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Seasonal Variation in Energy Intake and Expenditure, and Nutritional Status underlying mechanisms

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Seasonal Variations in Energy Intake and Expenditure, and Nutritional Status: underlying mechanisms

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Abbreviations and acronyms

AEE	: Activity Energy Expenditure
BMI	: Body Mass Index
BMR	: Base Metabolic Rate
EE	: Energy Expenditure
EI	: Energy Intake
FAO	: Food and Agriculture Organization of the United Nations
FFM	: Fat Free Mass
FM	: Fat Mass
FNS	: Food and Nutrition Security
HAZ	: Height-for-Age
HR	: Heart Rate
MAM	: Moderate Acute Malnutrition
MUAC	: Mid-Upper Arm Circumference
NGO	: Non-governmental Organization
PAEE	: Physical Activity Energy Expenditure
PAL	: Physical Activity Level
RQ	: Respiratory Quotient
SD	: Standard Deviation
SSA	: Sub-Saharan Africa
TEE	: Total Energy Expenditure
TEF	: Thermic effect of food
TEI	: Total Energy Intake
UNICEF	: United Nations Children's Fund
WAZ	: Weight-for-Age
WHO	: World Health Organization
WHZ	: Weight-for-Height

Abstract

Rural developing countries are among those most vulnerable to seasonal stress and undernutrition. This study reviews the underlying mechanisms of the seasonal variations in energy intake and expenditure, and nutritional status. A thematic content analysis has been primarily used for this assessment. Findings suggests a countercyclical relation of total energy expenditure, physical activity level and basal metabolic rate with nutritional status; a procyclical relation between energy balance and nutritional. Regardless of individuals the determinants of seasonal variations in nutritional status include the seasonal infectious diseases, unhealthy living environment and services, seasonal household food insecurity, seasonal poor quality of caring and feeding practices, seasonal inadequate dietary intake, and seasonal food energy intake. In addition seasonal activity energy expenditure, seasonal variability in basal metabolic rate, seasonal change in total energy expenditure, seasonal energy stress are specific for adults; and mother's nutritional status, seasonal intrahousehold allocation of food/nutrient, seasonal mother's activity energy expenditure, for children.

Keywords: Seasonality, food energy intake, energy expenditure, nutritional status

1. Introduction

Many developing countries rely on rain-fed agriculture, while rainfall are unstable and vary seasonally (Sinha and Lipton, 1999). Thereby, seasonality is a concern for most poor households engaged in rain-fed agriculture that clearly depends on the climate (Basu and Wong, 2015; Khandker et al., 2016). The seasonal climatic hazards (drought, flooding, etc.) determine the agricultural cropping patterns, hence agricultural production and the availability of basic foodstuffs across seasons; can lead to unpredictable harvests/low yields, food prices variability and create stress on livelihoods, food and nutrition security (Brown et al., 1982; Chikhungu and Madise, 2014; Khandker and Samad 2016). Therefore, seasonality has long been an issue of concern for those interested in the living standards, nutrition, energy expenditure, and health of individuals (Behrman, 1988; Paxson, 1993 ; Murayama and Ohtsuka, 1999; Vaitla et al., 2009) and continues to shape intra-annual food availability and prices in low-income countries (Abay and Hirvonen, 2016).

From the viewpoint of malnutrition[1], seasonality is important because it still affects millions of the world's poor, but also as a possible forerunner of some of the most widespread diseases (Prentice and Cole, 1994). According to Payne and Lipton (1994), the greatest extent of food insecurity, and hence the greatest potential for undernutrition is to be found in rural areas in developing countries. Not surprisingly most rural populations in developing countries have been reported to suffer from seasonal malnutrition especially in certain agricultural settings of Asia (Brown et al., 1982; Miller et al., 2013) and Africa (Schultink et al., 1993; Arsenault et al., 2014). Despite some improvements towards reducing hunger, malnutrition remains to be a major problem in the developing world (Abay and Hirvonen, 2016; Ayenew et al. 2018). In the developing world, estimates indicate that child undernutrition is responsible for nearly 3.5 million deaths (54% of the under-five mortality), 35% of the disease burden in this age group (Egata et al., 2013). In sub-Saharan Africa (SSA) alone 56.9 million children (40% of all children) are stunted and 31.1 million are underweight (22%) (Abay and Hirvonen, 2016).

Malnutrition has damaging impacts on children, their families (adults), and the posterity through (Abay and Hirvonen, 2016). All of these reduce human capital, lead to severe economic losses and slow down poverty reduction. Indeed, the undernutrition plays a key role in under five children mortality. It also has long-term effects on the survivors. In fact, during the first

[1] Malnutrition is a deficiency state of both macro and micronutrients (under-nutrition) or their over consumption (over-nutrition) (Egata et al., 2013). In this work, the term malnutrition refers to undernutrition.

1,000 days post conception the body is establishing its main building blocks for brain development and future growth. Thus, undernutrition of children in early life is largely irreversible, with a future school performance that tends to be below potential relatively to their better nourished peers, and a lower work capacity and productivity as adults (Sahn 1989; Alderman et al., 2006; Abay and Hirvonen, 2016).

Therefore, the seasonal food insecurity and undernutrition constitutes an important economic and food and nutrition security (FNS) challenges as well as a public health issues affecting young children and adults.

For all these reasons, this study is initiated. It aimed to identify and to examine the specific underlying mechanisms of seasonal variations in energy intake and expenditure, and nutritional status. A better understanding of those drivers is necessary to identify and design appropriate strategies to eliminate hunger and malnutrition and thereby improve the lives of the very poor in developing countries.

The remainder of the literature review is organized as follows: Section 2 conceptualizes the potential influence of seasonality on the determinants undernutrition. The main findings are exposed and discussed in the third section. Finally, the conclusions are shared.

2. Conceptual framework

The Figure 1 below illustrates the proposed conceptual framework, which is rooted in the model of Madan et al. (2018) for the causes of early child undernutrition in agriculture-nutrition pathways. This framework is chosen for the purpose of this study because it was developed recently in a rural developing-countries context and considers as well the concept of seasonality. In addition, it reflects the underlying and immediate causes of child's nutritional status presented in the original framework for the "causes of child malnutrition and death" (UNICEF, 1990; Madan et al., 2018). Finally, the framework accounts for the straightforward link between the nutritional status of a mother at childbearing age (pregnant or lactating) and her young child undernutrition. In this perspective, the seasonal mother's energy expenditure is considered apart from the seasonal infection diseases as drivers of the seasonal mother's nutritional status.

However we modify a bit the model of Madan et al. (2018) to account for the specificities of this study. The framework (Figure 1) illustrates the pathways through which agricultural livelihoods affect nutritional status of young child. This framework is applied here because it fits well in the case of a very poor rural population in developing countries context primarily engaged in rain-fed agriculture. In addition, markets are thin imperfectly integrated which might undermine a possible migration of adults for cheaper foods and expensive wages. Finally, we assume that these rural farmers are involved in subsistence agriculture (no cash crops) and have only one crops harvest per year. More concretely, the Figure 1 highlights the impact of the seasonality on its most components and the potential links through which they might affect one another and the seasonal variation in child's nutritional status.

