Evaluation of dietary diversity scores to assess nutrient adequacy among rural Kenyan women

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Dedicated to daughter Sally, Mum Teresa, Late Dad Ngala, Sella, Lucy, Jane, Magdalene, Christopher and Angela

Abstract

Background: The major cause of micronutrient deficiencies is low intake due to monotonous diets, especially among women of childbearing age. The dietary diversity score has been proposed and validated as a good proxy indicator for micronutrient adequacy. However, there are still outstanding methodological questions related to seasonal effects, food intake methods, selection of foods and the cut-off for estimating the prevalence of acceptable nutrient adequacy. This thesis evaluated the performance of a simple dietary diversity score for assessing nutrient adequacy in the diets of rural women in Kenya.

Methods: The study was conducted in Mbooni Division, Makueni District, Kenya among non-pregnant, non-lactating women of reproductive age having a child between 2-5 years. Food consumption data was collected by 3 non-consecutive quantitative 24hr-recalls and a qualitative free-listing 24hr-recall, in pre-harvest (Period 1, October 2007, n=73) and post-harvest (Period 2, April 2008, n=203) seasons. Dietary diversity scores (DDS) were derived based on 10 and 13 food groups with a minimum intake threshold per food group of 0 and 15 g, respectively. Mean probability of adequacy (MPA) was calculated based on intake of 11 micronutrients.

Results: The dietary diversity score (DDS) and mean probability of adequacy (MPA) were significantly but moderately associated in both seasons (r=0.40 and r=0.38 in Period 1 and 2), and the association was independent of season (p=0.45). The DDS from a qualitative 24hr-recall (DDSql) showed little agreement with the quantitative 24hr-recall (DDSqn) with a mean difference (DDSqn-DDSql) of -0.51±1.46 (Period 1) and -0.58±1.43 (Period 2), with lower correlations between MPA and DDS for DDSql (r=0.14 and 0.19 in Period 1 and 2, $p>0.05$) compared to DDSqn (0.40 and 0.54 in Period 1 and 2, $p<0.01$). The informative food-based scores and the food group-based scores were moderately associated with mean probability of adequacy (r=0.54-0.59 in Period 1; r=0.37-0.45 in Period 2) with higher values for informative food-based scores. The Minimum Dietary Diversity score for Women and mean probability of adequacy were significantly but moderately associated in both seasons (r=0.43-0.58 in Period 1; r=0.24-0.50 in Period 2), but the use of the cutoff of consuming 5 or more food groups as indication of nutrient adequacy resulted in high total misclassifications in both periods.

Conclusion: A dietary diversity score can be used as a simple proxy indicator for micronutrient adequacy, independent of season. The dietary diversity score derived from a qualitative free-listing 24hr-recall formed a poor indicator, needing further refinement to improve its performance. The informative food-based score performs moderately better in predicting nutrient adequacy, but its advantages do not outway those of the food group-based scores, and the latter is therefore preferred. The Minimum Dietary Diversity score for Women, formed a good indicator to predict nutrient adequacy, but using the cutoff of 5 or more food groups resulted in an overestimation of prevalence of adequate intake in our resource poor population.

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Chapter 1

General introduction

This section will explain the general magnitude of micronutrient malnutrition in women, in the world and specifically in Africa. The prevalence of the various micronutrient deficiencies will be presented to depict the extent of the problem. Improving dietary quality will be discussed as one of the most important ways to alleviate micronutrient malnutrition in developing countries. A dietary diversity score is proposed as a valid proxy indicator for micronutrient adequacy. To successfully use a dietary diversity score in large-scale studies, challenges on the indicators ability to predict nutrient adequacy that need further attention are addressed. The rationale for the study and research questions is presented, followed by a description of the study site in rural Kenya where food consumption data of women (of reproductive age) was collected.

Global micronutrient malnutrition

Micronutrient malnutrition affects a large percentage of the world's population. Worldwide, the most common micronutrient deficiencies are iron, zinc and vitamin A, though iodine, folate, vitamin B12 and other B vitamin deficiencies are also widespread. Over a quarter of the world's population is anaemic, with 486 million of these (30%) being non-pregnant women (1). Africa has the highest prevalence of anaemia, where 44% of non-pregnant women are affected (2). Iron deficiency is one of the major causes of anaemia. Worldwide, vitamin A deficiency is present in about 19% of pregnant women (3). Africa accounts for 25–35% of the global cases of maternal vitamin A deficiency (4). In sub-Saharan Africa about 26% of the population has an inadequate zinc intake reflecting the high risk on zinc deficiency (5).

The consequences of micronutrient malnutrition are pervasive, damaging and often irreversible contributing directly and indirectly to morbidity and mortality of billions of people worldwide. Vitamin and mineral deficiencies lead to poor pregnancy outcomes, reduced immune competence, and poor neural development, but also poor cognitive performance and poor psychomotor development. Suffering micronutrient deficiencies in adults lead to reduced work capacity or productivity implying that the afflicted incur economic losses and medical costs (5-8).

Dietary diversity is essential to nutrient adequacy

One of the most important causes leading to micronutrient deficiency is a poor diet lacking diversity (9). Good food sources providing micronutrients are for example seafood, all flesh foods, liver, wheat flour, spinach, pumpkin, beans and nuts, lentils, sweet potatoes, dark green leafy vegetables, especially kale, squash (butter nut) and lettuces (5-9). Data on nutrient adequacy of diets of women is often not available and, when available, mostly of poor quality and non-representative (9). However, the few studies that are available show that women in low-income countries consume poor quality, monotonous diets leading to low intakes of multiple micronutrients (9-13).

Dietary diversity is essential to nutrient adequacy as there is no single food, other than breast milk for the first six months of life, that contains all of the nutrients required to maintain good health and nutritional status (14). Dietary diversity is therefore a key element of high quality diets and the recommendation to consume a variety of foods appears in many nutritional guidelines (14). Diet quality has been used to refer to nutrient adequacy, which means consumption of a diet that meets both the energy and all essential nutrients requirements (15). To ensure that high-quality dietary patterns are achieved in developing countries, encouraging the consumption of a wide variety of foods among and within food groups is recommended (15).

