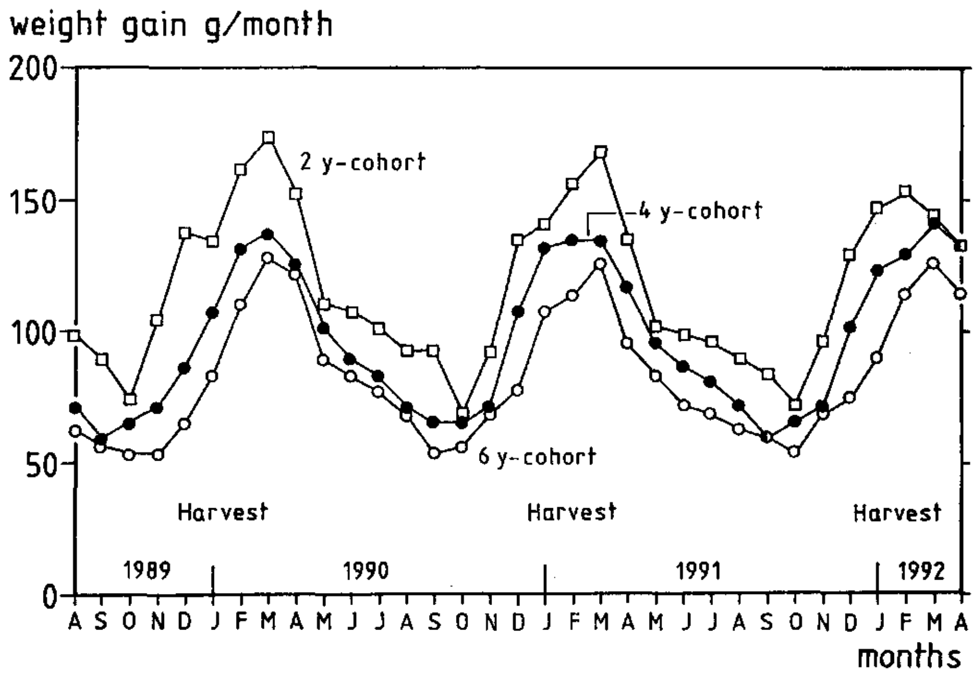
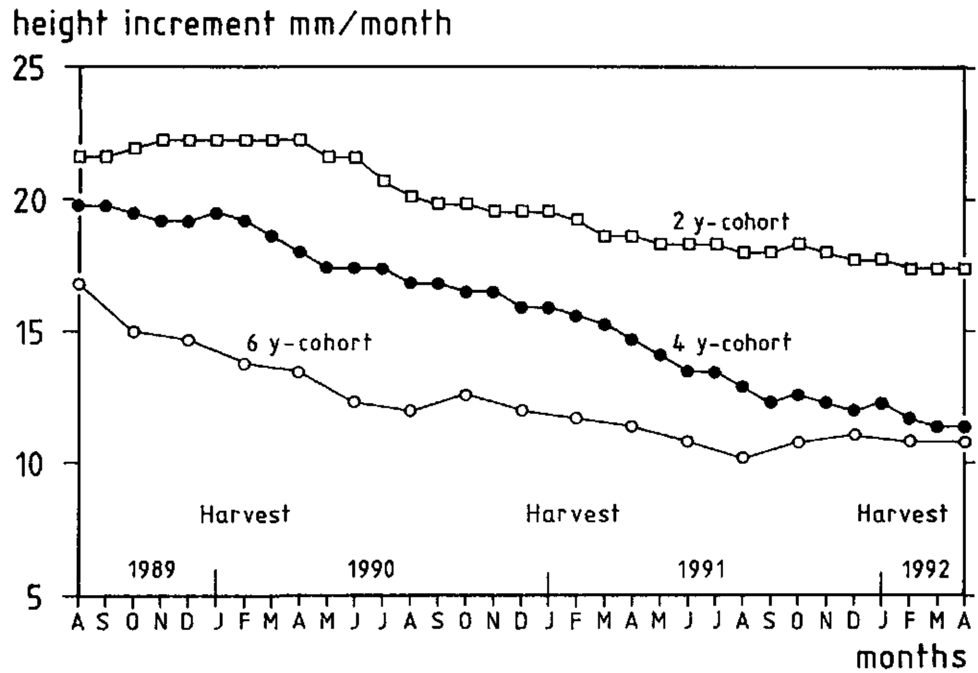


TABLE 3: Rates of weight and height gain of Manta's children, by age and seasons*

	Weight increment (g/month)			Height increment (mm/month)		
	Manta	NCHS P3†	NCHS P50‡	Manta	NCHS P3†	NCHS P50‡
3rd year (2y cohort)						
Post-harvest§	170.0(15.6)‖	125	192	5.8(2.4)	6.9	7.8
Pre-harvest§	120.0(13.4)	125	192	5.2(1.9)	6.9	7.8
4th year (2y cohort)						
Post-harvest	136.0(14.8)‖	125	167	5.4(1.9)	5.9	6.5
Pre-harvest	112.O(15.8)	125	167	4.9(2.3)	5.9	6.5
5th year (4y cohort)						
Post-harvest	126.0(16.2)‖	117	150	5.5(2.1)	5.2	5.8
Pre-harvest	110.0(13.8)	117	150	4.9(2.0)	5.2	5.8
6th year (4y cohort)						
Post-harvest	134.0(15.4)‖	117	158	5.1(1.8)	4.6	5.2
Pre-harvest	100.0(12.9)	117	158	4.3(2.4)	4.6	5.2
7th year (6y cohort)						
Post-harvest	146.0(16.8)‖	125	183	4.7(2.2)	4.2	4.8
Pre-harvest	112.0(13.9)	125	183	4.0(2.0)	4.2	4.8
8th year (6y cohort)						
Post-harvest	132.0(14.1)‖	133	225	4.4(1.9)	3.9	4.6
Pre-harvest	106.0(11.9)	133	225	3.6(2.3)	3.9	4.6

*) Values observed in Manta are presented as means (standard deviations)
†) Weight or height increment as derived from the 3rd percentile of NCHS references (15)
‡) Weight or height increment as derived from the 50th percentile of the NCHS references (15)
§) Pre-harvest season covers March to October and post-harvest season covers October to March
‖) Statistically higher than weight gain during the pre-harvest season ($p<0.05$)

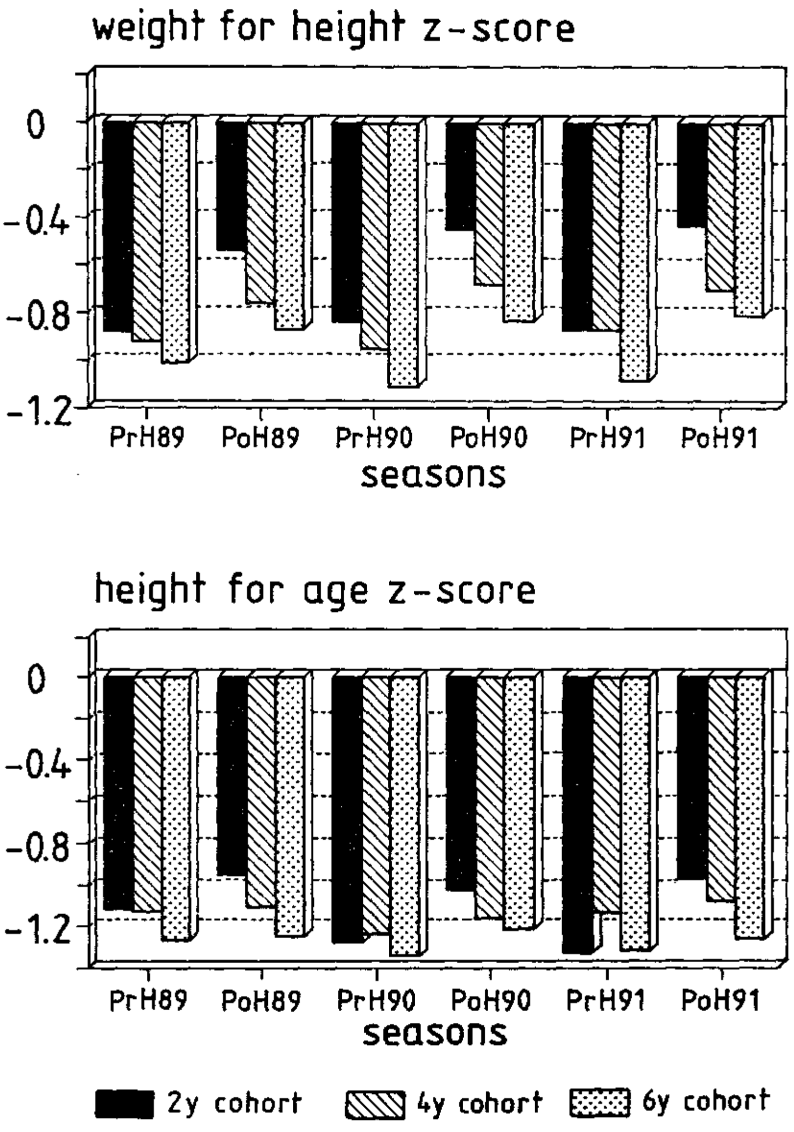
FIGURE 5: Monthly height increment of children from Manta, North Benin



For both weight and height, correlation analysis revealed no significant association between year-to-year pre-harvest gains or between year-to-year post-harvest gains. Observed correlation coefficients ranged from 0.07 to 0.23 for weight gain and from 0.02 to 0.23 for height increase. However, in all age cohorts, significant associations ($p<0.05$) were found between post-harvest and the following pre-harvest weight gains (Table 3). Observed correlation coefficients ranged from 0.26 to 0.40.

For the various pre- and post-harvest periods, weight and height of Manta's children were compared to the NCHS reference population. Z-scores were calculated for weight-for-height and height-for-age. For the index weight for height average Z-scores fluctuate from -0.45 in the 2y cohort (post-harvest 1990; PoH90) to -1.11 in the 6y cohort (pre-harvest 1990; PrH90) (Figure 6). For the indicator height-for-age, the observed Z-scores fluctuate from -0.96 for the 2y cohort (PoH89) to -1.35 for the 6y cohort (PrH90) (Figure 6). Children were classified as stunted or wasted using -2 as the cut-off point for the Z-score. Proportions of stunted or wasted children throughout different seasons are

FIGURE 6: Average weight-for-height and height-for-age Z-scores among Manta's children in various seasons. The pre-harvest periods in 1989, 1990 and 1991 are coded as PrH89, PrH90 and PrH91 respectively. The post-harvest periods in 1989, 1990 and 1991 are coded as PoH89, PoH90 and PoH91 respectively



shown in Table 4. It appears that the prevalence of stunting was high (between 28 and 36 % of the children) and that the prevalence did not significantly fluctuate with seasons. On the other hand, the prevalence of wasting remained on a lower level, affecting about 6 to 13 % of the children. In all age cohorts, proportions of wasted children were also comparable and did fluctuate between seasons.

TABLE 4: Percentages of wasted and stunted children in Manta in different seasons

	2y cohort	4y cohort	6y cohort
		Wasted†	
Pre-harvest 1989	12	11	8
Post-harvest 1989	7	8	6
Pre-harvest 1990	10	13	10
Post-harvest 1990	6	7	6
Pre-harvest 1991	13	10	8
Post-harvest 1991	7	6	6
		Stunted‡	
Pre-harvest 1989	30	33	33
Post-harvest 1989	28	31	31
Pre-harvest 1990	32	36	35
Post-harvest 1990	28	35	33
Pre-harvest 1991	31	34	36
Post-harvest 1991	30	32	29

†) Z-score for weight-for-height lower than -2
‡) Z-score for height-for-age lower than -2

DISCUSSION

Under adequate nutritional and health conditions, weight and height of children increase with age at a more or less regular pace. However, when seasonal food shortage and/or fluctuation in morbidity rates occur, growth performance may deviate from the expected pattern (12,19).

After two years of follow-up, the 2y cohort reached a mean weight and a mean height which were comparable with the mean weight and the mean height of the 4y cohort at the start of the study. Similarly, when the children from the 4y cohort reached the age of 6 years, their weights and heights were comparable to the initial weights and heights of the children from the 6y cohort (Figures 2 and 3). This suggests that there were no secular differences between cohorts and that the semi-longitudinal data on weight and height can be considered as comparable to longitudinal data from 2 to 9 years of age.

The yearly gain in weight of children from Manta decreased from 2.0 ± 1.2 kg/year during their third year of life to 1.1 ± 1.0 kg/year during the eighth year of life. Over the same period, the yearly increase in height declined from 7.0 ± 2.1 cm/year to 3.0 ± 1.9 cm/year. For each age group, these gains were significantly lower than the expected gains derived from the 50th percentile of the NCHS references (Table 2). This large deviation from the reference is in line with other reports on rural children in tropical countries (9,11,18,19).

An important finding of this study is the large seasonal fluctuation observed in children's growth pattern. Body weight gains were considerably lower (20-30%) during pre-harvest periods compared to post-harvest periods (Figure 4). Average weight gains during the pre-harvest periods were low even when compared to the growth rate expected from the 3rd percentile of the NCHS population. Average weight gains during the post-harvest periods were slightly lower than that expected from the 50th percentile of NCHS (Table 3). As a consequence, the yearly weight gain of Manta's children did not reach the expected gain from the NCHS references. Studies in other tropical countries also revealed significant differences in weight gain between pre-harvest and post-harvest seasons (9,11,13,18,19).

Height was less affected by seasons (Figure 5). Nevertheless, during pre-harvest periods growth rates were 15-20% lower than during post-harvest period. Even in post-harvest period, height increment was lower than expected. This pattern was also reported among children in other countries (9,11,13,18). During pre-harvest seasons observed height increments were lower than that performed by the 3rd percentile of the NCHS references.

Growth retardation for both weight and height were observed during pre-harvest periods. During post-harvest periods, growth rates were not enough to compensate for the growth retardation of the pre-harvest periods. Thus, we found no evidence for a catch up growth at the age of 2-10 years. The overall results show that the children studied are deviating more and more from the NCHS median with increasing age. From the age of five, the mean velocity is lower than that of the third NCHS percentile.

This seasonal pattern in growth rate of the children can be explained by the seasonal fluctuations in food availability found in Manta (20). An additional explanation is probably the high prevalence of infectious diseases during the rainy season, corresponding to the pre-harvest season (9,19,21). Moreover, in that particular period of the year the situation of the children is worsened by the fact that mothers often work for long hours outside the house, thus ensuring little time for child care. Negative effects of time spent out of the house by mothers in developing countries on child nutritional status are reported (11,22).

No significant association was found between year-to-year pre-harvest or post-harvest weight gains. Likewise, no significant association was observed between the year-to-year pre-harvest or the year-to-year post-harvest height increase. However, significant associations were found between post-harvest and the following pre-harvest weight gains, and between post-harvest and the following pre-harvest height increases. This finding suggests that growth performance of a child during the pre-harvest period is determined by his growth rate in the preceding post-harvest period.

The main consequence of the failure in growth performance is the occurrence of a high prevalence of stunting (Table 4). Throughout the year 6 to 13 % of the children may be considered as wasted. The same, or sometimes lower prevalence have been reported elsewhere (10,11,13). The prevalence of stunting was high in all age cohorts. The proportion of stunted children in Manta was between 30 and 40 %. Comparable levels of stunting were observed in other groups (1,11,21). Prevalence of stunting is high and this situation worsens with age. This observation is in line with what has been observed among children in Lesotho (21). If indeed, stunting is at such a high level, we agree with Gopalan (23) who describes the phenomenon of stunting as the main feature of the " poverty trap" in which the third world is imprisoned. This picture brings about the possibility of having, if nothing is done, a stabilization of height in the community. This may be of great concern, since working capacity and endurance may be related to body size (24-26). Relation between stunting and low intellectual quotient has also been reported (24,25), and it is important to look into why and how this phenomenon occurs. If during post-harvest season when food is fully available, growth performance was not enough to compensate for the poor growth performance observed in the bad season, this suggests that poor growth performance is not just a matter of energy. Infectious disease and/or food quality might also play major roles.

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CHAPTER 4

RESTING METABOLIC RATE AND WORK EFFICIENCY OF RURAL BENINESE WOMEN: A TWO YEAR LONGITUDINAL STUDY

Eric-Alain D Ategbo, Joop MA van Raaij, Frans LHA de Koning, Joseph GAJ Hautvast

ABSTRACT

The present study was performed on 45 female farmers in northern Benin during 2 consecutive years. Body composition, energy intake, Resting Metabolic Rate (RMR) and energy cost of cycling were measured in 3 periods a year. Daily energy intake showed seasonal fluctuations of about 1.7 MJ in 1990 and 0.6 MJ in 1991. The same pattern was observed in both Fat Mass (FM) and Fat Free Mass (FFM). RMR and the energy cost of cycling at 25 W and 50 W did not show any seasonal change. Moreover, Delta Work Efficiency (DWE) of women seemed to be higher during the post-harvest period than during pre-harvest period. It is concluded from this study that metabolic adaptation did not occur as a response to seasonal food shortage, even with a stress on energy intake created by a substantial seasonal stress

KEYWORDS: RMR, body weight, fat free mass, energy intake, energy cost of cycling, Delta Work Efficiency, metabolic adaptation.

INTRODUCTION

Small scale farmers in rural areas of developing countries often experience changes in their energy balance, as the outcome of seasonal changes in food availability and in energy expenditure (1-7). Studies carried out in the recent past all indicate that to establish a new energy balance, body weight reduction is a widely used mechanism. However, whether metabolic adaptation may be used as well, remains a controversial topic (2,8-11). The same studies also indicate that the magnitude of the observed weight loss is moderate, and explained the lack of evidence for metabolic adaptation by the mild seasonal stress experienced by different areas where studies have been performed (12). So far, data on adaptive processes used by people living under a more substantial seasonal conditions are scarce. Whether human being can change metabolic efficiency without changing either body weight or activities in order to cope with seasonal changes in food availability in areas experiencing a higher seasonality, for instance ecological zones with only one harvest a year, remains unclear. The present study, performed under an unimodal climate was designed to address this uncertainty. Findings are based on a longitudinal study among rural women in north-western Benin, during two consecutive years.

SUBJECTS AND METHODS

Study area

The present study was performed in the rural commune of Manta, situated in the north-western part of the Republic of Benin. Manta is located at 240 meters above sea level, between two mountain-ranges of 500 m altitude. Manta comprises 11 villages, five of them were chosen as research villages. Altogether, about 4000 inhabitants are living in the five villages. There is only one rainy season, from May to September. Average annual rainfall is about 1300 mm. Average daily temperature varies from 26°C in July to 36°C in April. The harmattan, a dry and cool wind blows from North to South in

December and January (13).