Due to the variability of agro-climatic indicators (rainfall, climate, and temperature), seasonality is an issue for those households. The farming system as well as the agricultural calendar/cycle are mainly determined by the seasons (rainy/wet season, preharvest hunger/lean season, harvest season, postharvest or dry season) of the year (Wijesinha-Bettoni et al., 2013; Madan et al. 2018). Indeed, these seasonal patterns drive patterns of, infectious diseases (health) status, food prices, preferences/taste, household economic factors (food production, agricultural income/earnings, agricultural labor demands, labor wages, food real expenditure and purchasing power), mutual/social insurance for interhousehold food transfer, food security (food availability, food accessibility), quality of caring and feeding practices for women and children, food intake/food energy intake/hunger, energy expenditure of adults[2] (basal metabolic rate/resting metabolic rate through metabolic adaptation, physical activity energy expenditure/activity energy expenditure/labor effort, total energy expenditure, physical activity level), energy balance, seasonal lack of foodgrain storage as buffer stock, allocation of food and nutrient, and malnutrition within the households.

The immediate causes of individual's undernutrition include the seasonal inadequate dietary intake, and the seasonal infection diseases (poor health) status. With an inadequate diet, requirements in energy are unmet, and macronutrients (protein, fat, and carbohydrates) and micronutrients (vitamins, minerals) absorbed in the human body are unbalanced. Both are interlinked since the loss of appetite of sick people due to infectious diseases might further undermine dietary absorption. In turn, an individual with inadequate dietary intake is more likely to be sick (Vaitla et al., 2009; Miller et al., 2013).

The underlying determinants (at household level) gather the seasonal household food insecurity, seasonal poor quality of caring and feeding practices for mothers and children (child care, child feeding, health-seeking behaviors, nutrition education, eating habits, caregiver control of resources and autonomy, caregiver physical and mental status, caregiver knowledge

[2] There is a less variation of energy expenditure for children

and beliefs, care and support of women during pregnancy and lactation), and unhealthy living environment and services (safe water supply, inadequate sanitation, hygiene, availability and access of healthcare, environmental safety/shelter, health environment, food safety). Adequate dietary intake at the individual's level is a direct consequence of the household food security. Roles of unhealthy environment and services in the explanations of immediate causes are obvious. Indeed, in rural developing countries, unhealthy household environments are the most common ways by which infectious diseases (Malaria and other infections) are spread (Vaitla et al., 2009). As regards, the energy expenditure, the seasonal infectious diseases may reduce the work capacity of adults (Miller et al., 2013).

Actually, the hunger or lean season is the time of year when the previous year's harvest stocks have dwindled, food prices are high, and jobs are scarce (Behrman, 1988; Vaitla et al., 2009). A seasonal shock (covariate risk) such as weather, drought or flood can ruin agricultural output and severely reduce their income. Food are less available and less accessible during the lean season (Burke et al. 2018). Therefore, food (dietary) intake and in turn food energy intake also varies seasonally in rural economies (Sahn, 1989; Chaudhuri and Paxson, 2002). Since markets are imperfectly integrated, foodgrain prices in major markets are often low in the harvest and post-harvest season and higher in the pre-harvest lean season (Aggarwal et al., 2018; Burke et al. 2018). Regarding income, households are poor in all seasons but this is more pronounced in the pre-harvest months (lean season). Seasonal increases in food prices and variability in available incomes at the household level all contribute to seasonal variations in the food purchasing power (Wijesinha-Bettoni et al., 2013). The preharvest hunger season is a period of peak agricultural activities and especially in that period agricultural labor demands are high, which in turn decreases labor wages. The mutual/social insurance for interhousehold food transfers are undermined during the lean season because the majority of rural households face the scarcity of food (Kazianga and Udry, 2006). Household's preferences vary seasonally since the time of work (agricultural) and leisure (festivals, holidays, celebrations, ceremonies) change seasonally.

Some authors (Vaitla et al., 2009; Arsenault et al., 2014) emphasized the fact that the pre-harvest hunger season is often the rainy season. The exposure to infectious diseases increases in the rainy season due to wet conditions. The activity energy expenditure is also affected given that agricultural work is intensive during the rainy season. Women are especially involved in agriculture during the busy planting season (Sahn, 1989; Wijesinha-Bettoni et al., 2013).

The combination of all of these factors will determine the likelihood, extent and ways in which seasonality is experienced by individuals within a given household. Accordingly, they affect the nutritional status of children and women.