Dietary diversity score

The methods used to collect food consumption data, such as the conventional quantitative 24hr-recall dietary assessment surveys, are costly, cumbersome to conduct and to analyse in poor resource settings (16). There is a need for a simple score to use as proxy indicator of food intake that can be used in large surveys, such as the Demographic Health Surveys and National Nutrition surveys, to predict micronutrient adequacy easily, yet still quickly and accurately (17). Simple measures of dietary diversity are increasingly used for assessment, especially in developing countries, as data collection and analysis are less time-consuming and less costly than quantitative food intake measures. Dietary diversity can be classified according to foods and food groups, nutrients only, or foods and nutrients taken together. In general, indices attributed to dietary diversity based on a combination of food groups and selected nutrients have been related to micronutrient deficiencies more directly

than those based on individual nutrients or foods (18). The most commonly used dietary diversity score is defined as the number of food groups consumed over a given specified time period (18).

In large surveys information on dietary diversity may be collected through qualitative 24hr-recalls (19), which are relatively straightforward for respondents, are not considered intrusive and do not impose burdensome demands on time and dependency on recall (14). A dietary diversity score (DDS) can be measured at the household (HDDS) or individual level (IDDS). At the household level, dietary diversity is usually considered as a measure of access to food, while at the individual level it reflects quality, mainly micronutrient adequacy, of the diet (19).

Dietary diversity scores can be used to: a) predict nutrient adequacy of vulnerable age groups; b) target the introduction or the promotion of certain food groups; c) use as advocacy and promotion tool to influence administrators into channelling their attention to the vulnerable communities, and what action they can take (20).

Nutrient adequacy

The quality of the diet can be estimated in terms of food or food group intakes and diet patterns, or in terms of nutrient intake and the level of compliance with the nutrient requirements. When evaluating the diet in terms of nutrient adequacy, diverse types of analyses are used. The method used depends on the purpose of the analysis (to assess individuals or a population), on the nutrient under study and the type of distribution of the nutrient intake (21, 22).

Nutrient adequacy refers to the achievement of recommended intakes of energy and other nutrients. The recommended intake is expressed as the Estimated Average Requirements (EAR) being the amount of a nutrient that is needed to meet the nutrient requirement of half the healthy individuals in a life-stage and sex group (23). Until recently, a (mean) Nutrient Adequacy Ratio (NAR or MAR) was calculated for energy and nutrients of interest to estimate the nutrition adequacy of the diet. The NAR for a given nutrient is the ratio of the subjects' daily intake to the current recommended allowance for the subjects' sex and age category (24).

As an overall measure of the nutrient adequacy of the diet, the Mean Adequacy Ratio (MAR) is calculated as the sum of all the NARs of nutrients of interest divided by the total number of nutrients of interest (24). All NARs are truncated at 1, as a nutrient with a high NAR cannot compensate for a nutrient with a low NAR (25). There is no standard list of nutrients for its assessment (6). However, NAR leads to imprecise estimates, particularly overestimation (26). This is because NAR does not fully consider the variability, both in usual nutrient intake among individuals and in their nutrient requirements. This method does not identify those particular individuals who have inadequate intakes, only the proportion of the population with inadequate intake (27).

The probability approach is an alternative method recommended for assessing nutrient adequacy. It is a statistical method that combines the distributions of requirements and intakes in the group to produce an estimate of the expected proportion of individuals at risk for inadequacy. For this method to perform well, little or no correlation should exist between intakes and requirements in the group.
The approach is based on statistical probabilities: at very low intakes the risk of inadequacy is high, whereas at very high intakes the risk of inadequacy is negligible. In fact, with information about the distribution of requirements for the group, a value for risk of inadequacy can be attached to each intake level. In a group there is a range of usual intakes, therefore, the prevalence of inadequacy in the group, referred to as the average group risk, is estimated as the weighted average of the risks at each possible intake level. What is needed for the calculation is the mean and standard deviation of the requirements, if it can be assumed that the requirements are normally distributed. The calculation of the probability of adequacy (PA) is based on the difference (D) between the reported intake and the EAR (28). The mean probability of adequate nutrient intake (MPA) for each subject is the average of the PA for all the nutrients of interest (29, 30).

Associations between dietary diversity and nutrient adequacy

Studies in different age groups have shown that an increase in an individual dietary diversity score is related to an increased nutrient adequacy of the diet. Dietary diversity scores have been validated for several age/sex groups as proxy measures for

macro- and/or micronutrient adequacy of the diet. Scores have been positively correlated with adequate micronutrient density of complementary foods for infants and young children (31), and macronutrient and micronutrient adequacy of the diet for non-breastfed children (25, 30, 32, 33), adolescents (34) and adults (35-37). Some of these validation studies refer to only one country while others have attempted to validate dietary diversity scores for several countries.

Due to the differences in methodologies used to study the relationship between dietary diversity and nutrient adequacy, there has been a need for a global harmonized and standardized indicator that can be used especially in developing countries to assess the micronutrient adequacy in women's diets. The Women's Dietary Diversity Project (WDDP) launched by the Food and Nutrition Technical Assistance Project in 2005, was designed to respond to the need or search for simple yet valid indicators of women's diet quality, with a specific focus on micronutrient adequacy.

The WDDP was charged with the responsibility to carry out research with the use of high-quality dietary datasets from a range of settings in Africa and Asia. With the use of a common analytic protocol and harmonized definitions, the first phase of the WDDP proposed a variety of dietary diversity indicators, but did not identify a single indicator for wide use. "Candidate" indicators with more food groups were more strongly associated with micronutrient adequacy for women, and indicators were strongest when consumption of trivial amounts (<15 g) of a food group did not count in dietary diversity scores (37). In the second phase, WDDP came up with a proposal of a nutritionally meaningful dichotomous indicator for global use. In a recent consensus meeting in 2014 involving experts from academia, international research institutes, the UN and donor agencies unanimously endorsed and supported the use of the new indicator, called Minimum Dietary Diversity – Women (MDD-W), with a threshold of at least five food groups out of ten. Women consuming foods from five or more food groups have a greater likelihood of meeting their micronutrient needs than women consuming foods from fewer food groups (38).

Limitations of the current dietary diversity score in relation to its ability to predict nutrient adequacy.