Subsistence farming is the main activity in the region. Main food crops are millet (Pennisetum spp), sorghum (Sorghum spp) and hungry rice commonly called *fonio* (Digitaria exilis). Beans (Vigna spp), yam (Dioscorea spp), rice (Oryza sativa) and Bambara groundnuts (Voandzeia subterranea) are also produced. Groundnuts (Arachis hypogaea) are produced as cash crop mainly by men. All food crops except hungry rice are harvested between November and December. Hungry rice is harvested in September. Cultivation is done by men as well as by women. Women cultivate their own land, but men usually help with clearing the field, while women help men with sowing and harvesting. Millet and sorghum are the staple foods. Sowing of millet and sorghum is done in May and in June; weeding is carried out in July, August and September. Bambara groundnuts and rice are exclusively produced by women.

Study design

Body weight, body composition, energy intake, Resting Metabolic Rate (RMR) and work efficiency were measured in six periods spread over two years. The measurements periods covered two pre-harvest periods (July-August); two post-harvest periods (mid November-January) and two intermediate periods (March-April). Anthropometric and energy expenditure measurements were done in a field laboratory by the same investigator all over the research period. The subjects were transported from their home to the laboratory by car at about 6.30 am, they were asked not to work or eat beforehand. In each period, the anthropometric and energy expenditure measurements were done on two different days within the same week. At each session, RMR was measured in triplicate. The averages of the six values were used for further analyses of the data. Immediately after the RMR measurements, the energy cost of cycling on a bicycle ergometer (speed 50 rpm) at workloads of 25 and 50 watts was assessed. During the first pre-harvest period, subjects were made familiar with the bicycle ergometer and were trained to cycle at a constant speed. Therefore, data on energy cost of cycling are only available for the remaining five periods. Food energy intake of each subject was measured within two weeks before or after the laboratory sessions. Height, mid-upper-arm circumference (MUAC) and skeletal diameters were measured at the entry of the study.

Subjects

A sample of 45 women was selected from the population. Women were chosen according to the following criteria: farming as main occupation, aged 18 to 45 years, non-pregnant and non-lactating, mother of at least one child and permanently resident in one of the research villages. Data of women who became pregnant during the study period were excluded from present analysis. Women dropped out due to pregnancy and moving from the villages. As a result, a complete data set covering the entire study period became available from 34 women. Anthropometric characteristics of participants are given in Table 1. Women eligible for participation and their husbands were invited for a visit to the laboratory to familiarize themselves with the equipment and the measurements procedures. Only women who had given their informed consent were allowed to participate in the study. The protocol of the study was submitted to and approved by the Medical - Ethical committee of the Wageningen Agricultural University.

TABLE 1: Anthropometric characteristics of subjects*†

	All women	Subgroup
Number	45	34
Age (years)	31.0 ± 4.3	30.8 ± 4.2
Weight (kg)	49.9 ± 5.1	48.4 ± 5.0
Height (cm)	160.0 ± 5.5	159.5 ± 5.8
Body fat (%)	19.0 ± 3.6	19.4 ± 4.1
Body mass index (kg/m^2)	19.5 ± 1.9	19.0 ± 1.6
Mid Upper Arm Circumference (cm)	25.4 ± 1.7	25.6 ± 1.6
Sum wrist diameters (cm)	9.7 ± 0.8	9.6 ± 0.9
Sum knee diameters (cm)	16.0 ± 0.7	16.0 ± 0.5
Shoulder diameter (cm)	34.0 ± 1.8	33.5 ± 1.9

*- Mean values ± SD
†- Characteristics at the start of the study, July 1990

Methods

Anthropometry

Body weight was measured using a SECA platform beam balance (SECA type

710, Vogel and Halke Mess Und Wiege Techniek, Hamburg, Germany). The balance was placed horizontally and was calibrated before each weighing session using a calibration weight of 50 kg. Women were wearing minimum clothing and body weight was measured to the nearest 0.1 kg. No correction for clothing was made.

Biceps, triceps, subscapular and supra-iliac skinfold thicknesses were measured in triplicate using a Holtain Caliper (Holtain Ltd, Briberian, UK; pressure 10 g/mm^2 precise at 0.2 mm). The four sites skinfold equation of Durnin and Womersley (14) was used in combination with Siri's equation (15) to estimate body fat percentage. Fat Free Mass (FFM) was calculated as the difference between subject's body weight and body Fat Mass (FM)

Height was measured at the start of the study, with women standing without shoes on a horizontal surface, against a wall with the heels together, chin chucked in, and stretched upwards to a full extent and the head in the Frankfurt plane. Heels, buttocks and shoulders were in contact with the wall to which a flexible metal tape was fixed. Readings were made to the nearest 0.5 cm.

Skeletal diameters were measured at study entry, using a Holtain Skeletal anthropometer calibrated to 0.2 mm.

Bio-electrical impedance analysis (BIA)

Bioelectrical impedance (BIA) was measured immediately after the RMR measurement. Women were in a supine position with limbs away from the trunk. The resistance and the reactance of their body to the passage of an electrical current were measured on their right side as described by Lukaski (16), using a body composition analyzer (RJL Systems, Inc., BIA-101, Detroit, MI, USA). Fat Free Mass (FFM) was calculated using the following equation of Lukaski (17):

$$\mathbf{FFM = 0.734\ Ht^2/R + 0.096Xc + 0.116\ Wt + 0.878G - 4.033}$$

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 measured fat free mass.

Resting Metabolic Rate (RMR)

RMR was measured on apparently healthy subjects (free of fever), between 6.00 and 8.00 am, 10 to 12 hours after the last meal. After lying down quietly for 45 minutes, RMR was measured by open circuit indirect calorimetry using the Douglas bag technique (18). Expired air was collected three times for eight minutes with intervals of five minutes between collections. Measurements were performed in a well-ventilated room. Temperature during measurements varied from 24 to 31°C depending on the season.

Since RMR was measured in triplicate on two days, six measurements were made on each subject per period. Differences between the three measurements within the same day (average values being 3,69; 3.73 and 3.73 kJ/min for the first, second and third measurement respectively), or between two days (means 3.70 and 3.72 kJ/min for the first and the second day respectively) were not statistically significant for days ($p=0.766$) or measurements ($p=0.303$). The reproducibility of the RMR measurements as based on triplicate measurements was 3.8 % (CV). For each subject, the average of six measurements (or in case of missing values, the average of remaining values) was used for further analyses.

Energy cost of cycling

A bicycle ergometer with a mechanical break (Monark Ergometer Model 818E Sweden) was used and energy expenditure was measured by the Douglas bag technique.

The test was performed on the same days as RMR measurements. At each workload, subjects first cycle for five minutes to reach a steady rate of gas exchange (19). After that, expired air was collected for 1 min 30 sec. The break of the bicycle ergometer was frequently checked with a calibration weight of 4 kgf. Prior to actual data collection, women were made familiar with the bicycle and were trained to cycle at a constant speed of 50 rpm indicated by a metronome. A pilot study was performed following the same scheme. In the pilot study, two Douglas bags of expired air were collected per workload and it appeared that there was no significant difference between days ($p= 0.178$) and between bags collected on the same day ($p= 0.345$). Therefore, it was decided to collect one bag of expired air per workload and to use the mean value of the two days as a valid estimate for the period (or in case of missing value to use the only one available). The pilot study was performed using 3 workloads 25, 50 and 75 watts. It turned out that 75 watts was too heavy for these women. The present study was then implemented using workloads of 25 and 50 watts.

Net energy cost of cycling was calculated as the difference between measured energy expenditure while cycling at a given workload and RMR measured on the same day.

Delta work efficiency was defined as the ratio between the increment in workload and the increment in the subject's energy expenditure (20).

Energy expenditure measurements

Resting Metabolic Rate (RMR) and energy cost of cycling were measured by open circuit indirect calorimetry using the Douglas bag technique. The women wore a nose clip and breathed through a low resistance respiratory valve. The volume of expired air was measured by a wet precision gasometer (Schlumberger, type 5 Meterfabriek Schlumberger, Dordrecht, The Netherlands) and was corrected for temperature, dryness and pressure. The carbon dioxide and the oxygen content of a small sample of expired air was analyzed by a Servomex CO_2 analyzer (Series 1400) and a paramagnetic oxygen analyzer (Type OA 570A; Taylor Instruments Analytic, Crowborough, Sussex, UK). The sample was dried before admission by passing it through a calcium chloride filter. The amount of air used for analysis was assessed by a flow-meter (BROOKS Show-rate II 1355 series) and the actual air volume was corrected for sampling. The oxygen analyzer was calibrated with outside air and then with zero gas (100 % nitrogen). Finally it was checked against a calibration gas of known composition. The CO_2 analyzer was calibrated with zero gas and a calibration gas (2.99 % CO_2, 16.8 % O_2 and 80.17 % N_2). Weir's (1949) equation (21) was used to calculate energy expenditure.

Energy intake

Daily energy intake was determined in six periods during four consecutive days per period using the observed weighed record method (22). Every food was weighed before and after preparation, as well as the subject's portion and leftovers, to the nearest gramme using a digital weighing scale (Soenhle type 800300) for weights up to 2 kg. Weights between 2 and 10 kg were weighed to the nearest 50 grammes, on a spring scale (Soenhle type 1203). Measurements were carried out by well-trained local assistants, well-known in the village, who stayed with the subjects from 7.00 am until the subject had eaten their last meal (usually around 8.00 pm). Foods which were eaten when the assistants were not present were determined using the recall method and quantities were estimated using household measures. To calculate energy intake, appropriate food composition tables were used (23,24). Daily energy intake for each subject per season was obtained by calculating the average intake over four consecutive days.

Data analysis and statistics

For each study year, the difference beween post-harvest and pre-harvest values was calculated for RMR, energy intake, body weight, fat free mass, energy cost of cycling and in delta work efficiency.

For RMR, energy cost of cycling and delta work efficiency, body composition and energy intake, differences between periods were studied by Multivariate Analysis of Variance (MANOVA) for repeated measurements (SPSS/PC+ V2.0) (25). When MANOVA revealed significant differences, Student's paired t-test was used to compare the pre- and the post-harvest periods. Pearson's correlation analysis (25,26) was used to study the type and the strength of the association between change in RMR and changes in body weight, energy intake and fat free mass. The same analysis was used to find whether there is any association between energy cost of cycling and body composition.

RESULTS

Body weight, fat mass and fat free mass

Results of the longitudinal data collection on body weight and body composition are shown in Table 2. Average body weight fluctuates between periods. Lowest values were observed in pre-harvest periods (48.4-48.5 kg) and highest body weight were found in post-harvest and intermediate periods (49.4-51.0 kg). It was only in 1990 that the average body weight observed during the post-harvest period was significantly higher ($p<0.05$) than that observed during the preceding pre-harvest period. In 1990, a weight change up to 2.6 ± 2.3 kg was observed, while in 1991 a smaller weight change of 0.9 ± 1.7 kg was observed. Pearson's correlation analysis revealed a weak but significant association between weight changes in 1990 and 1991 ($r= 0.29$; $p<0.05$).

TABLE 2: Body weight and body composition of rural Beninese women in various seasons*

	n	Weight (kg)	Skinfold method FFM (kg)	Skinfold method FM (kg)	BIA method FFM (kg)	BIA method FM(kg)
All women						
Pre-harvest 1990	45	48.4 ± 5.0	39.0 ± 3.5	9.4 ± 1.9	38.2 ± 3.1	10.2 ± 2.2
Post-harvest 1990	45	51.0 ± 4.8	40.3 ± 3.3	10.7 ± 2.2	38.9 ± 2.7	12.1 ± 3.1
Intermediate 1991	42	50.1 ± 5.3	40.3 ± 5.4	9.8 ± 2.9	39.0 ± 3.3	11.1 ± 3.6
Pre-harvest 1991	37	49.4 ± 5.0	39.8 ± 4.3	9.6 ± 1.9	39.1 ± 2.9	10.3 ± 3.4
Post-harvest 1991	34	49.4 ± 4.9	39.8 ± 3.6	9.6 ± 1.8	-	-
Intermediate 1992	34	49.9 ± 5.1	39.8 ± 3.7	10.1 ± 2.0	39.2 ± 2.7	10.7 ± 3.6
Subgroup of women with complete data set						
Pre-harvest 1990	34	48.4 ± 4.9†	39.0 ± 3.5	9.4 ± 1.9	38.4 ± 2.9	10.0 ± 3.1
Post-harvest 1990	34	51.0 ± 4.7	40.3 ± 3.1	10.7 ± 2.2	39.1 ± 2.8	11.9 ± 3.4
Intermediate 1991	34	49.9 ± 4.7	39.9 ± 3.8	10.0 ± 1.4	39.2 ± 2.8	10.7 ± 3.7
Pre-harvest 1991	34	48.5 ± 4.8†	39.2 ± 3.5	9.3 ± 1.8	38.9 ± 3.4	9.6 ± 3.0
Post-harvest 1991	34	49.4 ± 4.9	39.8 ± 3.6	9.6 ± 1.8	-	-
Intermediate 1992	34	49.9 ± 5.1	39.8 ± 3.7	10.1 ± 2.0	39.2 ± 2.7	10.7 ± 3.6

*- Mean values ± SD

†- Significantly lower than post-harvest and intermediate periods ($p<0.05$)

The same trend was observed for both fat free mass (FFM) and fat mass (FM), but the differences were not statistically significant. Mean FFM fluctuates between 39.0 and 39.2 kg during pre-harvest and between 39.8 and 40.3 kg during post-harvest periods. The change observed in FFM during 1990 (1.3 ± 0.9 kg) is twice as much as what was observed in 1991 (0.6 ± 0.8 kg). Mean FM was 9.3-9.4 kg in pre-harvest periods and 9.6-10.7 kg in post-harvest periods. Here again, change in FM during 1990, 1.3 ± 1.1 kg, was larger than that observed in 1991, 0.3 ± 0.5 kg.

BIA appeared to systematically yield higher values for FM than the skinfold method (Table 2). However, the observed differences were not significant. Because of technical problems, determination of body composition by BIA method during the post-harvest of 1991 was not possible.

Resting Metabolic Rate (RMR)

Results of the longitudinal study on Resting Metabolic Rate (RMR) are presented in Table 3. RMR values fluctuate throughout the year, with the lowest value during pre-harvest periods (3.68 - 3.70 kJ/min) and highest values in post-harvest and intermediate periods (3.78 - 3.82 kJ/min). Significant differences ($p<0.05$) between periods were found. Student's paired t-test indicated that RMR values in pre-harvest periods were significantly lower ($p<0.05$) than that observed during post-harvest and intermediate periods. There were no differences between post-harvest and intermediate periods.

Increases from pre-harvest to post-harvest RMR were 0.12 ± 0.19 kJ/min (3%) and 0.10 ± 0.20 kJ/min (3%) in the first and the second study year respectively. The mean increases did not differ from each other. There was a significant positive association ($r= 0.633$; $p<0.05$) between seasonal changes in RMR observed during the first and during the second study year.

Significant associations ($p<0.05$) were found between changes in RMR on one hand and changes in body weight ($r= 0.48$ in 1990; $r= 0.45$ in 1991) and in fat free mass ($r=0.52$ in 1990 and $r= 0.53$ in 1991) on the other hand.

When RMR values were expressed per unit of body weight or per unit of fat free mass, the seasonal variation in RMR disappeared. The average RMR over the whole study period was 77 ± 8 $J.kg^{-1}.min^{-1}$ and 95 ± 8 $J.kg\ FFM^{-1}.min^{-1}$

TABLE 3: RMR values of rural Beninese women in different seasons*

	n	RMR kJ.min^{-1}	RMR J.kg^{-1}.min^{-1}	RMR J.kgFFM^{-1}.min^{-1}
All women				
Pre-harvest 1990	45	3.71 ± 0.31	77 ± 8	95 ± 9
Post-harvest 1990	45	3.83 ± 0.24	76 ± 7	95 ± 9
Intermediate 1991	42	3.83 ± 0.22	77 ± 7	96 ± 8
Pre-harvest 1991	37	3.67 ± 0.26	77 ± 7	95 ± 8
Post-harvest 1991	34	3.78 ± 0.15	77 ± 7	95 ± 8
Intermediate 1992	34	3.81 ± 0.20	77 ± 6	96 ± 7
Subgroup of women with complete data set				
Pre-harvest 1990	34	3.70 ± 0.29†	77 ± 7	95 ± 8
Post-harvest 1990	34	3.82 ± 0.23	75 ± 6	95 ± 8
Intermediate 1991	34	3.82 ± 0.22	77 ± 6	96 ± 7
Pre-harvest 1991	34	3.68 ± 0.27†	76 ± 7	94 ± 8
Post-harvest 1991	34	3.78 ± 0.15	77 ± 7	95 ± 8
Intermediate 1992	34	3.81 ± 0.20	77 ± 6	96 ± 7

*- Mean values ± SD
†- Significantly lower than post-harvest and intermediate periods ($p < 0.05$)

Energy cost of cycling and work efficiency

The gross and net energy costs of cycling at different workloads are presented in Table 4. The gross energy cost of cycling at both workloads varies slightly but not significantly throughout periods. Significant differences between periods were observed for the energy cost of cycling at 50 W. Student's paired t-test revealed that observed values during pre-harvest period were significantly higher ($p < 0.05$) than that of the post-harvest periods (Table 4). Pearson's correlation analysis did not reveal any association between gross energy cost ($r = 0.16$) or net energy cost of cycling ($r = 0.18$) and body weight, either at 25 W or at 50 W.

The energy cost of cycling at a workload of 25 W and 50 W were used to calculate the delta work efficiency per period as shown in Table 4. Delta work efficiency fluctuates throughout periods with the lowest values being reached during intermediate and pre-

TABLE 4: Energy cost of cycling at various workloads and Delta Work Efficiency in different seasons*

	n	Gross EE25W $kJ.min^{-1}$	Gross EE50W $kJ.min^{-1}$	Net† EE25W $kJ.min^{-1}$	Net† EE50W $kJ.min^{-1}$	DWE‡ (%)
All women						
Pre-harvest 1990	-	-	-	-	-	-
Post-harvest 1990	45	12.4 ± 1.1	18.6 ± 0.8	8.6 ± 1.0	14.8 ± 0.8	24.9 ± 3.1
Intermediate 1991	42	12.7 ± 0.9	19.1 ± 0.9	8.8 ± 0.8	15.3 ± 0.8	23.6 ± 3.2
Pre - harvest 1991	37	12.3 ± 1.9	19.2 ± 0.8	8.9 ± 0.7	15.5 ± 0.8	23.3 ± 3.1
Post - harvest 1991	34	12.1 ± 0.9	18.3 ± 1.0	8.5 ± 0.9	14.5 ± 1.1	24.9 ± 3.3
Intermediate 1992	34	13.0 ± 1.0	19.7 ± 1.1	9.0 ± 1.1	15.9 ± 1.1	23.1 ± 4.1
Subgroup of women with complete data set						
Pre-harvest 1990	-	-	-	-	-	-
Post-harvest 1990	34	12.5 ± 0.9	18.2 ± 0.9§	8.6 ± 0.9	14.7 ± 0.9§	25.0 ± 3.3
Intermediate 1991	34	12.7 ± 1.0	19.1 ± 0.9	8.8 ± 0.9	15.3 ± 0.8	23.7 ± 3.3
Pre-harvest 1991	34	12.6 ± 0.8	19.2 ± 0.8	8.9 ± 0.7	15.6 ± 0.8	23.4 ± 3.2
Post-harvest 1991	34	12.3 ± 0.9	18.2 ± 1.0§	8.5 ± 0.9§	14.5 ± 1.1§	24.9 ± 3.2
Intermediate 1992	34	12.8 ± 1.1	19.7 ± 1.1	9.0 ± 1.1	15.8 ± 1.1	23.3 ± 3.8

*) Mean values ± SD
†) Net energy expenditure calculated as gross energy expenditure minus BMR
‡) Delta Work Efficiency was calculated as $(\Delta W / \Delta EE) \times 100$
§) Significantly lower than post-harvest and intermediate periods ($p<0.05$)

harvest periods (23.3-23.7 %) and highest values(24.9-25.0 %) during post-harvest periods. Analysis did not show any significant differences between periods. Correlation analysis did not reveal any associations between changes in delta work efficiency and changes in body weight and in RMR.