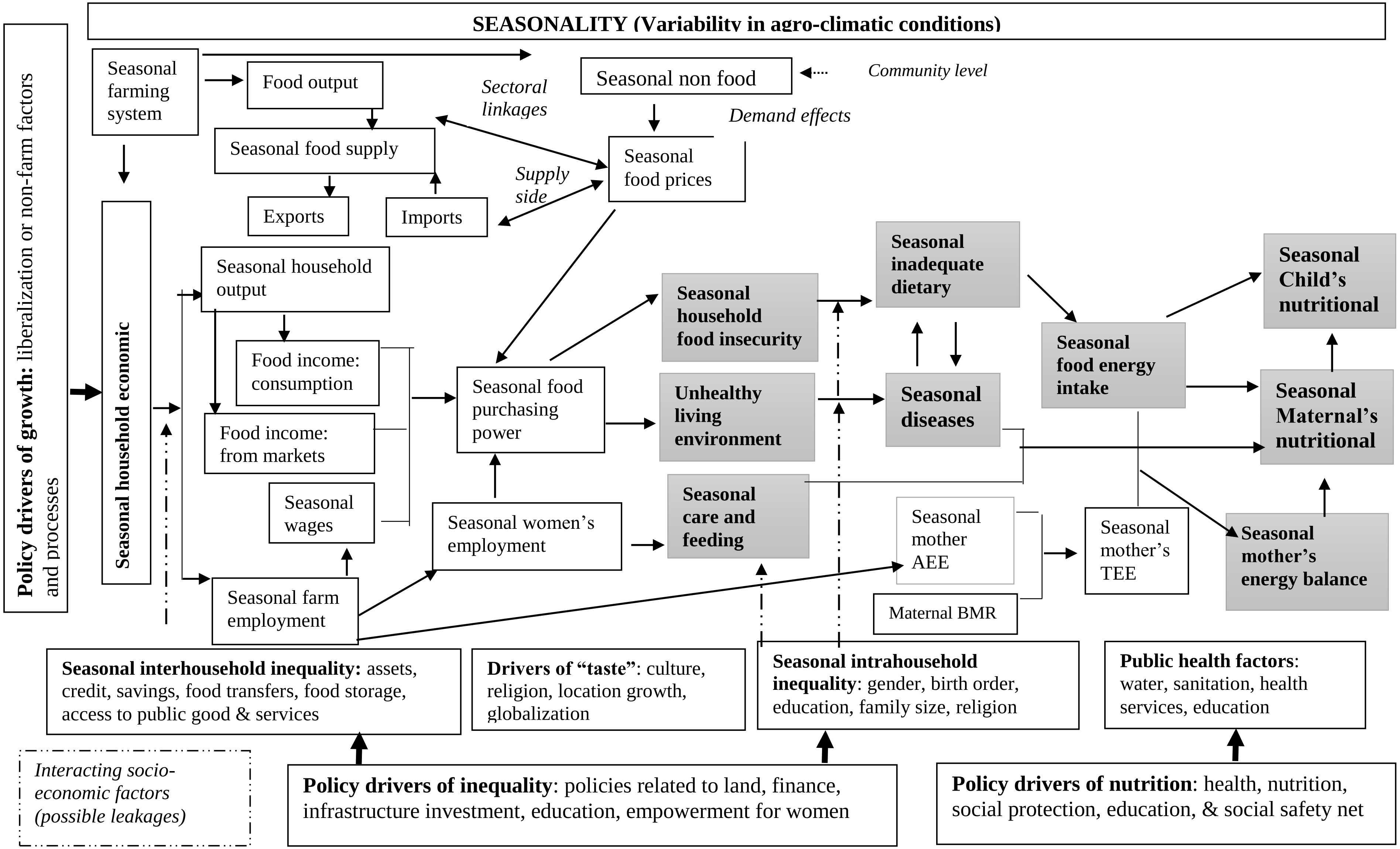

Figure 1 : Conceptual framework

BMR = Basal Metabolic Rate; PAAE: Physical Activity Energy Expenditure; TEE: Total Energy Expenditure

Source: Adapted and modified framework of Madan et al. (2018)

3. Results and discussion

In this section the results from the literature review are presented and discussed. First the evidence of seasonal changes in energy intake and expenditure, and nutritional status. Thereafter, the results and discussion of the determinants of seasonal variations in energy intake and expenditure, and nutritional status.

3.1. Evidence of seasonal changes in energy intake and expenditure, and nutritional status

The existence of seasonal changes in food energy intake, energy expenditure and nutritional status have been checked through different studies in the literature.

Evidence of the seasonal variation in food energy intake

The evidence of seasonal variation in food energy intake (EI) has been assessed in rural developing countries. Results are somewhat mixed. Some studies confirmed evidence of the significant effect of the seasonality on food energy intake (Sahn, 1989; Chaudhuri and Paxson, 2002; Arsenault et al., 2014). These studies suggest that the energy intake is lower in the rainy/lean season and higher in the dry season for children (Behrman, 1988; Arsenault et al., 2014), and women with BMI < 18 and BMI > 23 (Schultink et al., 1993). This decrease of EI in the lean season was not statistically significant for women who show small and large preharvest weight loss in previous year in the study of Schultink et al. (1993) in rural Benin, indicating those women experienced small decreases in energy intake in the preharvest season. In contrast, Arsenault et al. (2014) found in rural Burkina Faso that EI did not vary significantly across seasons for women and children, although the women's intakes were slightly higher in the postharvest season. In the same line, EI did not fluctuate or scarcely changed across seasons in the study of Murayama and Ohtsuka (1999) in Northeast Thailand under conditions of no shortage of food.

Evidence of seasonal variation in energy expenditure

Evidence concerning the existence of seasonal swings in the energy expenditure (EE) are somehow inconsistent. Indeed, some studies confirmed the seasonal changes in EE, indicating a significant decrease in the basal metabolic rate (BMR) of women with a body mass index (BMI < 18) in Benin during the preharvest season compared to the postharvest season (Schultink et al., 1993). Murayama and Ohtsuka (1999) have revealed a significant increase in the physical activity energy expenditure (PAEE), total energy expenditure (TEE) and physical activity level (PAL) of adults[3] male and female successively from postharvest to rainy seasons in Northeast Thailand. Nevertheless, Schultink et al. (1993) found respectively that PAL of rural Beninese women did not change significantly across seasons for all considered subjects. Murayama and Ohtsuka (1999), and Schultink et al. (1993) found respectively that the resting metabolic rate (RMR) of adults male and female, and BMR of women (BMI > 23, small preharvest weight loss, and large preharvest weight loss groups) did not change significantly across seasons (even if values are lower in preharvest season for most) for all considered groups. Precisely, the lowest PAL was 1.66 x BMR for women with BMI > 23 during the postharvest-season (January-February), and was significantly lower than the level of 1.74 x BMR for women with BMI < 18 in the same season (Schultink et al., 1993). Furthermore, BMR of BMI > 23 (66 J/kg per min) is significantly lower than BMR of women with BMI < 18 (80.7 J/kg per min) during the postharvest-season (January-February) same season Schultink et al. (1993). However the difference was no longer significant when BMR was expressed per unit fat free mass (FFM). These results suggest a countercyclical relation between PAL and BMI on the one hand and BMR and BMI on the other hand for rural Beninese women in the postharvest season (January-February). Moreover it is important to state that there is a less variation in energy expenditure for children.

Evidence of seasonal variation in nutritional status

Previous studies have put emphasis on the seasonal variation in nutritional status of children and adults in developing countries. The results of the literature concerning children undernutrition are inconsistent. Some studies revealed that young children face a nutritional stress, suggesting that they lose body weight (Prentice and Cole, 1994; Sinha and Lipton, 1999), higher levels of anthropometric indicators such as weight for age (WAZ) (Brown al., 1982; Hillbruner and Egan, 2008), height (or length) for age (HAZ) (Brown al., 1982) weight for height (WHZ) (Brown al., 1982), mid-upper arm circumference for age (MUACZ) (Brown al., 1982), and triceps skinfold thickness for age (TSFSZ) (Brown al., 1982; Behrman, 1988) during the rainy season compared to the dry season. Unlike them, Miller et al. (2013) found that under-five children HAZ and MUCAZ respectively, are marginally higher (lower) in the rainy (dry) season but not significant across seasons. Furthermore, others found rather that the prevalence of WHZ in Ethiopia (Egata et al., 2013), WAZ and HAZ in Malawi (Chikhungu and Madise, 2014) and MUACZ in Indonesia (Miller et al., 2013) are lower (higher) in the wet (dry) season, even if the change of WHZ in Ethiopia and HAZ in Indonesia were not significant. This lack

[3] The mean of AEE per season expressed in MJ/day is higher for male than female

of improvement of HAZ during the dry season is due to the fact that, the lack of growth nutrients such as zinc in the extra-food intake between time points, may have affected linear growth (Miller et al., 2013).

Overall, there is a consensus regarding the seasonal variations of adult's body weight and body composition, stipulating a decrease in those indicators from postharvest season to preharvest/rainy seasons. In fact, a significant decrease in the wet season has been observed in body fat mass (FM) of rural Beninese women of BMI < 18 and BMI > 23 (Schultink et al., 1993), of adult women at childbearing age (pregnant or lactating) in Third World (Prentice and Cole, 1994) and in both FM and fat free mass (FFM) of adults male and female in Northeast (Murayama and Ohtsuka, 1999). Pregnant and lactating women require more nutrients which are unmet during seasonal scarcity, leading to their lowest anthropometry (or highest nutritional stress) during the hungry season, characterizing by heavy agricultural workload (Sinha and Lipton, 1994). However, women who deliver in the hungry season have the highest cumulative weight gain since the majority of their pregnancy has been carried during the harvest months, and vice versa (Prentice and Cole, 1994).