This section briefly explains the gaps in knowledge in using the dietary diversity score as an indicator to predict micronutrient adequacy among rural women of reproductive

age. Recent developments, including dramatically increased attention and funding for nutrition-sensitive interventions, notably in agriculture, have increased the demand for indicators of dietary quality. To strengthen the use of the dietary diversity score as proxy indicator for nutrient adequacy, issues related to the effect of seasonality of the food supply, to the methodology to be used to collect food intake data and to define the foods or food-groups based upon which a dietary diversity score can be calculated, and the performance of the newly developed minimum dietary diversity indicator of women should be addressed.

Seasonality and dietary diversity score

In developing countries, people often experience seasonality in food availability and access at both household and individual levels. Developing countries mostly rely on rain-fed agriculture where fluctuations in rainfall determine how often and how much is harvested. This means that at certain times of the year, food is available in abundance, while at other times there is very little food (39-41). Food seasonality is, therefore, the existence of a certain period(s) during the year when food availability is scarce (but the need for food is high) followed by period(s) of abundance (42) often reflected in seasonal body weight losses, especially among women (43). This might imply that the dietary diversity of food varies or fluctuates with season. Few studies have dealt with the effect of seasonality on dietary patterns and nutrient intake.

A study in urban Burkina Faso, observed a decrease in dietary diversity and a decrease in nutrient adequacy when progressing from the abundant season to the lean season (44), whereas a higher dietary diversity with a decreased nutrient adequacy was found in the lean season in rural Burkina Faso(45). In North-Western Benin, consumption of foods rich in proteins and vegetables led to an increase in dietary diversity during the pre-harvest period (46). Consumption of different foods in the lean and post-harvest seasons affected the intake of some vitamins in the rural Tanzanian community (47). It is apparent from the studies enumerated above that there is no consistent pattern in the seasonal fluctuation of dietary diversity and nutrient adequacy. In addition, no study has been carried out to assess the impact of seasonality on the association between dietary diversity and nutrient adequacy and its determinants.

Quantitative versus qualitative 24hr-recall dietary diversity score

Most studies analysing the association between dietary diversity and nutrient adequacy use food intake data obtained by one or repeated quantitative 24hr-recalls. However, due to the complex and costly nature of a quantitative 24hr-recall, this method might not be appropriate in large surveys, as simple data that can be easily collected during one household visit are generally preferred. Qualitative 24hr-recall might be more suitable, as these recalls, though administered in the same manner, are found to be faster and easier to administer as compared to the conventional quantitative 24hr-recall. The respondent is not required to give estimates of quantities of foods consumed, but just to list them as consumed, reducing the interviewers' and respondents' burden or fatigue while shortening the interview time. The qualitative nature makes it possible to cover many households per day and the analysis of data is easier and faster and no highly skilled personnel is required (14, 48). A study among women in urban Burkina Faso compared a dietary diversity score derived from a qualitative list-based 24hr-recall to a score calculated from a quantitative 24hr-recall (48). Results revealed little agreement between the two types of indicators. The qualitative score tended to underreport the quantitative scores when a 1 g of minimum consumption requirement was used and to overreport the quantitative scores when a 15 g of minimum consumption requirement was used. Misreported food groups were generally nutrient-dense and often consumed in small quantities, which might lead to a lowered power of the qualitative score to predict nutrient adequacy (48). To overcome some of the limitations of a list-based recall, Martin-Prevel et al. (48) suggests the use of a qualitative free listing recall where respondents are allowed to recall freely with the aid of probing (49). This is suggested to reveal more accurate data (14). However, the performance of a dietary diversity score derived from free listing qualitative 24hr-recall to predict nutrient adequacy should be evaluated to justify use in large surveys.

Informative food-based dietary diversity score

Commonly used dietary diversity scores are defined as a simple count of food groups consumed over the past 24 hours, irrespective of which food within the food group is consumed. So far, the correlations found between the dietary diversity score and

nutrient adequacy were rather moderate, ranging from r=0.21 to r=0.53, reducing to r=0.12-0.46 when adjusted for energy intake (37). To be useful as proxies to assess micronutrient intake at the population level in large-scale studies, there is a need for further efforts to improve the performance of the dietary diversity indicators to predict micronutrient adequacy of the diet.

Applying a minimum amount required for a food group to count, will improve the performance of the indicator, as the dietary diversity score with a 15-g minimum requirement performed consistently better than ones with a 1-g minimum requirement (37). However, operationalizing such a minimum requirement is challenging and misreporting was shown to be much higher with the 15-g compared to the 1-g minimum requirement (37). Increasing the number of food groups in the score would likely improve the performance of the indicator, but results are not consistent across different studies (37, 48, 50, 52) and too much disaggregation might increase misreporting, especially for nutrient-dense foods (48).

One option that may improve the performance is limiting the score construction to informative foods. A simple food group count may comprise foods that do not or hardly contribute to nutrient intake, because they are rarely consumed, consumed in small quantities or do not contribute to micronutrient intake. Consuming those foods would increase the DDS, but not nutrient adequacy, weakening the association between the two. Focusing on informative foods, being nutrient-dense foods that either contribute most to the intake of micronutrients or that explain a large part of the variation of intake of micronutrients, could be another way of composing a dietary diversity score (51). So far, indicators calculated from nutrient-dense foods have only been studied in the developed world, assessing their ability to predict nutrient adequacy (51). There is a need to study whether an informative food-based dietary diversity score performs better in predicting nutrient adequacy compared to the food group-based score in poor-resource settings in developing countries.

Need for a universal indicator that will harmonise and offer comparability of studies

A dietary diversity score as proxy for nutrient adequacy is being used for more than a decade in the form of a quasi-continuous indicator. Much effort was given to come to a

universal standardized number of food groups to be used in the DDS as the inability to determine the best set of food groups to construct a dietary diversity score for use as a proxy indicator has been a stumbling block for the identification of a global international indicator (14). Results from the first phase of the Women Dietary Diversity Project (WDDP) did not justify a cut-off point for a dichotomous indicator that yielded an acceptable balance of sensitivity, specificity, and misclassification (14, 37). Nevertheless, the need for a nutritionally meaningful dichotomous indicator continued to be highlighted. A dichotomous indicator should favour sensitivity over specificity, while balancing the cut-off at the lowest percentage of false negatives. On the contrary, high false positives would increase the cost of any programme or intervention, as selected individuals would have been misclassified. Recently, the Minimum Dietary Diversity score for Women, suggested through the second phase of the WDDP, is the first indicator that has been recommended for use in predicting micronutrient adequacy for women. When using a dietary diversity score based on 10 food groups, the cut-off has been set at ≥5 food group (38). On an individual level it is recommended for having an adequate micronutrient adequacy (MPA>0.70) to consume 5 or more food groups in a specified time period, in developing countries. It was also recommended that an individual should consume a minimum quantity of 15 g of the food to count in a food group. There is a need for studies in developing countries to evaluate the ability of the minimum dietary diversity score to predict micronutrient adequacy among women and to assess its functioning and appropriateness in rural women living in poor resource settings.