Energy intake

Results of energy intake in various seasons are presented in Table 5. Energy intake values fluctuate throughout the year ($p<0.05$). The lowest values were observed during pre-harvest periods (9.3-9.4 MJ/day) and highest values in post-harvest and intermediate periods (9.6-11.0 MJ/day). Student's paired t-test indicated that energy intake values in pre-harvest periods were significantly lower ($p<0.05$) than that observed during post-harvest and intermediate periods. The magnitude of the difference between pre and post-harvest periods were 1.7 ± 1.4 MJ/day in 1990 and 0.6 ± 1.1 MJ/day in 1991. The observed difference in 1990 is significantly higher ($p<0.05$) than that observed in 1991. There was no significant association between the differences in 1990 and in 1991. Likewise, correlation analysis did not reveal any association between changes in energy intake and changes in body weight, fat free mass and RMR for each observation year.

DISCUSSION

The magnitude of the seasonal fluctuations in food availability in the studied population can be illustrated by changes in body weight, body composition and in energy intake. A substantial change in energy intake (1.7 MJ/day) between the pre- and the post-harvest periods was observed in 1990. However, the change in 1991 was only one third of the one observed in 1990. As expected, energy intake was the lowest in the pre-harvest periods, and the highest in the post-harvest periods. The same pattern was observed for body weight, fat free mass and fat mass. The increase in body weight between pre and post-harvest periods in 1990 was 2.6 kg and in 1991 the observed increase in weight over the same periods was 0.9 kg, only one third of that recorded in

TABLE 5: Energy intake in different seasons*

	n	Energy intake (MJ / day)
All women		
Pre-harvest 1990	45	9.8 ± 2.1
Post-harvest 1990	45	11.5 ± 2.8
Intermediate 1991	42	10.1 ± 2.5
Pre-harvest 1991	37	9.8 ± 2.3
Post-harvest 1991	34	10.0 ± 2.3
Intermediate 1992	34	9.6 ± 2.7
Subgroup of women with complete data set		
Pre-harvest 1990	34	9.3 ± 2.0†
Post-harvest 1990	34	11.0 ± 2.7
Intermediate 1991	34	9.7 ± 2.6
Pre-harvest 1991	34	9.4 ± 2.2†
Post-harvest 1991	34	10.0 ± 2.3
Intermediate 1992	34	9.6 ± 2.7

*- Mean values ± SD
†- Significantly lower than post-harvest and intermediate periods ($p<0.05$)

1990. These findings suggest that the seasonal fluctuations in food availability in 1991 results in a less pronounced reduction in energy intake, compared to 1990 and also indicate that there is a year-to-year variation in the seasonal stress as experienced by each area.

In the present study, the mean RMR varied from 5.3 to 5.5 MJ/day. Predicted RMR during pre-harvest season using the FAO/WHO/UNU (1985) equations (27) was on average 5.1 MJ/day which is only 5% less than the observed values. Similar differences (4%) between observed and predicted values were found for women in South Benin (10). When RMR was expressed per unit body weight, the average value of 77 $J.kg^{-1}.min^{-1}$ was comparable to values reported for other women in West Africa which are: Gambian women 80 $J.kg^{-1}.min^{-1}$ (28) and Beninese women 76 $J.kg^{-1}.min^{-1}$ (3,10).

Expressed by unit FFM, RMR was on average 95 J.kg $FFM^{-1}.min^{-1}$ and was again comparable to other Beninese women (3) and to Gambian women (29).

The modest 3% change in absolute RMR between periods was comparable to seasonal change of 4% reported among Beninese women (3). Although statistically significant, this small change, is not yet evidence for metabolic adaptation, because no seasonal change was observed when RMR was adjusted for body weight and FFM. In this respect our data are in line with what was reported by James (8) reviewing data from developing countries and by Durnin (11) for Indian women. However, substantial RMR reduction have been reported for Ethiopian women (9) and Indian labourers (30). The observed decrease in the present study was explained by body weight loss between post- and pre-harvest periods. The size of the change in RMR was comparable between the first and the second year and they were positively and significantly associated. This finding suggests that the same subjects do experience the same size of seasonal change in RMR. The present study also suggests that a seasonal reduction of energy intake as great as 15%, created by a substantial seasonal variation in food availability did not induce a metabolic adaptation by a reduction in RMR.

Another way to save energy is by performing physical activities at a lower energy cost by increasing work efficiency. To investigate that, energy costs of standardized activities were measured in different periods. During data collection, there was no indication of oxygen debt. Work level was sustainable and respiratory quotients (RQs) were normal (range 0.835-0.941; mean RQ = 0.856).

Energy cost of cycling at 25 W were about 12.5 kJ/min respectively. No significant change could be found between periods. Gross energy cost as well as net energy cost of cycling at 50 W were comparable to data reported on a group of big eaters in East Java (31). The reported intake for this group of big eaters was comparable to intake among Manta's women during post-harvest periods. Gross and net energy costs of cycling at 50 W fluctuate significantly between periods, with a modest change of about 0.9-1.0 kJ/min between pre- and post-harvest periods. Calculated Delta Work Efficiency (DWE), ranging from 23 to 25% is in line with what was reported by Gaesser (20). DWE did not fluctuate with seasons. The outcomes of the DWE is just the opposite of what could be expected. Women were about 6% (NS) more efficient during post-harvest periods than in pre-harvest period. Delta Work Efficiency could not be calculated for the first observation year and there was nearly no energy stress on the second year when information was available on DWE. The outcome should then be regarded with caution, with regards to the size of energy deficit. With a seasonal change in energy intake as substantial as the one observed in 1990, the situation may be different. The modesty of the change in energy cost of cycling which was observed between periods and the DWE which did not significantly change with seasons suggest that, there is nearly no evidence that metabolic adaptation occurred by performing physical activities at a lower energy cost. This finding is in line with Parizkova (32), noting that " the gross or net efficiency of standardized tasks appears not to increase with low food intake". However, it has been reported among small eaters in East Java (31), an improvement of work efficiency. The fact that no association was found between energy cost of cycling and body weight confirms that cycling is a non weight bearing activity and is in line with what was reported elsewhere (33). Physiologists may consider 50 W as a rather low workload and then still expect from the slight but significant change observed at this workload, evidence for metabolic adaptation at a higher level of work. This is out of the scope of this study. The aim of the present study was to study situations which reflected the real life of women in Manta, and it is well known that in free living condition rural women mainly performed sub-maximum work.

Sukhatme and Margen (34) postulated that an individual can adapt to varying level of energy intake by changing the efficiency of energy utilization as well as changing patterns of activity. Waterlow suggests that reduction in RMR up to 10% may occur in people on low energy intake (33). Reduction in RMR as energy saving mechanism has been reported for the well known classical Minnesota semi-starvation experiment (35). Likewise, reduction in RMR have been reported for undernourished labourers in India (30) and for women in Ethiopia (9). Edmundson (31) have reported improved work efficiency in Javanese subjects on a low plan of energy intake. The present study fail to show either reduction in RMR beyond a level which could be explained by change in body weight or higher efficiency in performing physical activity. Results obtained on rural women in Benin do not support Sukhatme and Margen's hypothesis and point out once again that people in real life arrive at a new energy balance mainly by lowering body weight. The outcomes of the Minnesota experiment were not likely to occur in free living conditions since this drastic reduction in energy intake is not likely to occur.

From the present study, it is concluded that rural farmers communities, even when experiencing a seasonality characterized by a single harvest and a decrease in energy intake as large as 15%, arrived at a new energy balance only by lowering body weight.

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CHAPTER 5

ACTIVITY PATTERN OF RURAL BENINESE WOMEN: A LONGITUDINAL STUDY OVER TWO CONSECUTIVE YEARS

Eric-Alain D Ategbo, Marti J van Liere, Joop MA van Raaij, Frans LHA de Koning, Joseph GAJ Hautvast

ABSTRACT

The aim of this study performed on rural women of North Benin was to investigate whether, faced with seasonal fluctuations in food availability created by an unimodal climate, women change their activity pattern in order to save energy. RMR, body weight, energy intake and activity pattern were measured at 6 periods over 2 years. During pre-harvest periods, time allocated to fieldwork increased ($p<0.05$) and time spent on domestic work and resting activities decreased. Further, PAL increased ($p<0.05$) by 10% from post- to pre-harvest periods. These findings suggest that despite the substantial fluctuations in food availability, changes observed in activity pattern result in an increased energy expenditure, rather than in energy sparing. Energy intake and body weight also show seasonal fluctuations with lowest ($p<0.05$) values during pre-harvest.

KEYWORDS : Activity pattern; PAL; energy balance; behavioural adaptation

INTRODUCTION

In developing countries, rural women are heavily engaged in agricultural production, mainly determined by rainfall pattern. Therefore, they experienced seasonal changes in their activity pattern resulting in a seasonal variation in their energy balance (1-3). Data on the activity pattern and the energy expenditure of rural women are scarce (4-6). Available studies on the activity pattern of rural female farmers do not always show seasonal changes, and they do not always provide evidence for changes in energy expenditure (4-8). Most of the studies on which such conclusions are based were performed in areas characterized by a low to a moderate seasonal fluctuations in food availability, with two rainy seasons, thus two harvests a year. So far, very little is known about the seasonal trend in activity pattern and the consequences on the energy expenditure of rural women living in areas characterized by only one harvest a year (9). Whether people may change activity pattern to save energy when they are in situation of energy debt generated by an unimodal climate is unknown. The present longitudinal study was designed to investigate whether under an unimodal climate, thus in areas with only one harvest a year, changes in activity pattern will result in a reduction of energy expenditure, thus acting as an energy saving mechanism. Also, the repeatability from year to year of this phenomenon is also considered in the present paper.

SUBJECTS AND METHODS

Study area

The study was carried out in five villages of the commune of Manta, situated in the ATACORA province, in the north-western region of the Republic of Benin. This area was chosen because of its unimodal climate, the known existence of a considerable seasonal fluctuations in body weight (10), the absence of food intervention programmes and a reasonably good accessibility of the area. Manta is located at an altitude of 240 meters above sea level, between two mountain-ranges of about 500 meters altitude.

Altogether 4,000 inhabitants are living in the research area. The population of the 5 study villages belongs to the ethnic group of Otammari and they are all subsistence farmers. Average rainfall is about 1300 mm a year, spread over one rainy season, from May to September. Daily average temperature varies between 26°C in July and 36°C in April. Relative humidity varies between seasons and fluctuates between 80% during the rainy season and 20% during the dry season (11).

Main food crops are millet (Pennisetum spp), sorghum (Sorghum spp) and hungry rice commonly called *fonio* (Digitaria exilis). Beans (Vigna spp), rice (Oryza sativa) and bambara groundnuts (Voandzeia subterraneae) are also produced. Groundnuts (Arachis hypogeae) are produced as cash crop mainly by men. Cultivation is done by men as well as women using the hoe; women cultivate their own land. Hungry rice is sown in April and May, followed by sorghum and millet in May and June. Groundnuts, beans, rice and bambara groundnuts are sown in June and July. Hungry rice is first harvested in September and the other crops are harvested in November and December. The start of the period of low food availability depends on the previous harvest, and usually occurs in July. This period is ended by the harvest of the hungry rice in September. Women are involved both in domestic work and productive activities. Bambara groundnuts and rice are exclusively produced by women.

Study design and subjects

Energy intake and activity pattern data were collected simultaneously for 4 consecutive days at 6 periods spread over two consecutive years. For the overall study, data were collected twice during the pre-harvest period (July - mid September), twice during the post-harvest period (November - January) and twice during the intermediate period (March - April). In addition, resting metabolic rate (RMR) was measured within two weeks before or after food consumption and activity pattern data collection.

A sample of 45 women was selected to participate in the study according to the following criteria: farming as their main occupation, aged 18 to 45 years, non-pregnant and non-lactating, mother of at least one child and permanent residence in one of the research villages. Data on women who became pregnant during the study period are excluded from the present analysis. Due to reasons of pregnancy, illness or moving, a complete data set became available from 34 women. Anthropometric characteristics of participants are given in Table 1. The purpose of the study was fully explained to women eligible for participation and their husbands. After receiving their informed consent, they were allowed to participate in the study. The protocol of the study was submitted to and approved by the Medical - Ethical committee of the Wageningen Agricultural University.

TABLE 1: Anthropometric characteristics of subjects*†

	All women	Subgroup
Number	45	34
Age (years)	31.0 + 4.3	30.8 ± 4.2
Weight (kg)	49.9 + 5.1	48.4 ± 5.0
Height (cm)	160.0 + 5.5	159.5 ± 5.8
Body fat (%)	19.0 + 3.6	19.4 ± 4.1
Body Mass Index (Kg/m^2)	19.5 + 1.9	19.0 ± 1.6
Mid Upper Arm Circumference (cm)	25.4 + 1.7	25.6 ± 1.6
Sum wrist diameters (cm)	9.7 + 0.8	9.6 ± 0.9
Sum knee diameters (cm)	16.0 + 0.7	16.0 ± 0.5
Shoulder diameters (cm)	34.0 + 1.8	33.5 ± 1.9

*) Means and their standard deviation
†) Characteristics at the start of the study in July 1990

Measurements

Resting Metabolic rate (RMR)

RMR was measured in a field laboratory using open circuit indirect calorimetry and the Douglas bag technique. Expired air was collected 3 times during eight minutes with intervals of five minutes between two samples. Expired air was analyzed for its oxygen content using a Servomex O_2 analyzer (Type OA 570; Taylor Instrument Analytics Ltd., Crowborough, Sussex, United Kingdom) and its volume was measured with a wet precise gasmeter (Schlumberger, type 5 Meterfabriek Schlumberger, Dordrecht, the Netherlands). The volume was adjusted for the sample which was derived for the oxygen content analysis and the total volume was corrected for temperature, dryness and pressure. RMR was calculated using Weir's (1949) equation (12). Measurements were performed between 6.00 and 9.00 am, 10 to 12 hours after the last meal, on apparently healthy women, physically and emotionally at rest. The women were collected at home and brought to the laboratory by car.

Physical activity pattern and total energy expenditure

Daily activity pattern was recorded using the minute to minute registration method (13) during four consecutive days. Recording was done by well-trained local female assistants who stayed with the subject from 7.00 am to 8.00 pm. One day before the start of data collection, subjects were clearly told that they should continue carrying out their usual daily activities during the presence of the research assistant. In order to minimize the interference of the presence of an observer with the daily activities of the participant, observers were selected among the well-known and accepted women of the community. Energy cost of daily activities expressed as a multiple of the RMR was obtained from values published by FAO/WHO/UNU (14). The amount of time spent daily on each activity was calculated and the average over the four days of observation was considered to be representative for the period. The daily energy expenditure of the women, expressed as a multiple of RMR, was calculated based on the time spent on the various activities and their energy cost.

Daily energy expenditure was estimated by multiplying the calculated PAL by the RMR measured in the same period. Energy balance was established by comparing estimated energy intake and estimated daily energy expenditure.

To study changes in activity pattern from period to period, activities were classified into 7 categories based on their function, whatever the energy cost. Beside *resting* which includes sleeping, lying and standing; *non-productive domestic work* including child care, sitting and standing activities; *productive domestic work* involving collecting food and fire wood, fetching water; *food preparation* which includes pounding, grinding and cooking; *agricultural fieldwork* including weeding, sowing, ploughing and harvesting, *eating* and *walking* are considered as separate activity categories.

Energy intake

Energy intake measurements were carried out in six periods during 4 consecutive days each period. Local market which takes place every four days occurs once during the 4 consecutive days for each woman. Energy intake was measured using the observed weighed record method (15). Every food was weighed before and after cooking as well as the subject's portion and leftovers, using a digital balance (Soehnle type 800300) for weights up to 2 kg, and between 2 and 10 kg, a spring balance (Soehnle type 1203) was used. Measurements were carried out by well-trained local assistants from 7.00 am until subjects had eaten their last meal (usually around 8.00 pm). Foods consumed when the assistant was not present were determined by recall and household measures were used to estimate quantities. Energy intake was calculated using appropriate food composition tables (16,17). Energy intake for each woman per period was obtained by averaging the intake of the four consecutive days or in case of missing data the average of the remaining days is used.

Statistics

Derived quantities defined, were changes in time spent in different activities and in PAL. For each of those quantities, changes were computed as the difference between post-harvest and pre-harvest periods of the same year.

Results on time allocation, PAL, RMR, energy intake body weight and energy balance are presented as means values and their standard deviations. Multivariate analysis of variance for repeated measurement (MANOVA SPSS PC+ /V2.0) (18) was used to find out seasonal changes in activity pattern and in the resulting PAL. When MANOVA revealed significant differences, the paired t-test was used to test differences between two periods. Pearson's correlation analysis was used to study the year-to-year consistency of changes in activity pattern and physical activity level between the pre and the post-harvest periods.

RESULTS

Physical activity pattern

Daily activity pattern of women in various periods was monitored and results are shown in Table 2. In all 6 periods, women in Manta spent a great share of the day on resting activities. The amount of time devoted to this activity fluctuates throughout periods with lowest values during pre-harvest periods (751-781 min) and highest values during post-harvest periods (783-888 min), corresponding to 52 to 62% of the day. The

TABLE 2: Time (minutes) allocated to various categories of daily activities by Otammari women in different season*

	Pre-harvest 1990	Post-harvest 1990	Inter mediate 1991	Pre-harvest 1991	Post-harvest 1991	Inter mediate 1992
All women						
n	45	45	42	37	34	34
Resting	753 ± 74	787 ± 65	867 ± 81	797 ± 87	982 ± 82	888 ± 84
Eating	40 ± 10	45 ± 13	47 ± 15	40 ± 10	40 ± 10	46 ± 15
Walking	112 ± 43	124 ± 35	123 ± 46	114 ± 38	149 ± 51	142 ± 44
Food preparation	169 ± 64	183 ± 59	151 ± 50	170 ± 68	149 ± 53	140 ± 64
Fieldwork	169 ± 46	15 ± 31	28 ± 30	145 ± 44	3 ± 15	10 ± 21
Productive domestic work	20 ± 16	29 ± 17	28 ± 14	11 ± 6	23 ± 10	33 ± 16
Non productive domestic work	177 ± 56	257 ± 66	196 ± 67	163 ± 59	184 ± 68	181 ± 58
Subgroup of women with complete data set						
n	34	34	34	34	34	34
Resting	751 ± 75†	783 ± 63	854 ± 78	781 ± 63†	888 ± 82	887 ± 86
Eating	42 ± 10	47 ± 14	47 ± 17	39 ± 9	40 ± 9	45 ± 14
Walking	116 ± 47	127 ± 31	128 ± 44	121 ± 32	151 ± 42	145 ± 44
Food preparation	171 ± 70	179 ± 65	151 ± 55	178 ± 68	148 ± 54	137 ± 65
Fieldwork	158 ± 41‡	18 ± 34	32 ± 25	147 ± 34‡	3 ± 16	10 ± 22
Productive domestic work	18 ± 12†	25 ± 12	25 ± 13	11 ± 6†	23 ± 10	31 ± 22
Non productive domestic work	184 ± 63†	261 ± 78	203 ± 70	163 ± 60†	187 ± 68	185 ± 67

*) Mean ± SD
†) Lower than in other periods ($p<0.05$)
‡) Higher than in other periods ($p<0.05$)

rest of the day was mainly divided between activities such as non productive domestic work (13-18 %), food preparation (10-12 %), walking (8-10%) and agricultural fieldwork (0-10%). Eating did occupy women consistently for 3% of the day whatever the season. For all activities, except for eating and walking, significant differences ($p<0.05$) were found between periods.