3.2. Determinants of seasonal variations in energy intake and expenditure, and nutritional status

Determinants of seasonal variations in food energy intake, energy expenditure, and nutritional status have been widely studied in the literature. These results present disparities whether it is food energy intake, energy expenditure, nutritional status. Details on the determinants of seasonal variation of each of these outcomes are presented in Table 1, showing a synoptic view of the aforesaid results.

Overall determinants of seasonal variations in food energy intake include: *cash-savings and credit market imperfections, seasonal variation food prices, seasonal infectious diseases, seasonal preferences/taste, buffer-stock (precautionary) savings and food storage imperfections, seasonal household economic factors, seasonal household food insecurity, seasonal inadequate dietary intake, seasonal variability in physical activity energy expenditure of adults*.

Regarding the energy expenditure, there is a less variation in children energy expenditure. For adults, this review suggests some factors as the possible determinants of the seasonal variation in total energy expenditure (TEE). Among them we have the *seasonal infectious diseases*, *seasonal variability in physical activity energy expenditure, and the seasonal variability in basal metabolic rate (metabolic adaptation).*

When we contrast the different results of evidence of seasonal variation in food energy intake, energy expenditure and nutritional status for adults some key findings can be derived. Although energy intake decreased in preharvest season and PAL is constant over seasons for all groups, results of Schultink et al. (1993) indicated that only women (BMI < 18 and BMI > 23) decreased their FM, but not those who show small and large preharvest weight loss groups in previous year. Normally a decrease in EI and a constant PAL would lead to weight loss in the preharvest season as a consequence of the decrease in energy balance. Thus one could think about the reasons why women showing small and large preharvest weight loss groups did not decrease FM. This can be explained by the fact that these women have already experienced weight loss in the past. Results of the aforementioned seasonal variation in nutritional status showed that only women with BMI < 18 decreased BMR (metabolic adaptation) during the preharvest season with 2.9 J/kg per min (**4.3%** lower than the other season), with a significant decrease of **0.8** (SD 1.4) kg in body weight. Thus, the decrease in body weight was not only caused by a decrease in EI (Myself). Indeed, they use metabolic adaptation to prevent large body weight loss during preharvest season. In very thin women with a BMI < 17, BMR expressed per unit body weight decreased even more during the preharvest season (by 12 %). This change in BMR across seasons represents a daily saving in energy expenditure of 0.63 MJ (150 kcal)/d, covering about 30% of the fall in energy intake (Schultink et al., 1993). Therefore, the preharvest weight losses are not only related to reductions in energy intake but also to reductions in energy expenditure caused by metabolic adaptations. Schultink et al. (1993) also suggest that a decrease in energy intake as well as a decrease in energy balance (EI decreases and PAL constant) do not necessary lead to body weight loss in preharvest season for rural Beninese women who show a small and large preharvest weight loss in previous year. This result contradicts the standard model of undernutrition stating that seasonal energy intake stress (due to bad harvest) surely cause a seasonal bodily strain.

On the other hand, Murayama and (1999) in rural Northeast Thailand, obtained a significant and modest decrease of body weight from post- to pre-harvest seasons for adults male (FM) and female (FM and FFM) facing a constant level of EI and a significant increase in PAEE, TEE, and PAL. Not surprisingly there is a procyclical relation between the magnitude of the body weight and energy balance for both males and females. They found also a countercyclical relation between the total energy expenditure (TEE) and body weight for adults male and female. Finally it is important to note that the relation between total (diet) energy intake (TEI) and TEE was acyclical. The modest seasonal changes in body weight were caused by the lack of response of TEI to the change of TEE.

Based on these findings and those from other studies used in this review, the main causes of seasonal swings nutritional status regardless of the type of individuals are the *seasonal infectious diseases, unhealthy living environment and services, seasonal household food insecurity, seasonal poor quality of caring and feeding practices, seasonal inadequate dietary intake, and seasonal food energy intake*. In addition to these factors the *seasonal activity energy expenditure, seasonal variability in basal metabolic rate, seasonal change in total energy expenditure, seasonal energy stress are specific for adults' nutritional status; and mother's nutritional status, seasonal intrahousehold allocation of food/nutrient, seasonal mother's activity energy expenditure, for child's nutritional status* (Table 1).

Table 1. Summary matrix of determinants of seasonal variations in energy intake and expenditure, and nutritional status

Determinants	Food energy intake	Energy expenditure of adults	Adult (mother) nutritional status	Child's Nutritional status	Authors
Cash-savings and credit market imperfections	X				Sahn, 1989; Stephens and Barrett, 2011; Khandker and Samad, 2016; Burke et al., 2018
Seasonal variations in preferences					Paxson, 1993; Chaudhuri and Paxson, 2002
Seasonal food prices	X				Sahn, 1989; Paxson, 1993
Buffer-stock savings and food storage imperfections	X				Sahn, 1989; Chaudhuri and Paxson, 2002; Kazianga and Udry, 2006; Khandker and Samad, 2016; Gross et al., 2017; Aggarwal et al., 2018;;
Seasonal household economic factors	X				Sahn, 1989; Khandker and Samad, 2016
Seasonal household food insecurity	X		X	X	Sahn, 1989; Prentice and Cole, 1994; Chaudhuri and Paxson, 2002; Vaitla et al., 2009; Nithya et al., 2018) Sahn, 1989
Seasonal inadequate dietary intake	X		X	X	Sahn, 1989; Vaitla et al., 2009; Payne and Lipton, 1994; Prentice and Cole, 1994; Sinha and Lipton, 1999; Schultink et al., 1993; Chaudhuri & Paxson, 2002; Vaitla et al., 2009; Madan et al., 2018; Nithya et al., 2018
Seasonal infectious diseases status	X	X	X	X	Sahn, 1989; Payne and Lipton, 1994; Prentice and Cole, 1994; Vaitla et al., 2009; Chikhungu and Madise, 2014; Madan et al., 2018
Unhealthy living environment and services			X	X	Egata et al., 2013; Madan et al., 2018
Poor quality of caring and feeding practices for mothers and children			X	X	Madan et al., 2018
Mother's own nutritional status				X	Madan et al., 2018

Seasonal intrahousehold food allocation			X	Behrman, 1988; Sahn, 1989
Seasonal change in total energy expenditure		X		Prentice and Cole, 1994; Murayama and Ohtsuka, 1999
Seasonal change in physical activity level		X		Schultink et al., 1993
Seasonal variability in physical activity energy expenditure	X	X	X*	Sahn, 1989; Payne and Lipton, 1994; Prentice and Cole, 1994; Murayama and Ohtsuka, 1999; Madan et al., 2018
Seasonal variability in basal metabolic rate	X	X		Sahn, 1989; Schultink et al., 1993; Payne and Lipton, 1994; Prentice and Cole, 1994
Seasonal variability in energy stress		X		Schultink et al., 1993; Payne and Lipton, 1994; Murayama and Ohtsuka, 1999; Vaitla et al., 2009

Legend: X: appears as determinant; * especially for mothers' agricultural workload

Source: Author's construction from the literature review

3.3. Discussion on determinants of the seasonal variations in energy intake and expenditure, and nutritional status

A better understanding of the specific pathways through which seasonality generates variations in nutritional status is critically important to improve the lives of the very poor in developing countries. Thus, this section aims at explaining the mechanisms through which the different identified factors could impact different outcomes.