Rationale and outline

Micronutrient malnutrition continues to be a problem of public health concern in developing countries, being predominantly caused by monotonous, starchy based diets with low diversity. The dietary diversity score is a promising indicator for use as a proxy for micronutrient adequacy because it is less complex and costly than other conventional quantitative measures to assess dietary intake. Dietary diversity scores are increasingly used in large scale studies like the Demographic and Health Surveys, and are proposed as indicators in impact assessments of nutrition-sensitive (agriculture) interventions. There are still several outstanding questions related to the seasonal changes in the performance of the dietary diversity score to predict nutrient

adequacy, to the best method to collect data and to derive at the dietary diversity score, and to the performance of a dichotomous dietary diversity indicator to predict prevalence of nutrient inadequacy at the population level. Answers to these questions would support the development of standardized indicators that are of global use in comparing dietary diversity across populations and over time.

The main aim of this research was to evaluate the dietary diversity score as a simple tool to assess nutrient adequacy in the diets of women of reproductive age. The following research questions are addressed:

1. What impact does seasonality have on the association between dietary diversity and nutrient adequacy and its determinants?
2. What is the effect of using different methodologies of determining dietary diversity on this association?
3. Does a dietary diversity score based on informative foods predict nutrient adequacy better than a dietary diversity score based on food groups?
4. How does a minimum dietary diversity score for women predict nutrient adequacy in a rural poor resource setting?

In Chapter 2 we studied how seasonal variation has an impact on the association between the dietary diversity score and nutrient adequacy (and their determinants) in the diets of women of reproductive age in rural Kenya. Food consumption data was collected from women by the use of 3 non-consecutive 24hr-recalls in two periods (seasons).

Chapter 3 describes a study comparing dietary diversity scores (based on 13 food groups) formulated from a qualitative free-listing 24hr-recall and a quantitative 24hr-recall obtained from the diets of rural Kenyan women. The dietary diversity scores derived from the two food consumption methods are correlated with mean probability of adequacy (MPA) calculated from the quantitative 24hr-recall.

Chapter 4 presents a study where a dietary diversity score was formed based on informative foods that contributed most to intake and variation of intake. The study assessed whether the informative food-based score predicted micronutrient adequacy better than the conventional food group-based dietary diversity score among rural Kenyan women.

The performance of the minimum dietary diversity score for women indicating that they should consumed at least 5 out of 10 predefined food groups to reach nutrient adequacy was evaluated in Chapter 5.

Finally, Chapter 6 presents the summary of main findings, as well as strengths and limitations of our research work. Moreover, suggestions for future research along with public health implication of the findings are given in this section.

The study site

The study was conducted in the Mbooni division of the Makueni district. The Makueni district is one of the 13 districts in the Eastern Province of Kenya. The Makueni district has 16 divisions, 66 locations and 108 sub-locations. The district has five constituencies namely, Mbooni, Kilome, Kaiti, Makueni and Kibwezi. The Makueni district has a population of 771,545 persons (1999 census) and an area of 7,966 sq km. It is semi-arid to arid land with low erratic rainfall, which on average is 500mm annually. The district is prone to frequent drought, severe food shortages and scarcity of water.

The actual field work was in the Mbooni division with a population of 55,984 persons. The Mbooni division lies between latitude 1^{o} 37' degrees South and longitude 37^{o} 28' degrees East. The division experiences two rainy seasons, where long rains occur in March/April and short rains occur in November/December. The Mbooni division has two distinct seasons, namely a wet /cool and a dry season. However, there is subsistence farming in the area (54). The map of Kenya showing Mbooni district is shown in Figure 1.

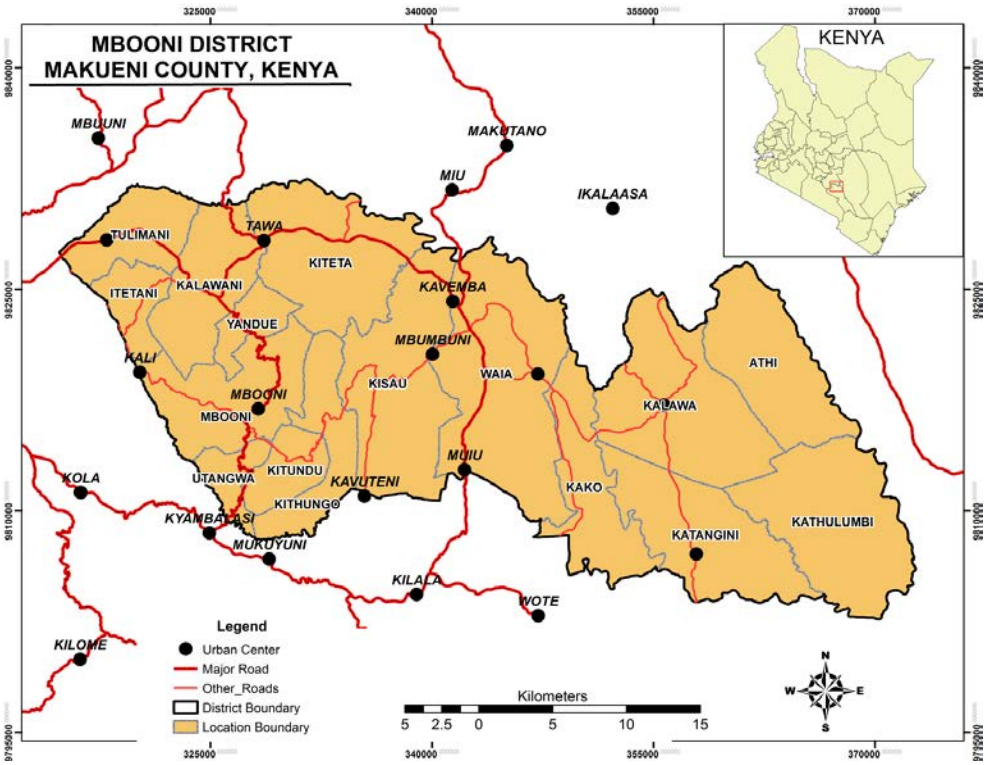

Figure 1: MBOONI DISTRICT, MAKUENI COUNTY, KENYA

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Chapter 2

Impact of season on the association between dietary diversity and micronutrient intake among Kenyan women.