For activities resting, non-productive domestic work and productive domestic work, paired t-test revealed that, time spent on those activities during pre-harvest periods were significantly lower ($p<0.05$) than during post-harvest periods. The activity fieldwork displayed an opposite trend. Time spent on fieldwork during pre-harvest periods were significantly higher ($p<0.05$) than during post-harvest periods. Food preparation also displayed some seasonal variations but did not show any consistent trend for the two study years.

Studying changes in time spent on each activity between pre- and post-harvest periods in 1990 and 1991, it appeared that changes observed for fieldwork (140-144 min) and productive domestic work (12 min) remain stable between years. The size of changes observed for resting (32 min in 1990 and 100 min in 1990) and food preparation (8 min in 1990 and 30 min in 1991) in 1991 were larger ($p<0.05$) than that observed in 1990. For non productive domestic work (80 min in 1990 and 24 min in 1991) the opposite was observed.

Correlation analysis revealed a significant association between year-to-year changes only for fieldwork ($r=0.55$; $p<0.001$), while no significant but suggestive correlation coefficient was found for walking ($r=0.20$) and resting ($r=0.23$).

Physical activity level and daily energy expenditure

Physical activity level (PAL) of women during the 6 periods are shown in Table 3. The PAL of Manta's women fluctuates throughout seasons. Paired t-test revealed that average values during pre-harvest periods (1.75-1.78) were significantly higher ($p<0.05$) than average values in intermediate and post-harvest periods (1.61 - 1.68) in both study years. Changes in the PAL observed were 0.10 ± 0.13 during the first study year and 0.13 ± 0.10 during the second year. The size of changes observed in 1990 and in 1991 did not reach significant difference. Correlation analysis did not reveal any association between changes in PAL from year to year ($r=0.16$).

RMR was measured during the same period as activity pattern data collection and results are presented in Table 3. Average RMR fluctuate between periods and varies between 5.33 MJ/day in pre-harvest periods and 5.50 MJ/day in intermediate and post-harvest periods. From PAL and RMR values Daily Energy Expenditure (DEE) was calculated. DEE fluctuates between periods (Table 4). Highest values were obtained during pre-harvest periods (9.3-9.5 MJ/day) and lowest values during intermediate and post-harvest periods (8.8-9.2 MJ/day).

TABLE 3: Physical activity level (PAL) and Resting Metabolic Rate (RMR) of rural women in different seasons in Manta*

	n	PAL	RMR (MJ/day)
All women			
Pre-harvest 1990	45	1.77 ± 0.11	5.34 ± 0.45
Post-harvest 1990	45	1.69 ± 0.13	5.52 ± 0.35
Intermediate 1991	42	1.62 ± 0.11	5.52 ± 0.32
Pre-harvest 1991	37	1.72 ± 0.12	5.28 ± 0.38
Post-harvest 1991	34	1.62 ± 0.10	5.44 ± 0.22
Intermediate 1992	34	1.61 ± 0.09	5.49 ± 0.29
Subgroup of women with complete data set			
Pre-harvest 1990	34	1.78 ± 0.09†	5.33 ± 0.42
Post-harvest 1990	34	1.68 ± 0.08	5.50 ± 0.33
Intermediate 1991	34	1.65 ± 0.10	5.50 ± 0.32
Pre-harvest 1991	34	1.75 ± 0.09†	5.30 ± 0.39
Post-harvest 1991	34	1.62 ± 0.10	5.44 ± 0.22
Intermediate 1992	34	1.61 ± 0.09	5.49 ± 0.29

*) Mean ± SD
†) Higher than in other periods ($p<0.05$)

Energy balance

Data on energy intake measured on the same days as activity pattern are presented in Table 4. Energy intake fluctuates between periods, with lowest average intake during pre-harvest periods (9.3-9.4 MJ/day) and highest intakes during

TABLE 4: Energy balance and body weight of rural female Beninese in different seasons*

	n	Energy intake (MJ/day)	Energy expenditure (MJ/day)	Energy balance (MJ/day)	Body weight (kg)
All women					
Pre-harvest 1990	45	9.8 ± 2.1	9.4 ± 2.0	+ 0.4 ± 0.3	48.4 ± 5.0
Post-harvest 1990	45	11.5 ± 2.8	9.3 ± 2.7	+ 2.2 ± 0.7	51.0 ± 4.8
Intermediate 1991	42	10.1 ± 2.5	8.9 ± 2.5	+ 1.2 ± 0.9	50.1 ± 5.3
Pre-harvest 1991	37	9.8 ± 2.3	9.1 ± 2.4	+ 0.7 ± 1.1	49.4 ± 5.0
Post-harvest 1991	34	10.0 ± 2.3	8.8 ± 2.8	+ 1.2 ± 0.5	49.4 ± 4.9
Intermediate 1992	34	9.6 ± 2.7	8.8 ± 2.6	+ 1.6 ± 0.6	49.9 ± 5.1
Subgroup of women with complete data set					
Pre-harvest 1990	34	9.3 ± 2.0†	9.5 ± 1.8	- 0.2 ± 0.8	48.4 ± 4.9
Post-harvest 1990	34	11.0 ± 2.7	9.2 ± 2.1	+ 1.8 ± 0.7	51.0 ± 4.7
Intermediate 1991	34	9.7 ± 2.6	9.1 ± 3.0	+ 0.6 ± 1.0	49.9 ± 4.7
Pre-harvest 1991	34	9.4 ± 2.2†	9.3 ± 2.7	+ 0.1 ± 1.1	48.5 ± 4.8
Post-harvest 1991	34	10.0 ± 2.3	8.8 ± 2.9	+ 1.2 ± 0.5	49.4 ± 4.9
Intermediate 1992	34	9.6 ± 2.7	8.8 ± 2.5	+ 1.6 ± 0.6	49.9 ± 5.1

*) Mean ± SD
†) Lower than in other periods ($p<0.05$)

intermediate and post-harvest periods (9.6-11.0 MJ/day). When the estimated daily energy expenditure was compared to the estimated energy intake for various periods, it turned out that for both study years, subjects were in positive energy balance for both intermediate and post-harvest periods. However, subjects were found to be in negative energy balance only during the first pre-harvest period and nearly in balance during the pre-harvest period of 1991.

DISCUSSION

Rural women of North Benin spent between 52 and 62 % of a day on resting activities and about 3% of the day eating. Thirteen to eighteen percent of the day was allocated to non-productive domestic work. Walking took about 8 to 10 % of the day. Again they spent 10 to 12% of their time in food preparation throughout seasons. Similar results were obtained among rural women in South Benin (6) with two harvests a year and Burkina-Faso (19) with only one harvest a year, where resting activities in the pre-harvest period took 60 % and 58% of the day. Food preparation in Ethiopia (4), Burkina-Faso and South Benin took 15%, 10-16% and 11% respectively during the pre-harvest period, and were similar to that obtained on Manta's women. For non-productive domestic work, similar amount of time spent by women in Manta was reported in Burkina-Faso (14%). Comparable proportion of time (10%) was allocated for walking in the North and the South of Benin.

During post-harvest periods, almost no time was allocated for agricultural work. However, this activity took 10% of the day during pre-harvest periods. This amount of time is higher than that reported for women in the South of Benin (5%) and was lower than the 15% reported in Burkina-Faso. This difference between Manta and Burkina-Faso may be explained by the fact that in the present study, data were collected for 4 days including each time a market day. The market is an important social event and on that day, fieldwork is done only for few hours. In the Burkina-Faso study, it was not clear whether data were collected on special days which may affect the time allocated to fieldwork. The difference between the North and the South of the country may be explained by the level of involvement of women in agriculture. Women in the North are more engaged in agriculture than in the South. This difference can also partly be explained by the low fertility of land in the North. For equal production, more work have to be done in the North.

Daily activity pattern of women showed seasonal changes. Time spent on resting activities, non-productive and productive domestic work were reduced during pre-harvest periods in favour of agricultural work. Similar increase was reported for women in other African countries showing moderate seasonal fluctuations in food availability (4,8,10). In Burkina-Faso (19), domestic work also showed a similar trend between pre- and post-harvest periods.

The unique aspect of the present study was to investigate the year-to-year consistency of observed changes in women's activity pattern. It appeared that only fieldwork showed a significant association. This may be explained by the relationship which may exist between size of the field and the work to be done. This association suggests that size of land on which each women can produce crops is a determining factor for her activity pattern during pre-harvest periods.

Activity pattern showed seasonal changes as well as PAL. The PAL observed in post-harvest periods were comparable to the 1.64 x RMR given by the FAO/WHO/UNU (14) for moderate activity level and the average of 1.78 x RMR observed during pre-harvest periods were comparable to the 1.82 x RMR suggested for heavy activity level. Other studies from areas with only one rainy season did report seasonal changes in PAL of rural women. PAL of Gambian women (8) fluctuates between 1.7 and 2.0 x RMR. In Burkina-Faso, PAL of rural women changes from 1.89 to 2.35 x RMR between dry season and rainy season. However, women in areas characterized by a bimodal climate did not show any seasonal change (4,5,10). The change in PAL was of a magnitude of 5-7%. The size of the reported change was 23% lower than that of women in Burkina-Faso (19) and 15% lower than in the Gambia (8). The observed change in PAL although of a modest size, reached a significant level. The fact that PAL increased in the pre-harvest periods, rather than a decrease, is a clear evidence that seasonal changes observed in activity pattern did not result in an energy saving. This study did not provide any evidence to support the idea that people may modify their activity pattern to save energy in order to cope with the seasonal fluctuations in food availability. This study suggests that under an unimodal climate, despite the substantial expected energy deficit during the pre-harvest periods, women's energy expenditure increased instead of decreasing as it is widely believed.

When energy intake is compared to energy expenditure, it was found that during post-harvest and intermediate periods, women are on positive energy balance. They were in negative energy balance during the pre-harvest period of 1991. The pattern followed by energy balance agreed with the seasonal pattern observed in body weight (20) except during 1991 when subjects who were apparently in balance during the pre-harvest period did loose weight. For rural women of other West African countries (6,8,19), negative energy balance was observed during pre-harvest periods, together with a weight loss. Our study yields similar results during the first study year. However, the size of the energy debt of 0.2 MJ was smaller than expected when compared to the 2.6 kg of weight loss observed in 1990. This limited size of the energy debt during pre-harvest periods indicated that either the estimate of energy expenditure was too low or the energy intake estimation was too high.

Energy expenditure data were collected by trained fieldworkers and energy cost of activities were those published by FAO/WHO/UNU and widely accepted. Fieldworkers were generally well accepted. This minimizes the interference of the observer with the activity pattern of the participant. Moreover, the calculated PALs were comparable with the PAL given by FAO/WHO/UNU (14) for moderate to heavy activity level. An undersetimation of the PAL was then unlikely to occur.

Energy intake observed among women in Manta was higher than that reported for rural women in South Benin (14), and in other West African countries (7,20-22). When expressed by kg of body weight, energy intake was between 192-215 $kJ.kg^{-1}.day^{-1}$. This intake was high when compared to intake reported for rural women in South Benin (122-181 $kJ.kg^{-1}.day^{-1}$). However, our data were still comparable but, to the upper level of the range of intake reported for women in Ethiopia (170-206 $kJ.kg^{-1}.day^{-1}$) (4) and in India (155-218 $kJ.kg^{-1}.day^{-1}$) (5). This suggests a probable overestimation of the energy intake in the studied population.

Energy intake was estimated by the observed weighed record method. Weighing scales were frequently calibrated, and the necessity not to modify their dietary pattern was fully explained to the subjects. The overestimation may be explained by the fact that in rural developing countries, eating pattern is an indicator of socio-economic status. Also, low social status is attached to poverty. Therefore, to avoid being considered as a poor family, they tend to eat more. The presence of a well-known observer could not help, since subjects still considered the investigator as an outsider. This observation once more brings about the discussion on the validity of this technique to estimate energy intake and clearly point out that despite all care with which data collection is planned and implemented using observed method, misestimation of intake is likely to occur. This statement is still to be confirmed by validating for instance protein intake data collected by the observed weighed record method, with the level of nitrogen in the urine.

It can be concluded from the present study that when time spent on fieldwork increases, time spent for resting and domestic work decreases. It can not be concluded whether this is done consciously in order to lower energy expenditure. The year-to-year consistency in the time spent in fieldwork played an important role as a determinant of activity pattern during pre-harvest. Seasonal changes in activity pattern of women result in an increase of the PAL, in opposite to the decrease which was expected. This suggests that there is no evidence for a reduced energy expenditure in individuals exposed to seasonal food shortage even under an unimodal climatic conditions.

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CHAPTER 6

A TWO YEAR STUDY OF FOOD AND NUTRIENT INTAKE IN RURAL BENINESE WOMEN

Eric-Alain D Ategbo, Marti J van Liere, Joop MA van Raaij, Joseph GAJ Hautvast

ABSTRACT

Food intake was studied during two consecutive years in a group of Beninese rural women living in an unimodal climatic environment which causes large seasonal differences in availability and use of food products. Cereals are the main suppliers of energy and protein, followed by pulses. Carbohydrate contribute to 72-76% of energy intake, protein about 11% and fats about 13-15%. Energy, protein and iron intake were probably adequate to cover the year round needs. Protein intake is stable throughout measurement periods, about 65-70 g/day and is higher than the Recommended Dietary Allowance. Iron intake throughout the years is about 31 mg/day which covers the recommended intake. The intake of retinol equivalents was often very low with the exception of the periods when mangoes are harvested. The combination with low fat intakes may lead to low vitamin A stores. This needs further study.

KEYWORDS: Food products use, energy intake, nutrients intake, seasonal variations, Otammari, Benin

INTRODUCTION

Most rural households in developing countries depend for their daily food consumption, largely on their own agricultural production. This is especially true for small scale farmers (1-3). In areas experiencing an unimodal climate, crops can be harvested only during a short period of the year and have to be stored until the next harvest. This harvest has to provide food during the household for the whole year. Storage facilities are often not very adequate, resulting in considerable post-harvest losses. Therefore, it might be expected that food products available vary throughout the year, inducing changes in food consumption pattern (2-9). Studies have been performed in order to point out what the consequences are of such variations in use of food products in areas characterized by a moderate seasonal variations in food availability (1,5,7,9). Knowledge of the impact of variations in use of food products on energy and nutrients intake in areas experiencing a substantial seasonal fluctuations in food availability is scarce. The purpose of the present study, performed in an area with only a short rainy season a year, thus one harvest, was to investigate the extent to which energy and nutrient intakes are influenced by changes in use of food products. The restriction to iron and vitamin A as only micronutrients described here may be explained by the fact that public health problems caused by anaemia and xerophtalmia have been widely reported among rural communities of developing countries (10). This food consumption survey is part of a comprehensive study on the adaptative processes used to cope with seasonal variations in food availability, carried out in North Benin.

SUBJECTS AND METHODS

Study area

The rural commune of Manta is located in the north-western part of the Republic of Benin, on the border with the Republic of Togo. The majority of the population is OTAMMARI, mainly sedentary farmers. The area undergoes a dry season between

October and May. The duration of the rainy season, usually between May and September, and the amount and distribution of rainfall throughout the rainy season determine the quality and the quantity of the harvest. Average annual rainfall is about 1300 mm with a peak in rainfall in July and August. Manta is situated between two mountain-ranges of 500 meters altitude. Due to the proximity of mountains, some farmers do produce food crops on the slopes of mountains (11).

Main food crops are millet (Pennisetum spp), sorghum (Sorghum spp) and hungry rice (Digitaria exilis). Beans (Vigna spp), yam (Dioscorea spp), rice (Oryza sativa) and bambara groundnuts (Voandzeia subterraneae) are also produced. Groundnuts (Arachis hypogea) were formerly produced as cash crop. Nowadays, its production is very limited since prices are no longer profitable. All crops are harvested in November and December, except for hungry rice which is harvested in September.

The study was conducted in five villages of the rural commune of Manta which were selected because of a relatively good accessibility all the year round, the absence of any intervention programme and a stable residential population.

Study design and subjects

A sample of 45 women were selected to participate in the present study according to the following criteria: farming as their main occupation, aged 18 to 45 years, non-pregnant and non-lactating, mother of at least one child and permanent residence in one of the research villages. When a woman became pregnant during the study period, her data were excluded from the present analysis. Due to pregnancy, illness or moving, a complete data set covering the whole study period became available for 34 women. Anthropometric characteristics of these subjects are given in Table 1.

Data have been collected by food consumption survey over two years, at three different periods a year, resulting in a data set covering each seasonal period twice as described below: pre-harvest period (July-August) when food availability is at its lowest; post-harvest period (mid November -January) corresponding to a period of plenty food availability, characterized by ceremonies and many social events, and an intermediate period (March-April) in which food availability is in-between and stable. At each period, data were collected for each woman for 4 consecutive days including a market day. At the same periods with food intake data collection, haemoglobin level in the blood had also been measured. The purpose of the study was fully explained to subjects

TABLE 1: Anthropometric characteristics of subjects*†

	WOMEN
Number	34
Age (years)	30.8 ± 4.2
Weight (kg)	48.4 ± 5.0
Height (cm)	159.5 ± 5.8
Body fat (%)	19.4 ± 4.1
Body Mass Index (BMI kg/m^2)	19.0 ± 1.6
Mid Upper Arm Circumference (cm)	25.6 ± 1.6
Sum wrist diameter (cm)	9.6 ± 0.9
Sum knee diameter (cm)	16.0 ± 0.5
Shoulder diameter (cm)	33.5 ± 1.9

*) Mean Values ± SD
†) Measured at the start of the study, in a Pre-harvest period

eligible for participation. After receiving their informed consent, they were allowed to participate. The research protocol was submitted to and approved by the Medical-Ethical Committee of the Wageningen Agricultural University.