Seasonal variations in preferences (taste)

The seasonal variation preferences (tastes) affect the seasonal food energy intake patterns. Actually, seasonal taste indicates the seasonal choices of a given household to allocate time for work or leisure (festivals, celebrations, ceremonies and holidays, weather). It therefore reflects the households desire to obtain food. Otherwise the seasonal taste or the seasonal allocated time for work determine the seasonal earnings. However if poor households allocate more time for leisure this will adversely affects its earnings and might decrease the seasonal food intake. Accordingly seasonal variation in preferences may lead to a seasonal food energy intake. For instance, lost work due to the weather was identified as specific pathways through which season affected household food security.

Seasonal food prices

The seasonal food prices appears as a determinant of seasonal variation in food energy intake. Prices of staple grains are low in the post-harvest seasons and high in preharvest season. This predictable characteristic is common for many rural developing countries and present an opportunity for intertemporal arbitrage farmers (Sahn, 1989; Aggarwal et al. 2018). It presents an opportunity for intertemporal arbitrage for farmers because they could have avoid to run out their food stocks before the lean season or develop other precautionary savings motives. Instead, they often sell their output at low prices just after harvest and buy back the same commodities later in the lean season at higher prices (Stephens and Barrett, 2011; Burke et al., 2018; Kadjo et al., 2018). The combination of this high prices with variability of agricultural incomes yields an unstable food expenditure and purchasing power. More precisely given that they get agricultural income only at the harvest season, and have been used it since that period the income. Accordingly the countercyclical relation between income and food prices may induce a decrease in the purchasing power during the lean period, ceteris paribus. This will lead to a seasonal decrease in food intake and in turn to a seasonal reduction in food energy intake.

Cash-savings and credit market imperfections

Results of this review suggest that cash-savings and credit market imperfections adversely affect the seasonal food energy intake. Better access to credit and ability to use cash savings can give incentives to farmers to invest and produce more. Thereby credit has a positive impact on agricultural output and productivity if it is used for the right purpose. Consequently, whether it is the lack of borrowing/liquidity constraint, the lack of pubic credit programs and the absence a microfinance institutions, agricultural output are negatively affected in the harvest/postharvest season. This will undermine income and the possibility to store foods. Their consequences on food intake and food energy intake are as mentioned before. On the other hand due to the cash savings and credit market imperfections famers are unable to smooth consumption during the lean season, characterizing by a high food price. By the way they face easily the seasonal food shortage, resulting in a seasonal food energy intake.

Buffer-stock savings and food storage imperfections

This review reveals that the buffer-stocks savings and the food storage imperfections adversely affect the seasonal food energy intake. The buffer-stocks savings and food storage imperfections could be the inadequate storage facilities/technologies/infrastructures, seasonal lack of grain storage as buffer stock, lack of livestock as buffer stock, lack of storage technologies (which leads to Inability of intertemporal savings in the form of assets and food), lack of space to breed livestock (which leads to inability of intertemporal savings in the form of assets), lack of social safety net programs. As regards the inability to have self-insurance, the importance of the sales of assets in the form of livestock in mitigating the stress of the lean season, by protecting the households from dramatic seasonal declines in calories intake is displayed in the literature (Sahn, 1989; Fafchamps et al., 1998 cited by Gross et al. 2017). In these situations households cannot use savings to smooth consumption during the lean season when prices are high and incomes very low (as they depend mainly on agricultural income).

Seasonal household economic factors

This review suggests that seasonal household economic factors affects seasonal change in food energy intake. Seasonal shock such as drought and flood can ruin crops and severely reduce their farmers' income. Wages also are low during the hunger season. The seasonal variation in income can be quite large especially for households already living close to subsistence level. Seasonal income shocks as well as seasonal wage changes, affect seasonal consumption patterns, which in turn affect the seasonal energy intake. Seasonal food energy intake track seasonal variation in income, because the poor households live already close to subsistence and mainly depend on this agricultural income. Since farmers receive agricultural income only at the harvest season, some of them run out of their food before the next harvest. Such farmers need to buy their food with cash, but food prices are usually high right before harvest. Those farmers who run out of food must buy their food when prices are high, and cannot buy enough food, decreasing the seasonal food energy intake. Regarding the effects of the seasonal wages it is the inability to change farming techniques who sustain the negative effect because irrigation for instance can stabilize the seasonal demand for labor, boosts wages for hired workers (Sahn, 1989).

Seasonal household food insecurity

Seasonal household food insecurity in terms of food availability and food accessibility affects the seasonal change in food energy intake as well as the as the seasonal variation in nutritional status of children and adults. As food is less available and accessible during the lean season, individuals within households will have less to consume/intake, reducing the seasonal food energy intake. Seasonality in food availability and food accessibility are among the known constraints to successful infant and young child feeding practices and their growth in rural developing countries (Brown and al., 1982; Wijesinha-Bettoni et al., 2013). Indeed, in the wet seasons there are poor quality of weaning foods and a decline in breast-milk intake (Prentice and Cole, 1994), (Weight-for-height). However child nutritional status does not always follow the pattern of food availability in the dry season. For Chikhungu and Madise (2014), this could explained by the lag between a child suffering from hunger and being affected by undernutrition.

Seasonal inadequate dietary intake

The direct consequence of seasonal inadequate dietary intake in the hunger season is the seasonal reduction in food energy intake, which might lead to a seasonal decrease in the nutritional status. However a seasonal lower energy intake has been observed in the postharvest in rural Burkina Faso (Arsenault et al., 2014) and in Bangladesh (Behrman, 1988). This decrease in energy intake during the postharvest season was mainly due to the higher (lower) consumption of dark green leafy vegetables in the rainy (postharvest) season. As stated by Ayenew et al. (2018) in Nigeria the production diversification can contribute to improve the dietary diversity of the household at post-harvest.

Seasonal infection diseases status

Seasonal infectious diseases affects the seasonal food energy intake, seasonal energy expenditure of adults and the seasonal nutritional status of children and adults. The seasonal infectious diseases may reduce the seasonal dietary intake (due to the loss of appetite) and physical activity energy expenditure or productivity of adults. A direct consequence of the seasonal inadequate dietary intake is the seasonal decrease in food energy intake of individuals within the households, which in turn might affect the nutritional status. On the other the decrease in the work capacity will have negative impact of the money available within the households to purchase. This also will then lead to a seasonal inadequate dietary intake and a seasonal reduction in seasonal food energy intake, which might lead to a seasonal nutritional stress. Moreover, with the seasonal infectious diseases, individuals within the households could be more stressed. Women are especially affected and this could adversely affect their nutritional status but also for their early young child if they are pregnant or lactating.