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Abstract

Background: Food seasonality has been shown to affect dietary diversity and nutrient adequacy, however, the direction of this effect and impact on the association between diversity and adequacy is not known. To ascertain that dietary diversity can be used as indicator of micronutrient adequacy irrespective of season, we examined seasonal variations in dietary diversity, nutrient adequacy, and their association among Kenyan women of reproductive age.

Methods: Repeated non-consecutive 24hr-recalls were collected during pre-harvest (Period 1, Oct 2007, n=73) and post-harvest (Period 2, April 2008, n=203) seasons. We constructed dietary diversity scores (DDS) based on 13 food groups with minimum intake threshold per food group of 15 g and calculated mean probability of adequacy (MPA) of intake for 11 micronutrients. Correlations/regression analysis tested associations between DDS and MPA and effects of season. Sensitivity/specificity analysis detected cut-off values of DDS indicating low nutrient adequacy.

Results: DDS ranged from 4.5 ± 1.2 in Period 1 to 4.0± 1.3 in Period 2, indicating low diverse diets, based on starchy staples, without consumption of organ meat and fish. MPA ranged from 0.41 ± 0.07 in Period 1 to 0.44 ± 0.08 in Period 2. DDS and MPA were significantly but moderately associated in both seasons with r=0.40 (Period 1) and r=0.38 (Period 2) (0.20 and 0.22 after adjusting for energy intake). DDS cut-off of 4 (MPA≤40%) in both periods, maximized sensitivity/specificity detecting low micronutrient adequacy of intake, however, with high level of misclassification.

Conclusion: DDS can be used as a simple indicator for micronutrient adequacy, independent of season. Further studies are needed to identify a firm cut-off point for creating a dichotomous indicator of adequate intake.

Introduction

Women from poor resource settings suffer from micronutrient deficiencies affecting their capacity to carry out their duties in society while bearing healthy children [1-3]. The main reason is inadequate intakes of multiple micronutrients emphasizing the need for increased quality of women's diets [4]. Dietary intake information is necessary to characterise diet quality, however, conventional methods for collecting this information are often time-consuming, costly, require highly trained enumerators and involve complex data analyses [5]. Diet diversification is a key dimension of diet quality and consuming a variety of foods among and within food groups is a recommended strategy to ensure adequate intake of micronutrients [6]. Dietary diversity scores (DDS) have been suggested as simple and valid indicators for micronutrient adequacy of diets [7]. Despite many methodological differences, most studies show that higher dietary diversity scores are associated with a higher micronutrient intake in women, having stronger associations when a minimum quantity of consumption required for a food group to count in the scores is applied [7-9].

Developing countries mostly rely on rain-fed agriculture. Yet, the annual rainfall is erratic, has a seasonal nature and is often insufficient, affecting agricultural output, which is worsened by insufficient farmland, drought and poverty [10-13]. Seasonality in crop production implies fluctuations in food supply and availability [14-16], and may result in unstable food security. Food seasonality is, therefore, the existence of a certain period(s) during the year when food availability is scarce (but the need for food is high) followed by period(s) of abundance [17] often reflected in seasonal body weight losses, especially among women [18].

People respond to food insecurity by using coping strategies to manage household food shortages. These strategies include dietary adjustments like: rationing portion sizes, diluting meals, reducing number of meals, consuming less-preferred wild or unconventional foods, and increasing purchase of food considered less preferable [19-22]. These coping strategies may affect the diversity as well as the (micro)nutrient adequacy of women's diets. A food seasonality study in a West-African urban setting found a decrease in the diversity and nutrient adequacy of diets as time progresses

from post-harvest to pre-harvest [19,22]. However, a study in Burkina Faso among women found an increase in consumption of pulses, tubers and wild plants contributing to a higher diversity but at the same time reported a reduction in nutrient adequacy especially concerning energy and protein intake [23]. Another study in Benin found an increase in the diversity of the diet at the end of pre-harvest period, mainly due to increase in consumption of legumes, cow's milk, and vegetables particularly among poor women. The adequacy of these diets was not reported [24]. A study in Tanzania found that in the lean season more cassava tubers and cassava leaves were consumed, while more fish was consumed in post-harvest season increasing protein intake. However, vitamin A requirements were met in the lean season while there was a low vitamin A adequacy during the post-harvest period [25]. A study in two provinces in Mozambique showed that in the lean season, fruit, legumes and fish consumption was higher and resulted in an increased DDS, but adequacy of diet was not assessed [26].

The above-referred studies indicate that information on the direction of the effect of food seasonality on dietary diversity and adequacy is inconsistent. Moreover, the consequence of seasonality for the association of dietary diversity and nutrient adequacy is unknown. In order to examine seasonal variations in dietary diversity, nutrient adequacy and their association, we used food consumption data of women of reproductive age in Kenya collected in two seasons to assess whether dietary diversity and nutrient adequacy differ per season and whether the direction of the found differences in dietary diversity and nutrient adequacy is in harmony or moves in opposite direction affecting the strength of the association.

Methods

Study site and sample selection

The study was conducted in 2007 and 2008 at Mbooni division, Makueni district in Eastern Kenya. Makueni district comprises of 16 divisions, 66 locations and 108 sub-locations. It is characterized as semi-arid to arid with low erratic rainfall, which on average is 500mm annually. The district is prone to frequent droughts and food shortages [27]. Mbooni division (with 4 sub-locations) has a distinct seasonality and experiences two rainy seasons; long rains in March/April and short rains in November/December. Subsistence farming is practised with most crops harvested

after the short rains. Kyuu sub location (having 14 villages) was randomly selected for the survey. The community is rural with cultural homogeneity, since all people are from the Kamba ethnic group.