Methods

Food consumption survey

The food consumption survey was performed using the observed weighed record method (12) during 4 consecutive days. All foods were weighed and recorded before and after preparation, as well as the subject's portion and leftovers, to the nearest gramme, using a digital balance (Soehnle type 800300) for weights up to 2 kg and a spring weighing scale (Soehnle type 1203) for weights between 2 and 10 kg. These scales were frequently checked and calibrated using standard weight of 1 or 5 kg. Measurements were carried out by a well-trained local assistant. The day before a food consumption session, an appointment was made with the subject and emphasis was put once again on the necessity to keep a normal dietary pattern during the four survey days. The assistant stayed with the subject from 7.00 am until after the last meal (usually around 8.00 pm). Foods eaten when the research assistant was not present were estimated using the recall method and recorded as well. Energy intake and nutrients (carbohydrate, protein, fat, iron and retinol equivalent) content of the diet were derived using appropriate food composition tables (13,14). Energy intake as well as nutrients intake per period for each subject were obtained by averaging energy and nutrients intake over four consecutive days. In case of missing data, the average of the remaining days is used.

Haemoglobin level

Haemoglobin level in the blood was measured in triplicate using the finger prick and a photometric analysis method (15). The HemoCue photometer (Sweden) was used. The average of the three measurements was used as a representative value for a period.

Data analysis and statistics

To study the contribution of different food groups to energy and nutrient intake in various seasons, food items were classified as cereals, tubers, pulses, animal products, fat, fruits and vegetables. Intake of foodstuffs falling under the same food group were added to yield the contribution of a given food group to energy and nutrients intake. Except for retinol equivalents changes were computed as the difference between the pre- and post-harvest periods. For retinol equivalents changes were calculated as differences between intermediate and post-harvest periods.

Multivariate analysis of variance (MANOVA) for repeated measurements procedure (SPSS PC+/V2.0) (16,17) was used to investigate whether there is a difference in food products use between seasons. When MANOVA revealed significant difference, paired t-test was used to point out the difference between pre- and post-harvest periods. The same procedure was used to assess whether there is any differences in nutrient intake between periods. Pearson's correlation analysis was used to study the consistency in changes in energy and nutrient intake from year-to-year as well as the year-to-year change in food products use.

RESULTS

Meals often consist of a thick porridge "pâte", which is eaten with a relish of green leafy vegetable or okra, including mustard, salt and red pepper. "Pâte" is made from millet, hungry rice or rice and most of the time during hungry season also from sorghum. On occasion dried fish, meat, eggs or cheese are also used, however in very small quantities. Pulses are cooked in water and are eaten with shea butter mixed with salt and pepper, or are processed into different types of cake. Tubers, local beer (Tchoukoutou), mangoes (Mangiféra indica), African locust (Parkia biglobosa) and shea nuts (Butyrospermun parkii) are also part of the dietary pattern of the Otammari community.

Seasonal changes in use of food products

Table 2 shows the average daily consumption of individual food products throughout the various seasons. Table 3 gives the average daily consumption of groups of food products. In terms of weight, the main group of product use in all seasons was cereals followed by either pulses in the pre-harvest and the intermediate periods or tubers in the post-harvest periods. Cereals used during the pre-harvest periods was lower ($p<0.05$) than in the post-harvest periods. Significant differences also exist between intermediate and post-harvest periods of the same year. The magnitude of the change in cereals use between pre- and post-harvest periods were 91 and 24 g/day in 1990 and 1991 respectively. Quantity of pulses used was the highest ($p<0.05$) during the pre-harvest periods. The quantity of pulses used was the highest ($p<0.05$) during the pre-harvest periods. The use of pulses in the post-harvest periods was higher ($p<0.05$) than during intermediate period of 1991. Changes in pulses used between pre- and post-harvest periods were 45 and 24 g/day in 1990 and 1991 respectively. Vegetables, fat and animal products all, showed the highest use in the pre-harvest periods. The use of vegetables, fat and animal products was higher in post-harvest than in intermediate periods, except for animal products in 1990. Changes between pre- and post-harvest periods were 12 g/day in 1990 and 25 g/day in 1991 for vegetables, 10 g/day in 1990 and 11 g/day in 1991 for fat and 11 g/day in 1990 and 7 g/day in 1991 for animal products. Fruits consumption, mainly mango was higher ($p<0.05$) in the intermediate periods than in pre and post-harvest periods.

TABLE 2: Use of individual food products by Otammari women (n=34) in different seasons*

	Pre-harvest 1990†	Post-harvest 1990‡	Inter-mediate 1991§	Pre-harvest 1991†	Post-harvest 1991‡	Inter-mediate 1992§
			g / day			
Millet	222 ± 142	166 ± 167	213 ± 178	185 ± 188	92 ± 156	159 ± 166
Sorghum	63 ± 80	75 ± 106	127 ± 177	116 ± 141	234 ± 178	160 ± 141
Hungry rice	32 ± 78	116 ± 148	22 ± 74	30 ± 57	14 ± 70	5 ± 20
Rice	43 ± 52	94 ± 121	47 ± 69	34 ± 48	49 ± 74	37 ± 52
Yam	54 ± 135	31 ± 91	16 ± 54	49 ± 117	109 ± 192	6 ± 24
Sweet potato	-	206 ± 247	-	-	88 ± 153	-
Bambara groundnuts	108 ± 97	114 ± 126	49 ± 74	78 ± 61	81 ± 89	59 ± 82
Beans	48 ± 54	14 ± 26	21 ± 40	31 ± 40	12 ± 31	38 ± 50
Locust beans	20 ± 42	1 ± 7	3 ± 11	7 ± 19	-	7 ± 22
Groundnuts	7 ± 12	9 ± 18	2 ± 4	2 ± 5	9 ± 15	1 ± 4
Mangoes	-	-	217 ± 271	-	-	298 ± 350
Karité fruit	4 ± 13	4 ± 23	-	-	1 ± 7	-
Shea butter	28 ± 20	18 ± 17	13 ± 16	27 ± 17	17 ± 18	12 ± 15
Animal products	19 ± 33	8 ± 20	14 ± 27	22 ± 34	15 ± 20	11 ± 15
Baobab leaves	6 ± 9	2 ± 7	5 ± 7	6 ± 8	5 ± 14	7 ± 7
Okra	27 ± 23	19 ± 20	1 ± 3	34 ± 33	10 ± 11	1 ± 4

*) Mean values ± Sd
†) Pre-harvest periods cover July and August
‡) Post-harvest periods cover November, December and January
§) Intermediate periods cover March and April

TABLE 3: Use of groups of food products by Otammari women (n=34) in different seasons*

	Pre-harvet 1990†	Post-harvest 1990‡	Inter-mediate 1991§	Pre-harvest 1991†	Post-harvest 1991‡	Inter-mediate 1992§
			g / day			
Cereals	360 ± 98‖¶	451 ± 97††	409 ± 101	365 ± 101‖	389 ± 131††	361 ± 128
Pulses	183 ± 49**††	138 ± 99††	75 ± 59	126 ± 95**††	102 ± 89	105 ± 91
Tubers	54 ± 135‖††	237 ± 147††	16 ± 54	49 ± 117‖††	197 ± 234††	6 ± 29
Shea butter	28 ± 20**††	18 ± 17	13 ± 16	28 ± 17**††	17 ± 18	12 ± 15
Vegetables	33 ± 14**††	21 ± 10††	6 ± 15	40 ± 25**††	15 ± 18††	8 ± 6
Fruits	4 ± 13¶	4 ± 23¶	217 ± 271	-	1 ± 7¶	298 ± 350
Animal products	19 ± 33**	8 ± 20¶	14 ± 27	22 ± 34**††	15 ± 20	11 ± 15

*) Mean values ± Sd
†) Pre-harvest periods cover July and August
‡) Post-harvest periods cover November, December and January
§) Intermediate periods cover March and April
‖) Lower than next post-harvest period ($p<0.05$)
¶) Lower than next intermediate period ($p<0.05$)
**) Higher than next post-harvest period ($p<0.05$)
††) Higher than next intermediate period ($p<0.05$)

Seasonal variations in energy and nutrient intake

Results of energy, carbohydrate, protein, fat, iron and retinol equivalents intake are given in Table 4. Energy, carbohydrate and protein intake fluctuate with seasons showing the highest ($p<0.05$) values in the post-harvest and intermediate periods. For energy intake in 1991 and carbohydrate in both years, intake during intermediate periods were significantly lower ($p<0.05$) than the preceding post-harvest periods. During the two observation years, carbohydrate intake during the intermediate periods was significantly higher ($p<0.05$) than during pre-harvest periods. Fat intake was higher ($p<0.05$) in pre- and post-harvest periods than in the intermediate periods. Retinol equivalents intake was highest ($p<0.05$) in the intermediate periods (1280-1660 μ/day). Retinol equivalents intake during pre-harvest periods was higher ($p<0.05$) than in post-harvest periods. Iron intake was stable throughout the year, about 31 ± 6 mg/day when calculations were made using the Platt's food composition table (14). The amount of iron consumed increased surprisingly to an average of 60 ± 9 mg/day, when the FAO food composition table for use in Africa (13) was used.

The magnitude of the observed differences in energy intake between periods was 1.7 ± 0.9 MJ/day in 1990 and 0.6 ± 1.1 MJ/day in 1991. For carbohydrate, between periods variations were 103 and 36 g/day in 1990 and 1991 respectively. Protein intake also shows changes of 13 and 7 g/day in 1990 and 1991 respectively. For the retinol equivalents intake, observed variations were 1206 and 1608 μ/day in 1990 and 1991 respectively.

Macronutrients intake were also considered for their contribution to energy intake (Table 4). Carbohydrate contributed to 74-76 % of energy intake during the post-harvest periods and this decreased slightly to 72 % during the pre-harvest periods. The amount of energy coming from protein appeared to be stable all the year round at about 11 %. Fat contributeed to about 13-15 % of energy intake during intermediate and post-harvest periods and increaseed to 17 % in the pre-harvest periods.

At the group level, a consistent pattern was observed between years for energy and nutrients intake, as well as for use of food groups. However, at the individual level, no consistency was found in the year-to-year change in either energy and nutrients intake or in food products use.

TABLE 4: Daily energy and nutrient intake by Otammari women (n=34) in various seasons*

		Pre-harvest 1990†	Post-harvest 1990‡	Inter-mediate 1991§	Pre-harvest 1991†	Post-harvest 1991‡	Inter-mediate 1992§
Energy	(MJ)	9.3 ± 2.0‖	11.0 ± 2.7††	9.7 ± 2.6	9.4 ± 2.2‖	10.0 ± 2.3	9.6 ± 2.7
Protein	(g)	65 ± 18‖	78 ± 24††	66 ± 21	62 ± 20	69 ± 19	65 ± 20
	(Energy %)	11	12	11	11	11	11
Carbohydrate	(g)	401 ± 85‖¶	504 ± 130††	442 ± 110	406 ± 114‖¶	442 ± 106††	438 ± 121
	(Energy %)	72	74	76	72	74	76
Fat	(g)	42 ± 18††	43 ± 23††	35 ± 20	43 ± 18††	40 ± 22††	34 ± 24
	(Energy %)	17	14	13	17	15	13
Iron‡‡	(mg)	33 ± 8	36 ± 9	30 ± 9	30 ± 10	31 ± 9¶	29 ± 7
		(63 ± 17)	(64 ± 21)	(65 ± 25)	(64 ± 21)	(57 ± 24)	(61 ± 23)
Retinol equivalent	(μg)	231 ± 243¶**	74 ± 134¶	1280 ± 1458	198 ± 218¶**	52 ± 51¶	1660 ± 1800

*) mean values ± Sd
†) Pre-harvest periods cover July and August
‡) Post-harvest periods cover November, December and January
§) Intermediate periods cover March and April
‖) lower than next post-harvest period ($p<0.05$)
¶) lower than next intermediate period ($p<0.05$)
**) higher than next post-harvest period ($p<0.01$)
††) higher than next intermediate period ($p<0.05$)
‡‡) Values between brackets are obtained using FAO food composition table for use in Africa

Energy and nutrients origins

Origins of energy, protein, iron and retinol are summarized for each seasonal periods in Figures 1 and 2. For each period, the average intake over was used. From Figure 1, it appears that cereals were providing in all periods the bulk of energy intake, up to 60 %. Cereals were followed during the pre-harvest periods by pulses contributing in these periods to about 20-28 % of energy intake. However, during the post-harvest periods, pulses contribution to energy intake was surpassed by tubers, contributing to about 18-27 % of energy intake. During intermediate periods, mangoes played an important role, providing between 20 to 26 % of energy intake. In all periods, cereals and pulses were providing the majority of the protein to the body. Contribution of animal products varies from 3 to 7 %, with highest contribution to protein intake during pre-harvest periods. Due to huge quantities of fruits eaten in the intermediate period, mangoes contributed to 2 % of protein intake (Figure 1). Iron in the diet was mainly provided by cereals, followed by pulses (Figure 2). Retinol equivalents were mainly provided by mango in the intermediate periods and mainly by vegetables during the pre-harvest periods (Figure 2).

Haemoglobin level in the blood

Haemoglobin level in the blood did not show any significant change throughout the year. An overall average of 13.8 ± 2.6 g/dl was found.

DISCUSSION

The observed seasonal variations in food products use may be partly explained by the aptitude for each product to be stored. Pulses, when mixed with ash can be stored from one harvest to another and tubers can easily be stored underground for a relatively long period. To be successfully stored, cereals have to be dried (11% humidity) and protected against rodents. These conditions can hardly been found in rural areas of

FIGURE 1: Contribution of various groups of food products to energy and protein intake in different seasons

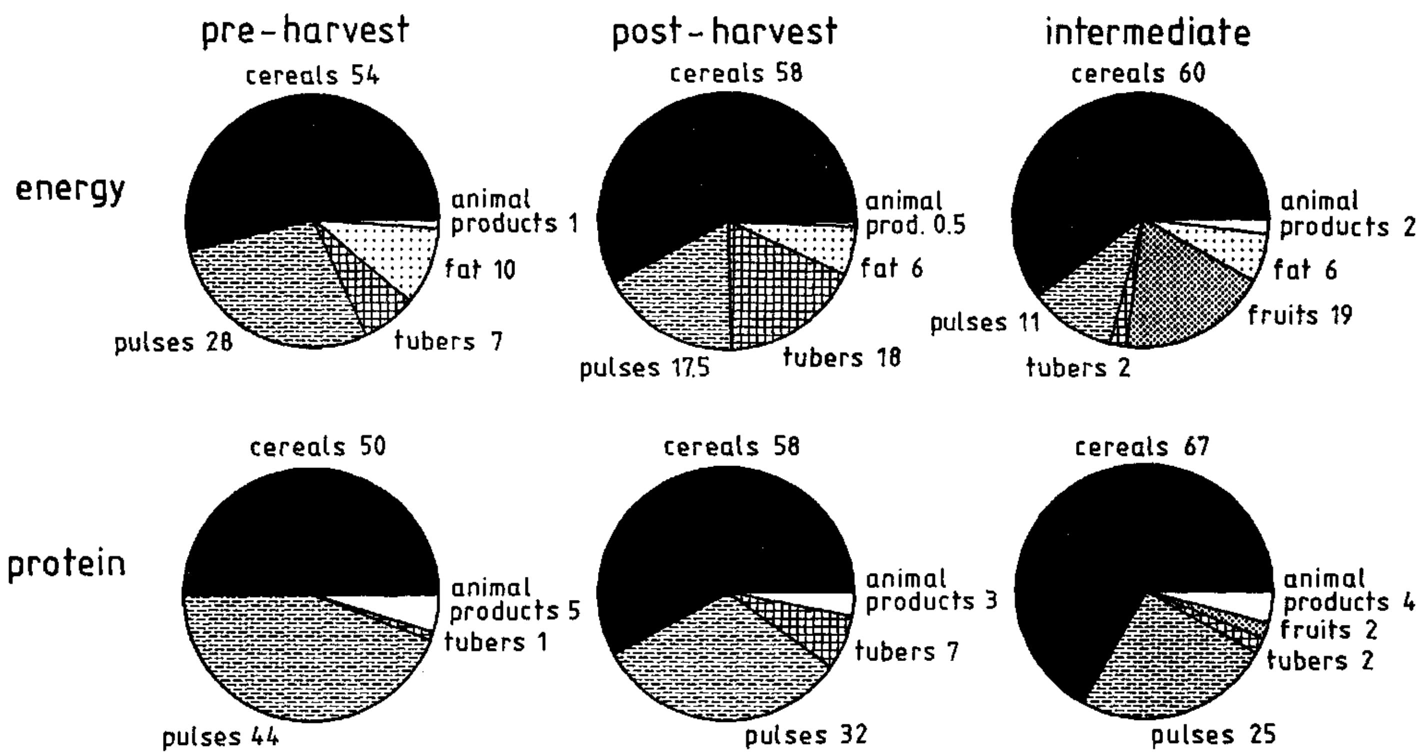
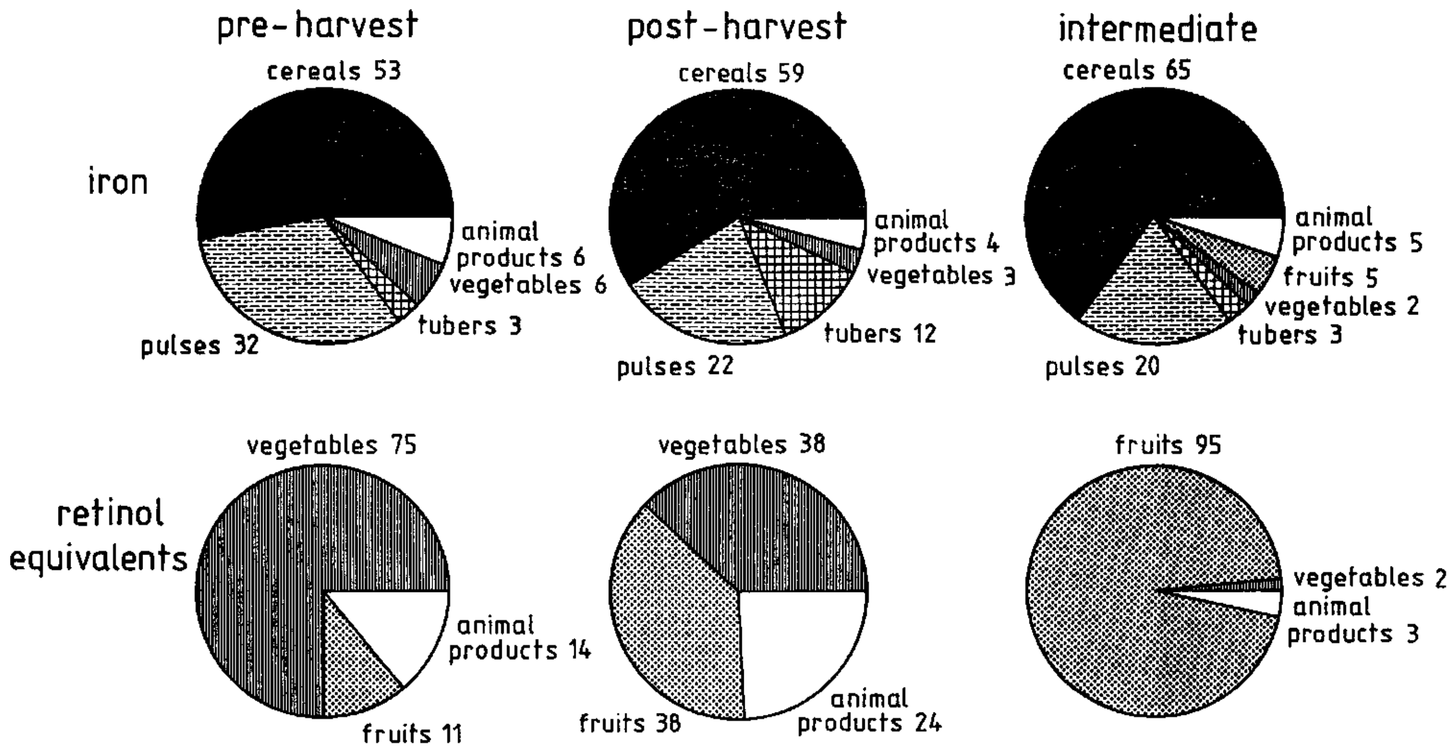


FIGURE 2: Contribution of various groups of food products to iron and retinol equivalents intake in different seasons



developing countries, resulting in high post-harvest losses. The intensive use of cereals just after the single harvest for ceremonies and other festivities mainly explains why the cereals stocks were depleted before the next harvest (18). Fat was mainly provided by shea butter and its use in the pre-harvest periods may be linked to the consumption of pulses, since these food products are eaten together. Farmers in developing countries do not consider animal products as a nutritionally valuable food. Simply, they are considered as luxurious food. This is the explanation of the low consumption of food from animal origin. The small quantity of animal products used is in contradiction with the observed amount of poultry and livestock owned by each Otammari household. Fruits and vegetables are highly perishable and are used when available. Vegetable use is high in the pre-harvest periods because at that moment there is enough water for their production.