Seasonal intrahousehold food/nutrient allocation factors

According to Behrman (1988) the relatively easily observed dimensions of child endowments are related to gender and birth order. Regarding intrahousehold food allocation, there is parental bias (favoring earlier-born (lower-order) children). Indeed, parental preferences regarding intrahousehold allocations of nutrients (by favoring the older children (under 15 year's age) as a pure investment strategy) during the lean season (where the productivity-equity tradeoff is much less due the scarcity of food) expose the younger children (more vulnerable) to greater malnutrition risk (Behrman, 1988). During both seasons, means are significantly higher for β-carotene and calcium for later-born than for earlier-born children, and vice versa for calories and vitamin C. For the child endowments related to gender, households display a strategy of protecting young girls (most vulnerable) by giving them greater share of household resources in the lean season, in contrast to the general pattern of discrimination evident during more prosperous seasons (Sahn, 1989).

Unhealthy living environment and services and mother's own nutritional status

Unsafe water and bad sanitation use are the most common ways by which the diseases are spread. The diseases will undermine the nutritional status of individuals within households. The same situation is observed when mother has a poor access to health facilities/services. The procyclical change between child-mother's health raised the importance to avoid weakening the mother (increasing gaps between births) to better protect children's health and lives.

Seasonal poor quality of caring and feeding practices for mothers and children

Women have key roles such as giving birth, breast-feeding and daily care takers within households. Therefore their magnitude of their daily activities are important the quality of care to themselves during pregnancy and postpartum and the quality of care they give to their children. Here we use the seasonal increase in mother's activity energy expenditure during the lean season as key driver. Due to the agricultural workload they have less available for household activities. This seasonal pressure on women's time impact negatively cooking and caring practices and intrafamily food distribution. A combination of those factors adversely affects nutritional status of women and their children.

Seasonal energy stress and metabolic adaptation

The main causes of the seasonal energy stress are the seasonal reduction in food energy intake and the seasonal increase in energy expenditure (Payne and Lipton, 1994). To deal with the seasonal energy stress, the use of behavioral responses (reduction in physical activity) by poor households are probably much more important (commoner, larger and more policy-influenced) than biological (Payne and Lipton, 1994); Prentice and Cole, 1994). However, poor households can also use the biological/physiological responses (variations in RMR or BMR). Indeed, the so-called metabolic adaptation notably the decrease in BMR can generate very large « savings » in energy requirements (Prentice and Cole, 1994; (Schultink et al., 1993). By this ability, individuals adapt to lower than optimal food energy intake. Actually, this decrease in EI undermine the possibility for energy intake to cover the basal metabolic rate (BMR), the metabolic response to food/thermic effect of food (TEF), the energy cost of activity energy expenditure, and energy costs of growth in childhood and pregnancy, as well as to produce milk during lactation. Therefore, metabolic adaptation during weight loss help to prevent or reduce effect of weight loss.

4. Conclusion

Rural developing countries are among those most vulnerable to undernutrition and to seasonal stress. This review suggests that seasonal variation in energy intake and expenditure are not always effective. Results of the nutritional status are mixed but consistent for adults. For the determinants of the seasonal variations in energy intake, energy expenditure are as follows:

- Food and energy intake: *cash-savings and credit market imperfections, seasonal variation food prices, seasonal infectious diseases, seasonal preferences/taste, buffer-stock (precautionary) savings and food storage imperfections, seasonal household economic factors, seasonal household food insecurity, seasonal inadequate dietary intake, seasonal variability in physical activity energy expenditure of adults.*
- Energy expenditure: *seasonal infectious diseases, seasonal variability in physical activity energy expenditure, and the seasonal variability in basal metabolic rate*.

As regards the changing of energy intake, energy expenditure, and nutritional status, findings indicate a countercyclical relation of total energy expenditure, physical activity level and basal metabolic rate with nutritional status; a procyclical relation between energy balance and nutritional status. Therefore, the preharvest weight losses are not only related to reductions in energy intake but also to reductions in energy expenditure caused by metabolic adaptations.

Regardless of individuals the determinants of nutritional status include the *seasonal infectious diseases, unhealthy living environment and services, seasonal household food insecurity, seasonal poor quality of caring and feeding practices, seasonal inadequate dietary intake, and seasonal food energy intake*. In addition *seasonal activity energy expenditure, seasonal variability in basal metabolic rate, seasonal change in total energy expenditure, seasonal* *energy stress are specific for adults' nutritional status; and mother's nutritional status, seasonal intrahousehold allocation of food/nutrient, seasonal mother's activity energy expenditure, for child's nutritional status.*

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References

Abay K. & Hirvonen K., 2016. Does market access mitigate the impact of seasonality on child growth? Panel data evidence from northern Ethiopia. The Journal of Development Studies, 1-16. 1.

Aggarwal S., Francis E. & Robinson J., 2018. Grain Today, Gain Tomorrow: Evidence from a Storage Experiment with Savings Clubs in Kenya. Journal of Development Economics, 134, 1-15.

Alderman H., Hoddinott J. & Kinsey B H., 2006. Long Term Consequences of Early Childhood Malnutrition. Oxford Economic Papers, Vol. 58, Issue 3, pp. 450-474, 2006.

Arsenault J E., Nikiema L., Allemand P., Ayassou K A., Lanou H., Moursi M., De Moura F F. & Martin-Prevel Y., 214. Seasonal differences in food and nutrient intakes among young children and their mothers in rural Burkina Faso. Journal of Nutritional Science, vol. 3, e55, page 1 of 9.

Ayenew H Y., Biadigilign S., Schickramm L., Abate-Kassa G. & Sauer J., 2018. Production diversification, dietary diversity and consumption seasonality: panel data evidence from Nigeria. BMC Public Health 18:988.

Basu K. & Wong M., 2015. Evaluating Seasonal Food Storage and Credit Programs in East Indonesia. Journal of Development Economics, *115* 200-216.

Behrman J R., 1988. Nutrition, Health, Birth Order and Seasonality. Intrahousehold Allocation among Children in Rural India. Journal of Development Economics, 28, 43-62. North Holland

Brown K H., Black R E. & Becker S., 1982. Seasonal changes in nutritional status and the prevalence of malnutrition in a longitudinal study of young children in rural Bangladesh. The American Journal of Clinical Nutrition, 36: 303-313.

Burke M., Bergquist L F. & Miguel E., 2018. Sell Low and Buy High: Arbitrage and Local Price Effects in Kenyan Markets.

Chaudhuri & Paxson, 2002. Smoothing Consumption under Income Seasonality: Buffer Stocks vs. Credit Markets. Discussion Paper #:0102-54. Department of Economics, Columbia University, New York, NY 10027.