In each village 15 households were randomly sampled by the random walk method [28]. One woman of reproductive age (non-pregnant and non-lactating) having a child between 2-5 years was selected from each household. Having a child above 2 years ensured that the women were non-lactating. When no eligible woman was available in the household, the next household was visited through the random walk method until 15 women per village were selected. When more eligible women were available (at a household), only one woman was randomly selected. Other inclusion criteria for the women were: apparently healthy, no chronic illness, no known HIV/Aids, not anorexic and taking no medication. Due to the post-election violence in Kenya in 2007, data collection had to be stopped and only 73 women were selected for the first data collection round (see below).For the second data collection round, 210 women were selected.

At the time of the study, there was no Institutional Review Board or Ethics Committee at the University of Nairobi. In consultation with the Ethics Committee at Wageningen University, The Netherlands, no other Ethical Review Board was consulted, as according to the Kenyan Government rules in 2007, the study was not entitled to ethical clearance as it did not involve feeding of participants nor withdrawing any bodily fluids. The study was registered with and approved by the Kenya Ministry of Education, Science and Technology. Verbal approval was obtained from the Mbooni District officials and the community authorities. Verbal informed consent was obtained from the subjects based on a written consent form. As most of the women were illiterate and not able to write, the consent forms were not personally signed but clipped to the filled questionnaire. The Ministry of Education, Science and Technology agreed with this procedure in 2007.

Data collection

Data was collected in two distinct seasons selected on the basis of rainfall and agricultural practices. The first round of data took place during the short rains period in October-December 2007, characterised by food shortage just before harvesting

starting from December onwards (referred to as Period 1, pre-harvest season). The second round took place in the long rains period in April-June 2008, when short rains harvest was still available and the long rains harvest started (referred to as Period 2, post-harvest season). Food availability in October-December 2007 was expected to be lower than that in April-June 2008.

In both pre- and post-harvest season, the mean daily food intake of the women was assessed using three repeated quantitative multi-pass 24hr-recalls, carried out by well-trained interviewers [28,29]. The repeated recalls were from non-consecutive days with 2-11 days apart from the first recall. All days of the week were represented except for Saturday due to unavailability of households on Sunday. Households were randomly allocated to day of the week, interviewers were randomly allocated to households and repeated household visits by the same interviewer were avoided. After selection, an appointment was made for the interview date in the household, but the women did not receive an orientation nor a visual food list was left [28]. During the survey, women were asked to mention all foods and beverages they had eaten during the preceding 24 hours (from the time they woke up the preceding day, to the time they woke up the interview day), including anything consumed outside of the home. They were then requested to describe the foods and beverages consumed, including ingredients and cooking methods of mixed dishes. Amounts of all foods, beverages, ingredients of mixed dishes consumed were weighed to the nearest 2 g (0.1 oz) using Soehnle electronic kitchen scale (Plateau Art, Germany, Model number 65086, maximum weight 10 kg). When not available, amounts were estimated either in household units, size, volume (measured by water), or monetary value. Plate sharing is not practised in the study area. The total volume of food cooked at the respondents' household and the volume of food specifically consumed by the respondent were measured to determine the proportion consumed. The resulting proportion was multiplied by the total amount of ingredients used in the preparation of the dish to determine the amount of ingredients consumed by the respondent. Standard recipes were generated to take care of all foods consumed outside the home. Conversion factors from household units, size, volume and monetary values to weight equivalent were determined.

Nutrient intake, probability of adequacy (PA) and mean PA (MPA)

Nutrient intake calculations were based on a food composition table specifically developed for the study. The primary data source for nutrient values of foods was the national food composition table of Kenya [30]. Foods and nutrient values missing in this table were taken, in order of priority, from food composition tables from East Africa [31], Mali [32], South Africa (MRC) [33], International Minilist (IML) [34] and the United States Department of Agriculture database (USDA) [35]. USDA retention factors release 6 [36] were applied to raw ingredients and foods to account for nutrient losses during food preparation. Retinol and β-carotene were converted into retinol activity equivalent (RAE) using conversion factors that reflect current knowledge [37,38].

Nutrient intakes were calculated using VBS software version 4 (Bas Nutrition Software, Arnhem, Netherlands). Intake of energy and the following micronutrients were assessed: iron, zinc, calcium, vitamin C, vitamin A (RAE), vitamin B6 , vitamin B12, folate, riboflavin, niacin and thiamine, being key micronutrients for women's health [4]. Vitamin C was included because of its role in enhancing the absorption of non-haem iron [39]. All nutrient intakes obtained from the 24hr-recall (per period) were adjusted for within-person variation using the National Research Council (NRC) adjustment procedure to arrive at the usual intake [40]. The probabilities of adequacy (PA) for vitamins A (RAE), C, B12, B6, riboflavin, niacin, thiamine, folate, zinc and calcium were calculated based on their respective estimated average requirements (EARs) and distributions [41-43] (See Supporting Information Table S1), using the PROBNORM function in SPSS (PA=PROBNORM [(adjusted individual intake-EAR)/SD], where PROBNORM is the statistical function that clarifies whether the probability of the individual intake is above the EAR). The distribution of iron requirement is skewed, therefore, probability of adequacy values derived by the Institute of Medicine [41] were used (See Supporting Information Table S2), but adjusted for 5% bioavailability to reflect the inhibitory nature of the predominantly cereal-based diet in the study area. Similarly, the EAR for zinc was adjusted for low (15%) bioavailability [6]. The mean probability of adequate micronutrient intake (MPA) for each individual, a summary measure of micronutrient adequacy, was computed as the average of the PA for the 11 micronutrients considered in this study. In this study, over- and under-

reporting was calculated using basal metabolic rate (BMR), energy intake and physical activity level. The cut-off of low (< 0.9* BMR) and high (> 3* BMR) energy intake was used to assess over- and under-reporting [44,45]. However, no woman was found to have been below or above these cut-off points.