Seasonal variations observed in use of food products result into seasonal variations in daily energy and nutrient intake of women. Energy intake varies between 9.3 and 11.0 MJ/day throughout the year. We have studied the Physical Activity Level (PAL) of the same subjects in the same periods. During the pre-harvest periods PAL were 1.78 and 1.75 x BMR in 1990 and 1991 respectively (19). These findings are very much in line with the recommendations of FAO/WHO/UNU (20). The recommended energy intake of 9.6 MJ/day for a woman with a PAL of 1.82 x BMR is not really different from the 9.3 MJ/day observed among rural women in Manta during the pre-harvest period. Furthermore, the observed energy intake of about 11.0 MJ/day during the post-harvest period, when the PAL of women was about 1.62 - 1.68 x BMR is higher than the 8.5 MJ/day recommended by FAO/WHO/UNU (20) for a woman with a PAL of 1.64 x BMR. The observed fluctuations in energy intake among women in Manta reflect the seasonal fluctuation in body weight as a response to seasonal variation in energy balance (21). Similar variations in energy intake were reported for other areas with two harvests a year (1,5,7,9,22). From Figure 1, the importance of cereals, pulses and tubers in the diet is clear. Altogether, they provide 70 to 93% of energy intake.

Protein intake also shown seasonal variations. About 95 % of protein ingested were of plant origin. For a diet based on cereals, the digestibility of protein may be estimated at about 85% (19). After adjusting the protein intake for the digestibility rate, the protein needs were satisfactorily covered all the year round. Even the lowest intake during pre-harvest periods was higher than the recommended intake of 44 g/day of protein of plant origin for a women weighing about 50 kg (19). This observation is comparable to what has been reported for areas with less substantial seasonal stress (1,22). The bulk of the protein intake, 93 to 95% was supplied by cereals, pulses and tubers (Figure 1). The 11 % of protein's contribution to energy intake all the year round is in line with the 10 % reported on Beninese rural women (1,22) and on Burmese farmers (8) and 12 % for Senegalese households (2). The contribution of carbohydrate and fat to energy intake showed slight variations with seasons. Carbohydrate contributed to 72 to 76 % of energy intake. These proportions are lower than the 80-84 % reported for a Senegalese farmer's community (2), but are comparable to the 74-78 % reported on Burmese farmers (8). The difference with the Senegal study may reside in the fact that the use of tubers in this community is very limited. Fat consumption contributed to 13-17 % of energy intake. These proportions are in all periods lower than the 21-23 % reported for the South Benin (22). This difference may be explained by the high use of palm oil in the South of the country providing up to 15 % of energy intake against 6-10 % of energy intake from shea butter in Manta. In the diet of Otammari women, mangoes were providing the maximum of retinol equivalents. During the intermediate period 95% of retinol equivalents intake came from mangoes. During the pre-harvest periods, the role of vegetables as retinol equivalents supplier was considerable (Figure 2).

Iron intake was rather stable in all periods at about 31 mg/day. In all periods, the observed intake was higher than the Recommended Dietary Allowance (RDA) of 29 mg/day for non-pregnant and non-lactating woman, on a diet characterized as of low bio-availability (10,23). Such level of intake was also reported for Senegalese communities (2,24). The low use of animal products indicates that most of the iron in the diet is from plant origin, thus non-haem iron. From Figure 2, about 95% of iron was from plant origin. The absorption of non-haem iron is known to be only 4 to 5% for a diet based on cereals with very little animal products intake (25). This justifies the low bio-availability assigned to the dietary pattern. However, the level of iron intake was surprisingly high and large differences were found between food composition tables (13,14,26). When iron intake is calculated using FAO food composition table (13), iron intake of women increased from 31 mg/day to 60 mg/day. Whatever the food composition table used, the observed iron intake of women was adequate the year round. This adequate level of iron intake is illustrated by an adequate haemoglobin level in the blood all the year round, higher than the lowest cut-off point of 12 g/dl. However, it is surprising that up to now, such differences still exist between food composition tables. The eventual contamination of samples by soil mentioned in the FAO food composition table appeared cleary here. It is therefore urgent to revise the FAO food composition table for use in Africa, specially with regards to iron content of various food products

Retinol equivalents intake showed a large seasonal variation with highest intake during intermediate periods. This extremely high retinol equivalents intake in this period may be explained by the amount of mango eaten during the intermediate periods. When retinol equivalents intake was compared to the RDA, adequate intake was observed only for the intermediate periods. During pre and post-harvest periods, the retinol equivalents intake of women was far below the recommended 800 μ/day (10). Retinol can be stored in the liver and this stock may be mobilized during periods of low intake. Presently, the size of the store which can be build up from the high intake of the intermediate periods, taking into account the low level of fat consumption is not known. More research is needed on this topic. From Figure 2, it appeared that during the intermediate periods, 95% of retinol equivalents consumed came from mango. The situation may become critical when a bad harvest of mango occurs.

It appeared from the present study that energy, protein and iron intake were probably adequate to cover the whole year needs. Retinol equivalents intake varied throughout seasons with intake lower than the RDA during pre- and post-harvest seasons. Despite the substantial seasonal variations in food availability, we cannot conclude that the impact on energy and nutrient intake was likely to be more severe compared to areas with moderate variability in food availability. For the future, more research is needed on the bio-chemical parameters of the nutritional status especially with regard to iron and vitamin A status. The findings of this carefully designed dietary study seem to indicate a rather positive situation for iron intake. Whether the high intake of retinol equivalents during the intermediate period in a situation of low fat consumption, can allow adequate retinol stores in the body remains unclear. Not only the intake of nutrients as such, but the bio-availability of the nutrients on the one hand and the prevalence of infectious diseases on the other hand, determine the nutritional status.

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CHAPTER 7

GENERAL DISCUSSION

Results presented in this thesis are based on a study carried out in the Otammari population of the Manta commune, district of Boukoumbé, in the ATACORA province situated in the north-western region of Benin. The Republic of Benin is located in West Africa, between the 6°30' and 12°30' parallel of latitude North and the 1° and 3°40' meridian of longitude East. The country is a strip of earth going from the coast to the heart of the continent. The situation and the length of the country, 700 km from the South to the North, mean that it is composed of different ecological zones. The North of Benin is at the border of the Sahel. This area is characterized by one short rainy season a year, high temperatures and a deteriorated soil and vegetation. The climate is of the soudanian type, with a savannah vegetation (1). The climate allows only one harvest a year. The stress of the season on this area is more pronounced than in the South of Benin where two harvests a year are possible (1,2). The observed seasonality in Manta is also more pronounced than that reported by studies carried out in other parts of the world (3,4,6,8,9) where two harvests of cereals a year are possible. Based on these stronger seasonal characteristics in the North of Benin, one may expect a higher impact of seasonality on daily life in Manta.

In the following, the outcomes of seasonal variations in food availability on the energy balance of adults and on children's growth performance will be discussed. As a reaction to the seasonal food shortage, biological, metabolic and behavioural adaptations may be used by adults as energy saving mechanisms. Together with children's growth performance, the biological adaptation will be discussed through the *anthropometric studies*, while the two other types of adaptation are considered under the heading *adaptation studies.* Further, the consequences of seasonal variations in use of food products for energy and nutrients intake will be discussed. Finally, main conclusions from the study will be summarized and suggestions for further research made.

Anthropometric studies

<u>Adults</u>

Body weight of subjects was measured during three consecutive years. Measurements of body weight were carried out more frequently and for a longer period than in other studies (3-9), resulting in a complete and repeated picture of seasonal weight changes in the north-western region of Benin. The aim of the study, was among others to investigate, whether under stronger seasonal stress subjects will lose more of their body weight when compared to people living in areas characterized by less severe seasonality and further to study the year to year repeatability of this event.

As expected, seasonal changes in body weight occurred among the population living in Manta, as it is the case for other rural communities of developing countries. Body weight declined during the rainy season and increased again during the dry season. The observed changes in body weight for men and for women were about 5 to 6 % of their average body weight. Similar size of weight changes have been reported for populations living under less severe climatic conditions (1,3,10). The present study does not confirm the hypothesis that under unimodal climate, body weight loss will be substantially higher than under bimodal climate and suggests that factors other than food intake may also be involved in determining seasonal body weight change. More research is needed to identify those factors and to assess the extent to which they may influence seasonal weight change. The difference in weight changes observed between years for men but not for women and the fact that men and women show different activity patterns suggest that energy expenditure is an important factor which must be taken into account while one is discussing seasonal weight changes.

The explanation for the moderate weight change, even under an unimodal climate may be found in the duration of the hungry period. In areas where there are two harvests a year, a hungry period of 8 to 10 weeks are generally reported. In Manta, with only one harvest a year, similar duration have been observed. This, because there are some short cycle crops which are used to shorten the hungry season.

Addressing the repeatability of seasonal weight changes, we found that the same subjects may experience to the same extent the seasonal stress from year to year. However, this repeatability may be highly influenced by other factors such as the load of disease on each household, the activity pattern as well as funerals and other ceremonies. Maybe, this year to year repeatability has much to do with the socio-economic status of each household. If this is the case, household characteristics will be of a great importance in a screening procedure aiming at the identification of families experiencing the most the seasonal stress.

What are the consequences of seasonal weight changes? The answer to this question is yet not clear. Particularly, when the size of the weight change is so modest, one may be inclined to neglect the phenomenon. However, this study shows that in 1990 and 1991 post-harvest weight gains were less important than the preceding pre-harvest weight losses. The cumulative effect may be harmful in the long term. Spurr (11) has demonstrated that the maximal Physical Work Capacity (PWC) and the productivity are depressed by marked stress in energy intake. The moderate weight loss in our study was not spectacular enough to investigate its functional impact in terms of PWC. However, in most rural communities, people do spend long hours in moderate physical work. In this case, measurements of PWC may not be relevant, but it will be important to measure the endurance of these farmers during the rainy season to investigate for how long they can sustain physical activities, when food intake is reduced. This knowledge will be of great importance for planners and policy makers.

Children

From a mixed-longitudinal study of body weight and height in children aged 2 to 9 years over three consecutive years, it appeared that growth performance is affected by seasonality, with lowest velocity during the rainy seasons and the highest velocity during the dry seasons. Moreover, it was noticed that deterioration of growth performance became more important with increasing age. These findings are in line with what has been reported elsewhere (12-14). The level of stunting among the Otammari community was very high, about 30% and is comparable to data reported in the literature (13,15,16). In the present study, it also appeared that growth velocity during the post-harvest period was not enough to be considered as catch up growth. Children are then definitely accumulating a growth deficit throughout years. Further research on food intake and infectious diseases is needed in order to clarify on the one hand the increasing gap between children in Manta and the reference population and on the other hand the high level of stunting. In rural areas of developing countries, hygiene and sanitation are poor. In Manta, less than 1% of the population has a latrine and about 75% gets water for the household supply from sources as stream, pond or river. Most of the time, children do not receive proper care since mothers are required to work for long hours outside the compound. The synergism between poor hygiene and sanitation and lack of proper care from the mother, easily lead to infectious diseases which may impaired the absorption of ingested food.

The fact that the situation among children is getting worse with age suggests that adults in the community will be small in size. However, despite the seasonal changes that occur in body weight, the Body Mass Index (BMI) of adult men and women was all the year round on average about 20.0, which is still within the acceptable range suggested by FAO/WHO/UNU (17). Whether adults in the future will have a BMI about the same as nowadays or whether they will be smaller in size can not be predicted from the present study. The outcome of the high prevalence of stunting for the future generations is still unknown. However, one may think that stunted children will become stunted adolescents. In such situation, more research is needed to find out whether food supplementation during adolescence may improve the adolescent growth spurt. If the growth spurt during adolescence can be considered as a favourable period for recovering from past stunting, energy and nutrients supplementation at this particular period may help to improve the nutritional status in adulthood. Another benefit which can be obtained from an eventual reversibility of growth retardation during adolescence is the possibility for female teenagers to complete their physiological maturation before motherhood. This question needs to be considered carefully.

Adaptation studies

Metabolic adaptation

Ferro-Luzzi (3) and Shetty (18) have reported substantial reduction in RMR as a result of negative energy balance among rural communities in free living conditions without any evidence for clinical abnormality. Edmundson (19) observed that during food deprivation, Javanese farmers may become metabolically more efficient. One of the outcomes of the Minnesota semi-starvation experiment (20) was an important reduction of RMR. Many other studies (1,4,10,21) have, however, failed to find any evidence for metabolic adaptation, either by lowering RMR or by performing physical activities at a lower energy cost. The stress of energy deprivation on Key's subjects was exceptionally severe and is not likely to be encountered in free living condition, under normal circumstances. The fact that most studies which fail to show any metabolic adaptation were carried out under bimodal climate, supports the hypothesis that metabolic adaptation may occur only under severe conditions. The conflicting outcomes of studies addressing this question allowed James and Shetty (22) who reviewed available information from developing countries to say that "there is remarkably little objective evidence as yet of metabolic adaptation in energy metabolism of adults who subsist on a long-term basis in agricultural communities of developing countries". To add to the existing knowledge on this issue, the present study was designed to investigate both RMR and the energy cost of activities in different seasons of rural women living in an area with an unimodal climate. The study area was carefully chosen to show a seasonal variation in food availability which is more important than that reported by previous studies (1,3,4). Results of our study could not support the assumption that under substantial climatic conditions, the energy deficit may be reduced by a substantial reduction in RMR, even when expressed by unit body weight, and/or by performing physical activity at a lower cost. It is true that the seasonal stress on the study area is severe, but the size of the seasonal climatic stress on the energy balance is not exclusively determined by the rainfall pattern. Seasonal variations in rainfall is a recurring effect and rural households always use some strategies to alter the adverse effects of such occurrence on their energy balance. In most rural areas of developing countries, households generally anticipate this phenomenon by making a set of decisions concerning food products use, cropping pattern and social network in order to facilitate the transit through the hungry season. The outcomes of these strategies are a moderate weight change and no evidence for metabolic adaptation to cope with seasonal food shortage. Our conclusions are in line with James and Shetty (22) noting that "...metabolic adaptation is likely to prove a far smaller component of the adaptative process than currently assumed...".

Behavioural adaptation

Behavioural adaptation is considered as logical, feasible and is widely believed to occur in real life (23). However, evidence for such type of adaptation is scarce and inconclusive. Some studies (24-27) suggest that physical activity does indeed play a central role in regulating energy balance and in limiting the excessive losses of body weight. Other studies (3,4) in contrast, show a stability in energy expenditure of rural women throughout seasons. The Manta study did find changes in activity pattern between the pre- and the post-harvest periods. In the pre-harvest periods, we observed higher energy expenditure than in the post-harvest periods. This is just the opposite of what was expected. Energy expenditure of Otammari women increased in the period when there is not enough food. Our study suggests that physical activity during the pre-harvest periods is, in the Otammari community, a factor which increase the deficit of the energy balance. In the same period, energy intake went down and energy expenditure went up. This increase in energy expenditure is explained by the fact that agricultural work did not prevent women from doing other tasks they usually performed in the dry seasons, such as domestic works and food preparation. To a certain extent, agricultural work can just be considered as an additional task. The development of instruments which may allow women to do the same amount of work in less time and with less energy may be considered as a solution for female farmers. One may think for example of the introduction of animal traction to replace the use of hoe in agricultural work. The development of appropriate technology may find here a field of application. Even under unimodal climate, this study did not support the evidence that changes in activity pattern may be considered as an energy saving mechanism.

Use of food products, energy and nutrient intake: impact of seasonality

In line with what have been reported for other rural areas of developing countries, food intake in Manta also showed seasonal changes. Energy intake was comparable to RDA during pre-harvest periods and was higher than RDA during post-harvest periods. Fat content of the diet was low all the year round. Protein and iron intakes were enough to cover the need of individuals all the year round even after adjusting for the absorption rate. Retinol equivalents intake fluctuates throughout various periods, with the highest intake during the intermediate periods. Intake of retinol equivalents during pre- and post-harvest periods was below the RDA. Intake of retinol equivalents in the intermediate period was very high. From such high intake, reserves can be build up in the body for periods of low intake. However, it is uncertain whether the low fat content of the diet will allow any reserve. In case this is possible, it is unknown how long this stock can provide adequate retinol equivalents. This situation has to be studied in more detail. The seasonal changes in energy intake reported for the first and the second observation years were 1.7 and 0.6 MJ/day respectively. Changes in energy intake reported for areas with two rainy seasons, areas with less pronounced seasonal variations in food availability, ranged from 0.6 to 1.8 MJ/day (2-4,10). Seasonal changes reported for a Senegalese community experiencing also an unimodal climate was about 0.3 MJ/day (6). Even under an unimodal climate the observed changes in energy intake are in the same range as reported for communities with two harvests a year. These indicate that despite the difference in rainfall pattern, changes in energy intake remain comparable. Energy, protein and iron intake were probably adequate to cover the whole years needs. However, the fact that most of the iron contained in the diet was from vegetable origin brings up the question of the bio-availability of iron. This question should receive a lot of attention to explain the inconsistency which exists now between this apparent adequate iron intake and the high prevalence of iron deficiency anaemia generally reported for those regions of the world. Whether a body stock of retinol can be made and for how long this may be used should also be investigated.