Chikhungu L C. & Madise N J., 2014. Seasonal variation of child under nutrition in Malawi: is seasonal food availability an important factor? Findings from a national level cross-sectional study. BMC Public Health, 14:1146

Egata G., Berhane Y. & Worku A., 2013. Seasonal variation in the prevalence of acute undernutrition among children under five years of age in east rural Ethiopia: a longitudinal study. BMC Public Health, 13:864. http://www.biomedcentral.com/1471-2458/13/864.

Gross J., Guirkinger C., & Platteau J-P, 2017. Buy as you need : Nutrition and Food Storage Imperfections. University of Namur, Center for Research in the Economics and Development (CRED). 53 pages.

Khandker & Samad, 2016. Is Seasonal Hunger a Distant Memory in Bangladesh? Revisiting Earlier Evidences. JICA Research Institute Working paper n° 110. 42 pages.

Madan E M., Haas J D., Menon P. & Gillespie S., 2018. Seasonal variation in the proximal determinants of undernutrition during the first 1000 days of life in rural South Asia: A comprehensive review. Global Food Security. Volume 19, December 2018, Pages 11-23.

Miller J., Ritchie B., Tran C., Beggs S., Lada C. O., Whetter K., Cobiac L. , 2013. Seasonal variation in the nutritional status of children aged 6 to 60 months in a resettlement village in West Timor. Asia Pac J Clin Nutr 22 (3):449-456.

Murayama N. & Ohtsuka R., 1999. Seasonal fluctuation in energy balance among farmers in Northeast Thailand: The lack of response of energy intake to the change of energy expenditure. European Journal of Clinical Nutrition 53, 39-49.

Nithya D J., Raju S., Pradhan A., 2018. Effect of Agricultural Seasons on Energy Intake: Evidence from Two Agro-Ecologically Different Rural Districts of India. Food and Nutrition Sciences, 9, 542-555.

Paxson C H., 1993. Consumption and Income Seasonality in Thailand. The Journal of Political Economy, Vol. 101, No. 1, pp. 39-72.

Payne P. & Lipton M., 1994. How Third World Households Adapt to Dietary Stress. Food Policy Review 2. IFPRI: Washington, D.C. 144 pages.

Prentice A M. & Cole T J., 1994. Seasonal changes in growth and energy status in the Third World. Proceedings of the Nutrition Society, 53,509-519.

Sahn D E., 1989. Seasonal variability in third-world agriculture: the consequence for food security. The Johns Hopkins University Press. International Food Policy Research Institute (IFPRI). Book, 380 p.

Schultink J W., Van Raaij J M A. & Hautvast J G A J., 1993. Seasonal weight loss and metabolic adaptation in rural Beninese women: the relationship with body mass index. British Journal of Nutrition, 70, 689-700.

Sinha S. & Lipton M., 1999. Damaging Fluctuations, Risk and Poverty: A Review. Background Paper for the World Development Report 2000/2001. 91 pages.

Stephens C. & Barrett C B., 2011. Incomplete Credit Markets and Commodity Marketing Behavior. Journal of Agricultural Economics 62 (1), 1-24, 1.

UNICEF. (1990). Strategy for improved nutrition of women and children in developing countries. New York: United Nations Children's Fund.

Vaitla B., Devereux S. & Swan S. H., 2009. Seasonal Hunger: A Neglected Problem with Proven Solutions. PLoS Med 6 (6)

Wijesinha-Bettoni R., Kennedy G., Dirorimwe C. & Muehlhoff E., 2013. Considering Seasonal Variations in Food Availability and Caring Capacity when Planning Complementary Feeding Interventions in Developing Countries. International Journal of Child Health and Nutrition, 2, 335-352.

https://dapa-toolkit.mrc.ac.uk/ : Diet Anthropometry and Physical Activity (DAPA) Measurement Toolkit (University of Cambridge), consulted in May 2019.

Glossarry

SEASONALITY

Seasonality - any regular pattern correlated with the seasons, predictable in occurrence, but not always in magnitude.

NUTRIENTS, FOODS, AND DIETS

Diet - consists broadly of the selection and consumption of foods and drinks, from which nutrients are derived and used for the body's needs. Diet can be analyzed by total energy intake or calorie intake, nutrient (macronutrient and/or micronutrient) intake, food consumption, dietary patterns, dietary behaviors (timing of food consumption).

Dietary pattern - overall combination of food consumption, which may result in synergistic or antagonistic effects on health above and beyond effects of single nutrients or foods.

Food - any nutritious substance that is consumed in order to maintain life and growth.

Food intake - amount of food expressed in quantity units.

Food energy intake - conversion of the average food intake in calories. Daily calorie per person or adult equivalent less than **2,100 kcal** is widely used as a proxy for food insecurity.

Micronutrients (vitamins and minerals) - chemical element or substance required in trace amounts for normal growth and development.

Macronutrients (Protein, Fat, Carbohydrate) - chemical element or substance required in large amounts for normal growth and development.

Nutrient - substance that provides nourishment essential for the maintenance of life and for growth, development or homeostasis.

Nutrition - intake of food, considered in relation to the body's dietary needs.

ENERGY EXPENDITURE

Basal metabolic rate (BMR) - rate of energy expenditure of an individual in a fasted state at complete rest the morning after sleep in a temperature neutral environment. This is the rate of energy expenditure required to maintain cellular functions.

Basal energy expenditure (BEE) - sum of energy expended by an individual in a fasted state at complete rest the morning after sleep in a temperature neutral environment during a specified time period. It is the energy expenditure required to maintain cellular functions.

Metabolic equivalent task (MET) - intensity of physical activity expressed relative to an individual's resting energy expenditure. Individual activities are assigned a MET value representing their energy cost relative to this resting value.

Physical activity (PA) - any bodily/body movement produced by skeletal muscles resulting in energy expenditure.

Physical activity energy expenditure (PAEE) or Activity energy expenditure (AEE) - sum of energy expended due to physical activity during a specified time period. It depends on the amount of body movement and the body size, since it takes more energy to move more mass. For a defined time-frame (hour, day, week etc.), PAEE is the product of the intensity, duration and frequency of body movement.

Physical activity level (PAL) - total energy expenditure for 24 hours expressed as a multiple of basal energy expenditure.

Physical activity pattern - variation of physical activity with time.

Rate of physical activity energy expenditure – is expressed per unit time and commonly referred to as activity intensity.

Respiratory exchange ratio (RER) or **respiratory quotient (RQ)** - ratio between the amount of carbon dioxide produced in metabolism and oxygen used.

Resting energy expenditure (REE) - sum of energy expenditure of an individual during rest. It is the largest component of total (daily) energy expenditure, including sleeping energy expenditure and the energy cost of wakefulness (arousal). REE is slightly higher than basal metabolic energy expenditure (typically within 10%).

Resting metabolic rate (RMR) - rate of energy expenditure of an individual at rest. Often measured in place of basal metabolic rate which requires strict conditions.

Sleeping energy expenditure (SEE) - sum of energy expenditure during sleep.