Dietary diversity score

The dietary diversity scores (DDS) were calculated based on 13 food groups as described by Arimond et al. [7] using a minimum quantity intake of 15 g for a food group to count. Comparable to other studies [6,8], the DDS was constructed based on the 24hr-recall from the first observation day; this in recognition that the score is meant for use in large scale surveys where only one household visit would be possible. Every food group consumed in the previous 24hr-recall hours received a score of 1 (irrespective of number of food items eaten from the food group), when consumed in quantities of 15 g or more. Arimond et al. [7] found that DDS based on thirteen food groups where a minimum of 15 g of each food group had been consumed, showed stronger correlations with MPA than without using a minimum intake requirement. The total food scores were finally summed up to arrive at the total DDS for each individual. The thirteen food groups comprised: all starchy staples, all legumes and nuts, all dairy, organ meat, eggs, small fish eaten whole with bones, all other flesh foods and miscellaneous small animal protein, vitamin A-rich dark green leafy vegetables, vitamin A-rich deep yellow, orange and red vegetables, vitamin C-rich vegetables, vitamin A-rich fruits, vitamin C-rich fruits, all other fruits and vegetables [7].

Anthropometric measurements

Body weight and height were measured according to WHO standardised procedures [46]. A microtoise (Bodymeter 208; Seca GMbH, Hamburg, Germany) was used to measure the height of women to a precision of 0.1 cm. Weight was measured with a platform spring balance scale with 150 kg maximum range and 0.5 kg graduation (Seca 761; Seca, Hamburg, Germany). For both weight and height, an average of two measurements was taken. The ages of women were determined by use of the National Identification cards, local calendar of events and memory. Based on Body mass index

(BMI, in kg/m^2), women were divided into 3 categories: underweight BMI < 18.5 kg/m^2, normal weight 18.5 ≥ BMI ≤ 24.9 kg/m^2, overweight or obese ≥ 25 kg/m^2 [17].

Statistical analysis

All statistical analyses were done using PASW 19 for Windows (IBM SPSS Statistics 19, SPSS Inc., Chicago). Complete data sets were available for 73 women (Period 1) and 203 women (Period 2). Complete datasets for both periods were available for 67 women. Anthropometry data were available for 60 women in Period 1 and 62 women in Period 2. The nutrient and dietary diversity data was visually checked and tested for normality using the Shapiro-Wilk test. Non-normally distributed data was log transformed to obtain normality. The proportion of women being underweight or overweight and women consuming the different food groups in the two periods was compared by use of the Chi-square test. For each period, Spearman's rank correlation (for non-normally distributed indicators) [47] and partial correlations (adjusted for energy intake) between DDS and PA (MPA) were calculated to verify linear associations. The independent sample t-test was used to compare height, weight, BMI, energy intake and the DDS and PA (MPA) between periods. To verify results of the independent sample t-test, the paired sample t-test was used only for subjects with data in both seasons (n= 67). To test the effect of season on the association between DDS and MPA, an interaction term was introduced in a linear regression model to determine any effect modification. For all statistical tests we considered values of $p<0.05$ to be statistically significant..

We tested the ability of the dietary diversity score to detect the prevalence of low mean nutrient adequacy (defined as MPA≤0.40) using sensitivity/specificity analysis. The Receiver Operating Characteristic (ROC) analysis was used to determine the area under the curve (AUC) for each period. Low MPA was defined based on ROC analysis using AUC ≥ 0.70 as cut-off point. The best DDS cut-off for maximising sensitivity/specificity was determined using the Youden index [48,49]. The Youden Index summarizes the information of the ROC analysis to evaluate the discriminatory ability of the dietary diversity score by maximizing the sum of sensitivity and specificity-1. Values for the index range between 0 and 1, where complete separation of the distributions of the DDS results in index=1 whereas complete overlap gives and

index=0. Sensitivity/specificity analyses reflected the full extent of misclassification and also investigated the proportions of all women who would be classified as 'false positives' and 'false negatives', and the 'positive predictive value' reflecting the true likelihood of having low MPA among those who were true positive.

Results

Description of sample

The average age of the women was 35 years (range 20-49), with none of the women younger than 20 years (**Table 2.1**). About 82% were married and 63% attained primary education. More than half of the women were subsistence farmers (58%).

Table 2.1. Demographic characteristics of women of reproductive age in Mbooni Division, Kenya[1,2].

Demography	Value
Age (in years)	34.9 ± 9.0
Relationship to Head of households, (%)	
Wife	81.5
Daughter	8.3
Other relative	10.2
Marital Status, (%)	
Married	82.4
Single	12.2
Divorced/Widowed	5.4
Level of Education, (%)	
Primary	63.4
Secondary or higher	30.7
Literate (read/write)	2.9
Illiterate	2.9
Occupation (%)	
Farmer	58.3
Housekeeper	24.0
Trader	10.3
Other	7.3

[1] n=205
[2] Data collected at start of study in Period 1(n=73) and Period 2 (n=203)

Mean BMI of women was 23 kg/m^2 with no significant differences between the periods (**Table 2.2**). The percentage of overweight women (BMI>25) ranged from 16-23% with the lowest value in the 2008 post-harvest season though not significant. The percentage of underweight women ranged from 5-10%, with the highest percentage in the 2007 pre-harvest season but the differences were not significant. Mean daily energy intake of the women was significantly different in both periods, with the

highest energy intake in Period 2 (2097 ± 151 kcal) and lowest in Period 1 (2039 ± 162 kcal).

Table 2.2. Nutrition status indicators, mean probability of adequacy, dietary diversity score and their association among women of reproductive age per season in Mbooni Division, Kenya[1].

	Period 1 2007 Pre-harvest (n=73)	**Period 2 2008 Post-harvest (n=203)**
Weight (kg)	56.2 ± 9.5	56.6 ± 8.4
Height (cm)	156.0 ± 4.7	157.4 ± 5.8
BMI (kg/m^2)[2]	23.0 ± 4.1	22.8 ± 3.7
Obese: BMI>25 (%)	23.1	16.1
Underweight: BMI<18.5 (%)	5.0	9.7
Energy intake (kcal, SD) [3]	2039(±162)[a]	2097(±151)[b]
MPA	0.41±0.07 [a]	0.44±0.08 [b]
DDS	4.5±1.2 [a]	4.0±1.3 [b]
Correlation of MPA and DDS		
Unadjusted	0.40**	0.38**
Adjusted for energy intake	0.20**	0.22**