The composition of the diet largely determines nutrient intake. In Manta, cereals are the most important food products, while animal products do not deserve any recognition. The proportion of fat in the diet is very low (13-17%) and is mainly provided by shea butter.

Conclusions

In this study carried out in an area with an unimodal climate and therefore only one harvest a year, the seasonal stress on the population was expected to be higher than in an area with a bimodal rainfall pattern. The high prevalence of stunting and the increasing gap between children in Manta and children of the reference population indeed indicate that the studied area did experience a strong energy stress. However, observed changes in body weight were comparable to seasonal fluctuations in body weight found in area with two harvests a year. Moreover, neither metabolic nor behavioural adaptation have been identified in order to cope with the energy stress.

The food consumption survey indicated that iron intake was adequate the whole year round. However, prevalence of anaemia in this part of the world reported by international bodies is high. The methodology of the food consumption survey should be validated using bio-chemical parameters to evaluate the bio-availability of this nutrient for the organism. The low intake of retinol equivalents during the pre- and the post-harvest periods suggests a situation of vitamin A inadequacy. However, whether the high intake of the intermediate period is able to correct the situation needs more attention.

To successfully address energy stress, in both areas with unimodal or bimodal rainfall pattern, it is very important when programmes, directed towards food aid are implemented in periods when food intake is low. Stunting in children may be reversed in a positive way, if food supplements are given to adolescents.

Suggestions for further research

From the results reported in this thesis, growth retardation among children is worsening with increasing age. To ensure its full development, a community must be constituted by adults who attain their full growth potential. To reach this objective, growth retardation must be stopped and the accumulated effects reversed. Research is needed to investigate whether energy and nutrient supplementation in adolescents may reverse the growth retardation experienced in childhood.

The observed level of stunting is very high and does not fluctuate with seasons. Such level of stunting may have other causes that reduced energy intake. A thorough investigation of the role of minerals may be indicative in this situation.

The level of weight change due to the seasonal fluctuations in food availability is moderate. However, it may be important to investigate whether such changes in body weight have any impact on the endurance of individuals, thus on the productivity.

The present studies indicate on one hand a rather positive situation with regard to iron intake all the year round, and on the other hand, a very high intake of retinol equivalents during the intermediate periods. Not only the intake of a nutrient as such, but also the bio-availability of the nutrient determine the nutritional status. In the future, more research is needed on the bio-chemical parameters of the nutritional status with special regard to iron and vitamin A.

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APPENDIX 1

BACKGROUND INFORMATION ON THE RESEARCH AREA

History, religion and ethnology

The origins of the Otammari, the ethnic group living in Boukoumbé, are in Burkina-Faso, probably in the region of DINABA. The first settlers in the region came from Burkina-Faso via Tanguiéta to the environment of Manta about one and a half century ago. At that time, there was nothing there except for forest and wild animals. The first settlers cut trees in order to clear some lands for cultivation. Those families gained in this way the property rights of the land they cleared for their successors nowadays. Since then, six generations have passed. In the beginning, the Otammari were mainly hunters but they already cultivated some land with sorghum, fonio and other crops (Maurice 1990)[1].

A great majority of the Otammari are animist. Ninety percent of the population believe and worship ancestral divinities named "DISIM'PO". They believe that their ancestors still play a great role in their life and that animals or other objects are specifically significant or powerful to them (totems). If someone falls ill or in case of a funeral or in case of birth ceremony, they may kill animals and offer them on the altars of the ancestors. The "chef-féticheur", the "charlatan" and the "traditional healer" all play an important role in advising and curing people. Meanwhile, foreign religions have been introduced, making a small proportion of the population either christian or muslim. Less than 10 % of the population are christian, either from roman catholic or protestant, church while only 0.5 % of the population is muslim.

The ethnic group Otammari is part of a larger ethnic group named OTAMMARIBE. The Otammaribe are spread over the north-western part of the Atacora province, covering the district of Boukoumbé, Natitingou and Toukountouna

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[1]Maurice AM. Atakora. Otiau Otammari Osuri. Peuple du nord Benin (1950) Académie des Sciences d'Outre Mer. Paris 1986.

Agriculture and livestock

Agriculture

The agricultural calendar starts in April when people start clearing fields from the old millet stalks. However, some farmers have already prepared their fields for yam in February. After the first rains they will start sowing the grain in May. July, August and September are the weeding months. The first cereal to be harvested will be the hungry rice in September. Some early crops like maize, early beans, early millet, sweet potato and yam may be harvested in small quantities already in August, September just to shorten the hungry period. The main crops millet and sorghum are harvested in December. Rice and groundnuts may be harvested earlier.

Typical female crops are rice, beans and Bambara groundnuts. Men and women work together on their fields but there is a certain task division. Labouring the land is a man's job, sowing will often be done together or only by women. Weeding is again for both sexes. During the harvest, men will be cutting the crops while the women will be gathering them and carrying them home.

Someone owns lands because his ancestors were the first settlers on the land. However, an outsider may ask permission to cultivate the land which he is allowed to use, without any obligations towards the owner. The land owner may take back his property at any time. The use of the tree crops like the African locust and the baobab are not included in the land use. They remain the property of the owner. The shea is not strictly for use of the landowner since the fruits (nuts) have to be gathered as soon as they fall of the tree otherwise animals may eat them.

To lighten the work, a system of invitation exist. One farmer may invite his neighbours or family to help him do the field work. In return, he offers the local beer or something to eat to the workers. Some women work in association with others, which means that they help each other but they don't have to pay money or to give food for that.

Livestock

Most households have some poultry (chicken, guinea fowl or duck) and some small livestock like sheep or goats. Not many have cows or oxen. If they do, they may have given them to Peulh to guard them. Peulh is an ethnic group of the north-eastern part of Benin. They are originally from Niger and their main occupation is animal raising. Nowadays, they are spread over the country.

During the dry season, the cattle may graze everywhere and no one is watching them. During the rainy seasons however small boys are guarding the troops of cattle in order not to ruin the crops. At night all animals come back to there own house where they are put away in their "tata-somba", the castle-like characteristic houses. Animals are mainly kept as an investment for more difficult times. They are slaughtered when there is a ceremony or sold if someone is in need of money (for medical care or in order to buy grain)

Economical aspects

Income generating activities

Most of the women have some small trading activities, especially during the dry season. Many prepare the local beer and sell it on the market. Others have some small trades in mustard, shea butter or nuts, seeds of the fruits of baobab, dried red peppers, beans or rice.

Men can be involved in handicrafts during the dry season like making mats or rope or in the trades in tobacco, rice or salt. Some undertake hunting activities or construct houses and granaries for money. However, the majority of the men say they have no income generating activities at all. Income for men is generally higher than for women. Women with their small trades fall in the income category of less than $ 35 per season, men are more easily to be found in the category up to $ 180 or even up to $ 360 per season (van Liere)[2].

Market system

Every fourth day is a market in Manta. People from the surrounding villages come to the market to buy and to sell and to enjoy the social talk and the local beer (Koutoukoutou).

Bigger merchants from Boukoumbé or even from Tanguiéta come to sell "manufactured goods" like batteries, soap, torches, jewellery, canned fish or tomatoes, clothes and bicycle parts. Local merchants come with little bits of beans, rice or other

[2]van Liere MJ, Ategbo EAD, den Hartog AP. Personal notes

cereals, néré, mustard or shea butter. Women sell these things often in small quantities just to be able to buy some salt or some clothes. The exchange system also survived in this region. Hungry rice can be exchanged with big water jars which are brought into Manta from another commune. Beans or African locust beans can be exchanged for sorghum, especially in the hungry season when large quantities of sorghum are imported in the region by big merchants from Tanguiéta or from the South.

The prices of cereals vary throughout the year and are determined by the availability of the product on the local market.

Bride price

Thirty percent of the households in our study group is polygamous. There are several ways in which a man can get himself a wife. The easiest way is exchange of sisters. A man marries a woman in one family, than his family also has to deliver a woman to his wife's relatives. For the more wealthy villagers there is the possibility to pay two cows to the bride's parents.

The bride price is the most difficult way to obtain a wife but often the only one if one does not have money or a sister, daughter or niece to exchange. This may involve a arrangement between the parents when their children are still young. A young man has to work on his parents in law's fields during nine years and also give them a part of his own harvest.

A woman may decide to leave her husband but then, he may reclaim his bride price: the cows or his sister who is married to his wife's brother. The pressure of her own family may cause the woman to stay with her husband.

Administrative organization and infrastructure

The administrative organization in republic of Benin is of a decentralized type. From the provincial level to the village level, various committees are taking care of the administration of the country. The "préfet" is heading the province in collaboration with a certain number of "sous-préfet", heading themselves a district each. This latter is ruling the district backed up by a consultative group made of resource persons of the district. The district itself is subdivided into communes headed by a Mayor backed up by a number of "chef du village" in charge of a village each. The village is the simplest administrative unit. At the village level, the "chef du village" is ruling in collaboration with 7 advisers elected by the population, based on their knowledge, wisdom and socio-economical status. The rural commune of Manta is subdivided into 11 villages.

Generally, houses are rather dispersed in this region so it is difficult to speak of villages. However, the center is a real village since there is a concentration of houses (about 500 families) clustered around the market, dispensary and maternity clinic.

There is a catholic church as well as a mosque. For water supply there are in each village a deep well and/or a water pump. Most of the time, water pumps do not work. Six out of the eleven villages of the commune of Manta have a primary school. However, the attendance rate to school is extremely low. Less than 5 % of children are attending school.

Manta lies at about 20 km North of Boukoumbé and is connected by a dirt road. Since August 1989 a bridge between the two villages tumbled down and has just been repaired in 1992. This does pose some problems during the rains since the stream may be too high and wild even for cars to cross. Each village is connected to the center by a dirt roads which are in most of cases part time usable for cars. During rainy season, it is not always possible to go from one village to another by car.

In each village, there is a traditional birth attendant (TBA) and a village health worker (VHW). The VHW's task is to detect and treat minor ailments and in case of complicate situations to refer their patients to the communal health center where a nurse is available. Likewise, the TBA help women delivering and when things become difficult at the village level, she will transfer the pregnant woman to the maternity clinic at the center where a midwife is working.

Households characteristics

The following characteristics are only valuable for our study group which has been selected following specific criteria. Therefore, they will not totally be representative for the total population of the commune of Manta.

Five percent of the households included in the study are headed by females. Literacy rate is low in the area. Seventy eight percent of adults men of the study group had no school education at all and 82% of adult women had never attended school. Sixty five percent of households is monogamous and 35 % is polygamous. Twenty six percent had 2 wives, 3 % had 3 wives and 1 % has more than three wives.

About 49% of the households cultivated groundnuts, the only one cash crop produced in the area. However, there was a marked variation between the villages. Only 29% of the households in Manta centre cultivated groundnuts but 68% of the households in Koutangou, a village in the neighbourhood do produce groundnuts.

Bicycle is the most used mean of transportation. About 56% of households has a bicycle and 2% other mean of transportation such as motorbikes. Only 10% has a radio and 9% of households, a cassette recorder.

Sanitation is very bad. Less than 1 % of households has a latrine. In 49% of households a bathcorner can be found and 50% of households has nothing.

Livestock ownership, type of housing, water source in different seasons and fuel source in dry and rainy seasons are summarized in Tables 1 to 4

__TABLE 1__: Livestock has been grouped following this categories (in percentages)

more than 5 cows	10%
1 - 5 cows	40%
no cows but sheep/goats	43%
only poultry or nothing	7%

__TABLE 2__: Type of habitation (in percentages)

no tata-somba, roof of straw	31%
tata-somba, roof of straw	43%
no tata-somba, iron sheet roof	9%
tata-somba, iron sheet roof	17%

TABLE 3: Water source used in dry and rainy season (in percentages)

	Dry season	Rainy season
pump	8%	6%
well	30%	22%
stream	51%	47%
diggen source	11%	7%
pond	-	17%
river	-	1%

TABLE 4: Fuel source in dry season and rainy season (in percentages)

	Dry season	Rainy season
wood	11%	95%
millet stalks	89%	4%
both	-	1%

APPENDIX 2

SOME PRACTICAL ASPECTS OF THE FIELD STUDIES

The purpose of this appendix is to give to readers and to researchers preparing for a fieldwork in the tropics some hints. In this chapter, how the target group has been approached, the sampling procedure, how to keep the cooperation of the subjects, the personnel and the equipment needed and the supply system of the research team will be described.

Getting in touch with the target population

Before the study was implemented, courtesy letters were sent to the head of the ATACORA province, to the head of the medical and health services at the province level and to the head of rural development agency at the province level, to explain the purpose of the study and to get their informed consent. Similar steps have been taken at the district level toward the "Sous-Préfet", the medical doctor running the health center and the responsible of the rural development agency at the district level. These contacts have been taken at 3 districts: Matéri, Cobly and Boukoumbé, all situated in the ATACORA province. Based on information available, these are the districts where food availability is the most in question and their location did not allow a fair economic development. These 3 districts have been screened for the following criteria:

- no intervention programme such as food for work, food aid and no intention to start such programme soon
- main activity being agriculture
- infrastructure
    - . accessible all the year round
    - . households not too spread apart
    - . housing for the investigators
    - . preferably not a muslim area (because of the ramadan)

After looking around in all 3 districts and after discussions with resource persons, it has appeared that Boukoumbé displays the best profile for being selected as the study area.

Another set of letters has been written to the aforementioned authorities to notify the choice of Boukoumbé as the study area.

In Bénin, as in most developing countries, it is very important to gain political support to ensure full cooperation from the target population. Once this support obtained, both at the province and at the district level, all the 7 communes of Boukoumbé have been screened for the aforementioned criteria and the commune of Manta has been selected. A strong relationship was set up with the local nurse. Without his support, the study could have been difficult to be performed.

Together with the medical doctor and the head of the rural development agency, a courtesy visit was paid to the mayor of the commune of Manta to explain the reasons why his commune has been chosen, what the study is about and the kind of cooperation we were expecting from him and from the population. After getting the informed consent of the mayor and based on the same criteria we already used at the district level, 5 villages have been selected out of the 11 villages of the commune. They were: Koutangou, Takotiéta, Kouhingou, Dikon-hein and Dikouténi.

Finally assembly meetings were held and were attended by the investigator and the research team, village officials ("chef du village" and his staff), the "Sous-Préfet", the nurse, the responsible of social welfare and all residents of the study villages. At this meetings, the purpose and practical aspects of the study was presented. All what the study is about have been fully explained and the type of cooperation we were expecting from the population has been well defined. By the same occasion, the research team is becoming familiar with the environment and the population.

Sampling procedure

The result of a census performed by the rural development agency in order to identify all the households earning their living from agriculture was used as a baseline. From this census, it is only possible to get the name and the location of the male head of the household. This census has been up to date by a quick census in order to check for the consistency of information available and at the same time to include households headed by females in the existing list. Every house were visited and a list of households fulfilling the following criteria has been made. The composition of each household was recorded as well.

1- Permanent residence in the area

2- Female head of the household still being within the reproductive age range.

3- Presence of at least a child of 2, 4 or 6 years old in the household.

Out of 309 households pre-selected based on the above mentioned criteria 214 have been selected at random for the study. Once a household was selected, all members of this household, including children within the above mentioned age groups are members of the study population. However, ill subjects have been excluded from the sample. Our study population is made of apparently healthy members. The distribution of the population in different age groups is given in the following Table.

Distribution of the population in different age groups

	GENDER		
	Male		Female
Adults	198		214
Adolescents	54		43
6 years children		68	
4 years children		87	
2 years children		66	

Cooperation of subjects and incentive

The study described here, was a longitudinal study, carried out during three consecutive years. A full cooperation was necessary from the subjects to attain full compliance of data collection. One may rely on the good will of the population. However, in a study in which measurements frequency is heavy and in which many different type of measures have to be performed, the pressure on the population became too much to be supported for several years. In order to prevent loss of interest and large number of drop out, the cooperation of the subjects has to be maintained. In this respect, the research team usually offers small presents to subjects as incentive. Salt, rice, aspirin, quinine or concentrated tomato in negligible quantities were given after weighing sessions. When rice is given, it was only 1 kg per household and when aspirin or quinine are given, it was only ten tablets for the whole household. Such small quantities can not change significantly their dietary pattern. All what has been distributed are also well-known products in the area, so we did not bring anything new which may change the food habit of the community. Food consumption survey and laboratory sessions are more demanding from women. So, better presents were given. After a round of measurement in the laboratory (2 days) or a round of food consumption survey (4 consecutive days), presents such as headscarf, blouse, pair of shoes, piece of cloth or a couple of dishes were given. The strategy of keeping the interest of people in the research programme by giving small presents turned out to be very efficient and should be considered in the planning stage of any research of such importance.

Personnel

To implement the study, a research team has been set up. The team was led by two senior investigators. Together, the investigators worked with 5 female assistants, 2 male assistants and 2 junior researchers. During the 3 years period the study has lasted, 10 Msc students have carried out their practical periods training in the setting of the study for a period of 5 to 6 months each. During their presence within the research group, they also participated in data collection. All the research assistants were locally recruited at Boukoumbé.

Supply system

Manta is in the middle of nowhere, located far from any well infrastructured city.

It is not possible to buy there a certain range of products. What can be found in Manta are grain, pulses depending on the season and shea butter. For daily survival and for fuel supply for cars, generator and the refrigerators, the research workers were dependent upon Boukoumbé, Natitingou, Lama-Kara or even Cotonou. Natitingou is the closest city, located at 70 km, Lama-Kara is the most important city in the North of Togo, located at about 110 km away from Manta while Cotonou is at about 700 km from Manta. The study was following a seasonal pattern and data collection was defined by period. Between two periods about two weeks were free. That was the best moment to constitute the food stock of the research workers for the next measurement period. From Cotonou, we could buy every foodstuff which is not easily perishable (rice, spaghetti, macaroni, canned fish, jam etc). For vegetable supply, the research team depended on Natitingou or Lama-Kara. Once every fortnight, someone travelled either to Lama-Kara or to Natitingou to buy vegetable, cheese, butter and even bread since this was not available in Manta. For fuel supply, we were depending on Boukoumbé or sometimes, during rainy season, when the truck could not supply fuel to Boukoumbé, research workers were obliged to go to Natitingou. It was necessary to have an extra fuel stock at home mainly during rainy season, despite all the risk this contains.

Equipment needed and field laboratory

To carry out such type of research in this kind of area, one has to be self-reliant. A field laboratory equipped with all the apparatus necessary to perform all the measurements needed according to the research proposal should be set up. More important is the availability of adequate tools for maintaining the equipment. The researcher himself should also have ability in such tasks.

To be able to move all the year round a four wheels drive car is needed and some lighter means of transportation like a motorcycle as well. With regards to the supply problems mentioned above, a refrigerator is necessary.

Manta does not have access to electrical power. To make life enjoyable sun collectors have been used and it turn out to be very efficient. We would suggest such equipment to anyone, preparing himself for a similar research project.