Thermic effect of food (TEF) or dietary induced thermogenesis (DIT) - energy expenditure associated with the digestion, absorption and storage of food.

Total energy expenditure (TEE) - sum of all energy expended by an individual during a specified time period (e.g. one day). It consists of BEE, TEF, and PAEE. Otherwise, for an average young adult TEE = SEE + Arousal + TEF + PAEE.

ENERGY BALANCE

Human consumption and expenditure of energy, alongside any change in the body's energy (macronutrient) stores (e.g. fat, protein, and glycogen/carbohydrate) is summarized by the energy balance equation:

$$Energy\ consumed - Energy\ expended = Change\ in\ energy\ stores$$

The parts of the equation are often expressed as kilocalories (kcal), kilojoules (kJ) or megajoules (MJ), and usually expressed per unit of time, for example kcal per day. 1 kcal = 4.184 kJ, 1 kJ=0.239 kcal. KJ and MJ (measures of energy) are preferred as defined in the International System of Units; however kcal (a measure of heat) is also commonly used.

ANTHROPOMETRY: MEASUREMENTS, INDICES, GROWTH INDICES

Anthropometry literally means human measurements. It derives from the Greek words "anthropos" meaning "human", and "metron" meaning "measure". In epidemiological studies, anthropometry is often used to evaluate disease risk and body composition changes.

Anthropometry can also be used to evaluate the **nutritional status**, such as obesity resulting from over-nutrition or emaciation caused by malnutrition.

Anthropometric measurements - used to assess the size, proportions and composition of the human body: weight (or mass), height, recumbent length, circumferences (head, waist, hip, mid-upper arm, mid-thigh, calf, chest, neck), limb lengths (knee height, arm-span, demi-span, and half-span), abdominal sagittal diameter, and skinfold thicknesses (biceps, triceps, sub-scapular, suprailiac and abdominal).

Anthropometric indices – combination of anthropometric measurements with each other or with other information: body mass index (BMI), waist-to-hip ratio, waist-to-height ratio, ponderal index, fat mass index, and fat free mass.

- **Body mass index (BMI) or Quetelet index** (Weight/Height^2) (kg/m^2) – a value derived from the weight and height of an individual. It is used to identify individuals who are the most likely to be overweight or obese but also chronic energy deficiency in adults.

- **Fat mass index (FMI)** (Fat Mass/Height^2) (kg/m^2) and **Fat free mass index (FFMI)** (lean mass or FFM/height^2) (kg/m^2) – FFMI is able to identify individuals with elevated BMI but without excess FM. Conversely, FMI can also identify individuals with 'normal' BMI, but who are at potential risk because of elevated FM. Mathematically,

$$\text{BMI (kg/m}^2\text{)} = \text{FFMI (kg/m}^2\text{)} + \text{FMI (kg/m}^2\text{)}$$

Growth indices - anthropometric measurements can be adjusted for non-anthropometric parameters (e.g. age and sex) to infer childhood growth and states of under or over-nutrition.

Percentiles and Z-scores are routinely used in clinical and epidemiological studies to assess and interpret children's growth and nutritional status in infancy, childhood and adolescence (up to 19 years of age). Percentile indicates the percentage of observations that fall below a certain value. Median is regarded as a reference value, and 3rd and 97th percentiles as thresholds to indicate abnormally low or abnormally high values. Z-score (or standard deviation scores) is the distance and direction of an observation away from the population mean. It is derived by using the formula (assuming normal distribution): (Measured value – Average value in the reference population) / Standard deviation of the reference population. Z-scores are also often used to 'clean' large datasets by excluding outlying data. Z-scores that lie outside +/- 4, 5 or 6 might be considered to be implausible and are changed to missing values.

BMI-for-age (BMI-Z or BAZ) - child's BMI for their age and sex relative to the reference population. It is used (usually in children aged older than two years) to indicate weight status independent for height, and is used to define childhood overweight, obesity and thinness.

Height (or length)-for-age (HCAZ) or chronic undernutrition or stunting - child's height (or supine length in children less than two years old) for their age and sex relative to the reference population. It is used to monitor a child's growth.

Weight-for-age (WAZ) or acute undernutrition or wasting - child's body weight for their age and sex relative to the reference population. It is an important indicator of underweight or overweight in young children aged less than two years old.

Head circumference-for-age – Head circumference is measured on infants and children until the age of five years. The head circumference-for-age is used together with other growth indices to assess infants' growth and development. Typically, an infant with a HC > 97th percentile is considered to present with macrocephaly, while a HC of <3rd percentile has microcephaly.

Arm circumference-for-age - arm anthropometry is used as a proxy measure of body composition (e.g. muscularity, FFM, and FM) by assessing the shape of the upper arm and includes: upper arm length, mid upper arm circumference (MUAC), triceps skinfold (TSF). The arm circumference-for-age is used as an alternative indicator of nutritional status when the collection of length/height and weight measurements is difficult, as happens in emergency humanitarian situations due to famine or refugee crises.

Skinfold thickness-for-age indices - The skinfold indices - triceps skinfold-for-age (TSFZ) and subscapular skinfold-for-age - are useful addition to the battery of growth standards for assessing childhood obesity in infants between 3 months to 5 years.

Weight-for-height (or length) (WHZ) - indicates a child's weight status independent of their height relative to a reference population, typically in children aged under two years old. It is often used to indicate whether children are overweight, obese or underweight.

Appendix

The methodology used to achieve the different objectives of the literature review are presented here

Study search
Documents such as empirical papers, literature review papers, theoretical papers, policy papers and books available and closely related to the investigated topic were searched.

Study selection
A literature survey enabled to go through the different documents and to select the relevant studies. The eligibility criteria for this literature review were documents which had clear objectives, theories, methodology and results, which put emphasis on the seasonality and its roles the variations in food energy intake, and expenditure and nutritional status. Studies were excluded if they did not provide at least one of the needed information.

Data extraction and analysis
Secondary information collected from the relevant studies and documents were used in the study. A qualitative approach was used to gather, analyze and explain collected data. In fact, thematic content analysis served to analyze those documents after a comprehensive reading. This method was used to describe and interpret the meaning of the extracted information based on the table below. After filling the table, a short summary of each document is written in own words, which constitute a good basis for the writing of the literature review. The aim was not to analyze each document but to retain a holistic and critical view of their different contents.

Author	Purpose	Type of study	Method (sampling, data collection & analysis, …)	Major findings / arguments	Critical appraisal (similarities, uniqueness, strength, weakness,..)
Author (s) 1					
…					
Author (s) n					

Selected studies and characteristics
The selected studies include both cross-sectional and longitudinal data and were carried out mainly in rural areas of Asia and Africa. The target population of the selected documents consisted of young children (Brown et al., 1982; Hillbruner & Egan, 2008; Miller et al., 2013), women (Schultink et al., 1993), mother–child[4] pairs (Egata et al. 2013; Arsenault et al., 2014), and pair of husband-wife (Murayama and Ohtsuka, 1999).

[4] Preschool child : 6 to 36 months