In order to be able to have a quick but frequent view on the type and the quality of the data which have been collected, a personal computer is necessary. In our situation a portable Toshiba T3200 was used and was very powerful but needs a generator for it energy supply. A generator was used and everything worked fine. However we would like to advise researchers to buy when possible a portable personal computer with at least some hours of autonomy. This will allow the investigator to work late in the evening without disturbing the neighbourhood.

SUMMARY

Households of subsistence farmers depend on their own production for their food supply throughout the year. In rural areas of developing countries, food crop production and food availability are mainly determined by the rainfall pattern. In these areas, agriculture is exclusively rainfed and rainfall also determines the activity pattern of members of the community. By influencing both food availability and activity pattern, thus energy intake and energy expenditure, rainfall also determines the energy balance of people living in these areas. The aim of the study described in this thesis was to examine the consequences of a substantantial seasonal variations in food availability, as created by an unimodal climate, on the energy balance of adults and how do they cope with this disturbance of the energy balance. The extent to which children are influenced by seasonal variations in food supply was also investigated.

In Chapter 1, determinants of energy balance, causes of seasonal cycling of food availability and consequences for human energy metabolism are discussed. Three possible adaptative processes to decrease energy expenditure when habitual energy intake is lowered are discussed: the biological adaptation operationalized by a reduction of body weight; the behavioural adaptation which induce a change in activity pattern in the direction that overall energy expenditure is reduced; the metabolic adaptation, realized by either a substantial reduction in resting metabolic rate, a decreased dietary induced thermogenesis or an increased work efficiency.

In Chapters 2 and 3 , results of body weight measurements during three consecutive years among children and adults men and women, all coming from households of subsistence farmers living in an unimodal climate are discussed. Pre-harvest weight loss was about 5% of both men and women's average body weight. Significant associations were found between post-harvest weight gains and the preceding pre-harvest weight losses. The average BMI calculated over two complete calendar years was 21.1 ± 1.9 for men and 20.2 ± 1.8 for women. Depending of the period of the year, 6 to 10% of the adults had a BMI lower than 18.5, of which 2 to 5% were between 16.0 and 17.0. No association was found between body mass index and pre-harvest weight losses.Significant associations found between year to year pre-harvest weight losses and between post-harvest year to year weight gains suggest that the same individuals may experience the seasonal stress to the same extent every year. However, many factors other than rainfall pattern may also be involved in determining the year to year repeatability of the seasonal weight change. Among children it appeared that yearly growth rate was lower than that derived from the 50th percentile of the National Center

for Health Statistics (NCHS) reference. From the age of 5, the observed growth rate was even lower than that derived from the 3^{rd} percentile of the NCHS reference. Growth velocity clearly was depressed during the hungry period and post-harvest growth was not enough to be considered as a catch up growth. In all age groups, the prevalence of stunting was high (28-36%).

Chapter 4 deals with a study of metabolic adaptation among a group of rural women. Body composition, energy intake, resting metabolic rate and energy cost of cycling were measured during two consecutive years at three different periods defined according to the level food availability. Energy intake showed seasonal fluctuations (9.3-11.0 MJ/day). Seasonal fluctuations were also observed in both fat mass and fat free mass, with lowest values recorded during pre-harvest periods. RMR and energy cost of cycling did not show any seasonal cycling. Moreover, Delta Work Efficiency of women appeared to be the higher during the post-harvest periods than during the pre-harvest period. It is concluded from this study that metabolic adaptation is not playing a role as an energy saving mechanism, in the population studied.

Chapter 5 deals with a study in which a group of women, during two consecutive years participated. During three seasons a year, the daily activity pattern of women was measured. From this daily activity pattern, the Physical Level (PAL) was calculated. During pre-harvest period, time allocated to fieldwork increased and time spent on domestic work and resting activities decreased. However, this adjustment did not result in an energy saving. Physical Activity Level increased by 10% from post- to pre-harvest periods. These findings show clearly that women in Manta did not change activity pattern in order to save energy. Behavioural adaptation is then not likely to be used by a farmer's community experiencing seasonal food shortage created by an unimodal climate.

Chapter 6 presents results on the consequences of seasonal variation in use of food products for energy and nutrient intake of rural women. The results show that energy, protein and iron intake were adequate all the year round, even after adjusting for the quality of iron and protein. The present study indicate a rather positive situation with regard to iron. However, its bio-availability in the local diet needs further attention. Retinol equivalents intake was lower than the RDA during pre- and post-harvest periods and was much higher during the intermediate periods because people eat a lot of mangoes. It is not known whether adequate body stores are produced by the high intake of the intermediate period.

Chapter 7 consists of the general discussion. Suggestions for further research are made. Potential areas for further research include: the reversibility of stunting during adolescence; the role of minerals in the occurrence of stunting; the functional impact of seasonal weight loss and the bio-availability of iron and vitamin A in the local diet.

SAMENVATTING

Huishoudens op het platteland in ontwikkelingslanden zijn vaak volledig aangewezen op de landbouw. Zij zijn wat hun voedselvoorziening door het jaar heen betreft dan ook grotendeels afhankelijk van hun eigen voedselproductie. Het is duidelijk dat deze voedselproductie en dus ook de voedselbeschikbaarheid, zal afhangen van het patroon van de jaarlijkse regenval. Het is ook duidelijk dat dit patroon van regenval het dagelijks activiteitenpatroon van de bevolking beïnvloedt, dit geldt zeker voor de landbouwactiviteiten. Door deze beïnvloeding van voedselbeschikbaarheid en activiteitenpatroon heeft de regenval invloed op de energie-inneming en het energieverbruik, en dus ook op de energie-balans. Het doel van het in dit proefschrift beschreven onderzoek is het bestuderen van de gevolgen van seizoensvariatie in voedselbeschikbaarheid veroorzaakt door een klimaat met één regenseizoen per jaar op de energiebalans van volwassenen en op de groei van kinderen.

In hoofdstuk 1 wordt eerst ingegaan op de verschillende componenten van de energiebalans, op seizoensvariatie in voedselbeschikbaarheid en activiteitenpatroon, en op de gevolgen van deze seizoensvariatie voor het energiemetabolisme. Vervolgens worden drie processen besproken die, als reactie op een verlaging van de energie-inneming, het energieverbruik zouden kunnen verlagen: biologische adaptatie, een verlaging van het energieverbruik door een verlaging van het lichaamsgewicht; gedragsadaptatie, een verlaging van het energieverbruik door een wijziging van het dagelijks activiteitenpatroon; en metabole adaptatie, een verlaging van het energieverbruik mogelijk ten gevolge van een verlaging van het rustmetabolisme, van een verlaging van de door voeding geïnduceerde thermogenese, of van een verhoogde arbeidsefficiëntie.

In de hoofdstukken 2 en 3 worden de resultaten besproken van antropometrische metingen bij volwassenen en kinderen over drie opeenvolgende jaren. Voor zowel mannen als vrouwen bedroeg het gewichtsverlies in de perioden vóór de oogst ('pre-harvest') ongeveer 5% van het lichaamsgewicht. Er werden significant positieve verbanden gevonden tussen de gewichtstoenames ná de oogst ('post-harvest') en de gewichtsverliezen voor de oogst ('pre-harvest'). De gemiddelde body mass index (BMI) over een periode van twee volledige kalenderjaren was 21.1 ± 1.9 voor mannen en 20.2 ± 1.8 voor vrouwen. Afhankelijk van de periode in het jaar had 6 tot 10% van de volwassenen een BMI lager dan 18.5, waarvan 2 tot 5% een BMI tussen 16 en 17. Er was geen associatie tussen de BMI en de 'pre-harvest' gewichtsverliezen. De associaties tussen 'pre-harvest' gewichtsverliezen van de verschillende jaren en tussen 'post-harvest' gewichtstoenames suggereren dat het veelal dezelfde individuen zijn die jaarlijkse de grote gewichtsschommelingen laten zien. Bij kinderen was de jaarlijkse groeisnelheid lager dan de groeisnelheid behorend bij de 50ste percentiel van de NCHS (National Center for Health Statistics) referentiepopulatie. Vanaf de leeftijd van 5 jaar was de jaarlijkse groeisnelheid zelfs lager dan de groeisnelheid behorend bij de 3de percentiel van de referentiepopulatie. De groeisnelheid was in de 'pre-harvest' perioden duidelijk verlaagd, maar in de 'post-harvest' perioden was de groeisnelheid echter niet groot genoeg om van een 'catch-up' groei te kunnen spreken. In alle leeftijdsgroepen was de prevalentie van in groei achter gebleven kinderen ('stunted') hoog (28-36%).

In hoofdstuk 4 wordt een studie beschreven waarin bij een groep vrouwen over twee opeenvolgende jaren tijdens drie seizoenen per jaar de lichaamssamenstelling, de energie-inneming, het rustmetabolisme en het energieverbruik bij gestandaardiseerde fietsactiviteiten gemeten is. Zoals verwacht waren er duidelijke seizoensvariaties in energie-inneming (9.3 -11.0 MJ/dag) en in lichaamsgewicht en lichaamsvetmassa, maar er konden geen variaties aangetoond worden in rustmetabolisme of energiekosten tijdens de fietsactiviteiten. De delta-arbeidsefficiëntie ('delta work efficiency') was in de 'post-harvest' perioden niet significant hoger dan in de 'pre-harvest' perioden. We concluderen dat bij de door ons onderzochte vrouwen geen aanwijzingen zijn voor metabole adaptatie.

Hoofdstuk 5 beschrijft een studie waarbij bij een groep vrouwen over twee opeenvolgende jaren tijdens drie seizoenen per jaar het dagelijks activiteitenpatroon gemeten is. Uit het dagelijks activiteitenpatroon is tevens één waarde voor mate van lichamelijke activiteit berekend (PAL-waarde, 'Physical Activity Level'). Gedurende de 'pre-harvest' seizoenen was de tijdsbesteding aan landbouwactiviteiten significant toegenomen en de tijdsbesteding aan huishoudelijke bezigheden en nietsdoen afgenomen. Vergeleken met de 'post-harvest' perioden was de PAL in de 'pre-harvest' periode 10% hoger. De resultaten tonen duidelijk aan dat de onderzochte vrouwen hun activiteitenpatroon niet aanpassen om in de periode van verminderde voedselbeschikbaarheid op hun energieverbruik te sparen.

In hoofdstuk 6 wordt ingegaan op de gevolgen van de veranderingen in gebruik van voedingsmiddelen op de inname aan energie en voedingsstoffen. De resultaten geven aan dat de inneming aan energie, eiwit en ijzer het hele jaar rond adequaat lijkt te zijn. De ijzerinneming zou zelfs goed genoemd kunnen worden, maar de beschikbaarheid ('bioavailability') uit de locale voeding verdient nog verdere aandacht. De inneming aan retinolequivalenten vóór en nà de oogst ligt lager dan de aanbevelingen, maar is door het hoge fruitgebruik hoog in de periode tussen de 'post-harvest' periode en de volgende 'pre-harvest' periode. Het is echter niet duidelijk of in deze periode voldoende opgeslagen kan worden om het hele jaar een adequate voorziening te hebben.

Hoofdstuk 7 omvat een discussie van alle bevindingen tezamen en geeft aanbevelingen voor verder onderzoek. Suggesties voor verder onderzoek betreffen o.a. de vraag waarom 'stunting' gedurende adolescentie lijkt te verdwijnen, welke de rol van mineralen is in het proces van stunting, wat de functionele gevolgen zijn van seizoensmatige gewichtsverliezen, en hoe de beschikbaarheid van ijzer en vitamine A in de locale voeding is.

RESUME

Pour leur approvisionnement en nourriture, les ménages vivant d'agriculture de subsistance dépendent presque exclusivement de leur propre production. Dans les zones rurales des pays en développement, la production et la disponibilité alimentaire sont tributaires de la pluviométrie. Dans ces régions où le calendrier agricole est régit par les saisons, l'emploi du temps des individus est aussi déterminé par l'alternance des saisons de pluie et des saisons sèches. En influençant à la fois la disponibilité alimentaire et l'emploi du temps, donc à la fois l'apport énergétique et la dépense énergétique, la pluviométrie détermine aussi le bilan énergétique des personnes vivant dans ces régions. L' objectif de l'étude décrite dans cette thèse est d'examiner les conséquences d'une variation saisonnière substantielle dans la disponobilité alimentaire, générée par un climat à une saison de pluie, sur le bilan énergétique des adultes et la façon dont il réagissent, face à cette pertubation du bilan énergétique. Aussi, l'importance de l'effet des variations saisonnières dans la disponibilité alimentaire sur les enfants a été étudiée.

Au Chapitre 1, les déterminants du bilan énergétique, les causes de variations saisonnières dans la disponibilité alimentaire et ses conséquences sur le métabolisme énergétique de l'homme sont décrits. Lorsque la consommation énergétique est réduite, les trois mécanismes par lesquels ont peut réduire la dépense énergétique sont aussi décrits. Il s'agit de: l'adaptation biologique qui se manifeste par une réduction du poids corporel, l'adaptation sociale qui s'initie par un changement dans la gestion du temps résultant en une diminution des dépenses énergétiques et l'adaptation métabolique réalisée soit par une réduction substantielle du Métabloisme de Base (MB), soit par une réduction de l'Action Dynamique Spécifique (ADS) ou encore par une augmentation de l'efficacité du travail.

Au Chapitres 2 et 3, les résultats des mesures anthropométriques effectuées pendant 3 années consécutives sur les enfants, les femmes et les hommes issue de ménages vivant de l'agriculture de subsistance et habitant une zone écologique défavorisée sont discutés. La perte de poids observée dans la période pré-récolte est de l'ordre de 5% du poids moyen des hommes et des femmes. Il existe des associations significatives entre le gain de poids de la période post-récolte et la perte de poids de la période pré-récolte précédente. L'Indice de Masse corporelle (IMC) moyen calculé sur une période de deux ans est de 20,2 ± 1,8 kg/m^2 pour les femmes et de 21,1 ± 1,9 kg/m^2 pour les hommes. Selon la période de l'année, 6 à 10% des adultes ont un IMC inférieur à 18,5, dont seulement 2 à 5% compris entre 16,0 et 17,0. Il n'existe aucune

relation entre l'IMC et la perte de poids pré-récolte. Il existe une association significative entre les pertes de poids de la période pré-récolte et les gains de poids de la période post-récolte d'une année à une autre. Celles ci suggèrent que d'une année à l'autre, les effets de la saisonnalité sur chaque individu pourraient être comparable. Toutefois, des facteurs autres que la pluviométrie pourraient être impliqués dans le déterminisme de la répétition d'une année à l'autre des fluctuations saisonnières du poids corporel. Parmis les enfants, il apparaît que le taux de croissance annuel est inférieur à celui dérivé de la médiane de la référence du "National Center for Health Statistics (NCHS)". A partir de cinq ans, le taux de croissance observé est même inférieur à celui dérivé du 3eme centile de la référence du NCHS. Le taux de croissance est plus faible dans la période pré-récolte et celui de la période post-récolte n'est pas suffisant pour constituer une croissance compensatoire. Dans tous les groupes d'âges, la proportion d'enfants présentant un retard de croissance staturale (Stunted child) est élevée, entre 28 et 36%.

Le Chapitre 4 est consacré à l'adaptation métabolique au sein d'un groupe de femmes rurales. La composition du corps, le MB, l'apport énergétique et le coût énergétique du pédalage d'une bicyclette à ergomètre à des niveaux de puissance donnés sont mesurés pendant 2 années consécutives en 3 périodes par an, définies selon la disponibilité alimentaire. L'apport énergétique présente des variations saisonnières (9,3-11,0 MJ/jour) avec le plus faible apport pendant la période pré-récolte. Des différences saisonnières existent aussi dans la composition du corps avec les plus bas seuils atteints pendant la période pré-récolte. Le MB et le coût énergétique du pédalage restent stables toute l'année. L'efficacité du travail des femmes exprimé comme "Delta Work Efficiency (DWE)" semble, sans atteindre un seuil significatif, être plus élevé en période post-récolte, contrairement aux espérances. On peut donc conclure de cette étude qu'au sein de cette population, l'adaptation métabolique n'intervient pas dans le rétablissement du bilan énergétique.

Le Chapitre 5 décrit une étude sur des femmes rurales. Pendant deux années consécutives et en 3 périodes par an, leur emploi du temps a été suivi et le niveau d'activité physique a été calculé. Pendant la période pré-récolte, le temps alloué aux travaux champêtres a augmenté tandis que le temps consacré aux activités domestiques a diminué. Il en résulte, contrairement à ce qu'on pouvait espérer, une augmentation du niveau d'activité physique d'environ 10% entre les périodes post- et pré-récolte. Ceci montre que les femmes rurales ne modifent pas leur emploi du temps afin d'épargner de l'énergie. L' adaptation sociale n'est donc pas utilisée dans les communautés vivant d'agriculture de subsistance, qui connaissent une variation saisonnière annuelle dans la disponibilité alimentaire.

Le Chapitre 6 présente les conséquences de la variation saisonnière dans la disponibilité alimentaire sur la consommation des femmes rurales. Les résultats montrent une consommation d'énergie, de proteïne et de fer satisfaisante toute l'année durant, même après correction pour la qualité des proteïnes et du fer. Toutefois, la bio-disponibilité du fer dans les plats locaux nécessite une étude approfondie. La consommation de rétinol et des caroténoïdes est inférieure aux recommandations pendant les périodes pré- et post-récolte et y est supérieure pendant la période intermédiaire (Mars-Avril). Ceci grâce à la forte consommation de mangue pendant cette période. Il est encore incertain que la forte consommation de mangue au cours de la période intermédiaire puisse constituer une réserve adéquate pour couvrir les besoins de toute l'année.

Le Chapitre 7 est consacré à la discussion générale. Des suggestions pour de nouvelles études ont été faites . Des Domaines de recherche potentielle sont: la reversibilité, pendant l'adolescence, du retard de croissance staturale; l'impact fonctionnelle de la perte saisonnière du poids corporel et la bio-disponibilité du fer et de la vitamine A dans les plats locaux.

CURRICULUM VITAE

Eric-Alain Dona Ategbo was born on 23 June 1960 in Porto-Novo, Republic of Benin and attended primary and secondary schools in Porto-Novo at "Ecole Urbaine Centre" and "Lycée Toffa 1er" respectively. After graduating from the secondary school in 1979, he joined the army for one year. He joined the Faculty of Agricultural Sciences of the National University of Benin in 1981 and graduated as "Ingénieur Agronome : Option Nutrition et Sciences Alimentaires" in December 1985. After serving the Ministry of Agriculture and Rural Development in the MONO Province, as a nutrition officer from April 1986 till March 1987, he joined the Department of Nutrition and Food Sciences of the Faculty of Agricultural Sciences of the National University of Benin in May 1987, where he is serving as a junior staff member.

Eric-Alain D Ategbo followed the Post-graduate International Course in Food Sciences and Nutrition (ICFSN) of the International Agricultural Center of Wageningen in 1988. From October 1988 until June 1993, he carried out the work described in this thesis with the fieldwork being performed in Benin from June 1989 to May 1992, and the preparatory and final phases being undertaken in the Department of Human Nutrition of the Wageningen Agricultural University.