[1] Values are in means±SD unless stated otherwise, BMI body mass index (kg/m^2); DDS, dietary diversity score; MPA, mean probability of adequacy.
[2] Only for weight, height and BMI, Period 1: n=60, Period 2: n=62
[3] Geometric means (SD).
[ab] Values not sharing superscript in a row are significantly different, P<0.05
** correlation is significant (P<0.01)

Diet patterns

In both periods, almost all women consumed starchy staples (**Table 2.3**). However, hardly any or no woman consumed vitamin A rich fruits, eggs, organ meat or small fish. Less than 10% of the women in both periods consumed vitamin A-rich deep yellow/orange/red vegetables and foods from all other flesh foods and miscellaneous small animal protein. In Period 1, >65% women, consumed vitamin C-rich vegetables (90%), vitamin A-rich dark green vegetables (78%), all other fruits and vegetables (82%), dairy (73%), and legumes and nuts (69%). In Period 2, there was a small but significant increase in percentage of women consuming the food groups all dairy (75%) and vitamin C-rich fruits (36%), but there was a significant decrease in consumption of vitamin A-rich dark green leafy vegetables (59%) and all other fruits

and vegetables (48%). The consumption of vitamin C-rich vegetables in Period 2 was comparable to that in Period 1.

Table 2.3. Proportion of women of reproductive age consuming various food groups per period in Mbooni Division, Kenya[1]

Food groups	Period 1 2007 Pre-harvest (n=73)	Period 2 2008 Post-harvest (n=203)
All starchy staples	98.6 [a]	100.0 [a]
Vitamin C-rich vegetables	90.4[a]	84.7[a]
All other fruits and vegetables	82.1[a]	48.2[b]
Vitamin A-rich dark green leafy vegetables	78.1[a]	58.6[b]
All dairy	72.6[a]	75.4[a]
All legumes and nuts	68.5[a]	64.0[a]
Vitamin C-rich fruits	23.7[a]	36.4[b]
All other flesh foods and miscellaneous small animal protein	8.2[a]	5.4[a]
Vitamin A-rich deep yellow/orange/red vegetables	5.4[a]	0[b]
Vitamin A-rich fruits	0 [a]	0.5 [a]
Eggs	2.7 [a]	0.5 [a]
Organ meat	0 [a]	0 [a]
Small fish eaten whole with bones	0 [a]	0 [a]
Miscellaneous[2]	100.0 [a]	100.0 [a]

[1]Values in %

[2]Foods and drinks in this group contribute to energy intake but not to micronutrient intake. These included water, baking powder, fanta, coca cola, fat (cowboy, kasuku, kimbo, mallow, oil elianto, golden fry, rina, ufuta, blueband-margarine), tealeaves, white sugar, brown sugar, sugarcane, salt royco, cocoa powder, coffee powder and jam zenta red.

[ab]Proportions sharing superscript in a row are not significantly different $p<0.05$

Dietary diversity scores and micronutrient adequacy

The DDS decreased as the periods progressed, from 4.5 ± 1.2 in Period 1, to 4.0 ± 1.3 in Period 2 (**Table 2.2**). In general, the PAs of nutrients in Period 1 were significantly lower compared to those in Period 2 (**Table 2.4**), except for PA of vitamin C intake. The PA of vitamin B_{12}, calcium, riboflavin and folate intake were below 10% in both periods. The PA of iron, thiamin, zinc, vitamin B6 and vitamin C intake were over 70% in periods 1 and 2. The MPA was significantly lower in Period 1 (41%) compared to Period 2 (44%), see **Table 2.2**. DDS and PAs were significantly correlated in all periods (range r=0.20 – 0.50), with higher correlations in Period 1 for 7 out of 11 nutrients. After adjusting for energy, the correlations (range r=0.01 to 0.30) decreased and remained significant for only some of the nutrients (**Table 2.4**). MPA was significantly correlated with DDS in both periods and correlations reduced after adjusting for energy intake but remained significant (**Table 2.2**).

Table 2.4. Probability of adequacy of intake of 11 micronutrients and their association with DDS of 13 food groups among women of reproductive age in Mbooni Division, Kenya.

Nutrients	Period 1 (n=73) 2007 Pre-harvest			Period 2 (n=203) 2008 Post-harvest		
	correlations		% PA	correlations		% PA
	Spearman	Partial[1]		Spearman	Partial[1]	
Iron (mg)	0.32**	0.13	77.1[a]	0.28**	0.07	80.4[b]
Zinc (mg)	0.37**	0.30**	70.7[a]	0.31**	0.09	76.8[b]
Vitamin C (mg)	0.50**	0.26**	98.5[a]	0.39**	0.24**	90.9[b]
Vitamin A(µg)	0.34**	0.04*	11.7[a]	0.42**	0.18**	17.4[a]
Calcium (mg)	0.39**	-0.01	0.07[a]	0.32**	-0.05	0.22[a]
Thiamin (mg)	0.29**	0.16	99.9[a]	0.34**	0.06	99.9[a]
Riboflavin (mg)	0.50**	0.02	5.1[a]	0.20**	-0.13*	9.8[b]
Niacin (mg)	0.27**	-0.11	14.2[a]	0.33**	0.08	18.9[b]
Vitamin B_6 (µg)	0.32**	0.12	75.9[a]	0.33**	0.15**	84.4[b]
Vitamin B_{12} (µg)	0.46**	0.27**	0.0	0.28**	0.08	0.0
Folate (µg)	0.41**	-0.10	0.01	0.23**	-0.09	0.14

*Correlation is significant at the 0.05 level (1-tailed);** Correlation is significant at the 0.01 level (1-tailed)

[1] All partial corelations were adjusted for energy intakes. PA, probability of adequacy

[ab]Proportions sharing superscript in a row are not significantly different p<0.05

Table 2.5. Season as determinant of MPA in the diets of women of reproductive age in Mbooni Division, Kenya[1]

Interacting Variables	Unstandardized β	Coefficient Standard Error	Standardised coefficient β	P-value
Model without interaction between Period and DDS[§]				
Period 2	-0.01	0.01	0.03	0.40
DDS	0.01	0.00	0.14	0.00
Energy	0.00	0.00	0.74	0.00
Model with interaction between Period and DDS[§]				
Period 2	-0.01	0.03	-0.07	0.62
Period 2* DDS[a]	0.00	0.01	0.11	0.45
DDS	0.01	0.01	-0.09	0.22
Energy	0.00	0.00	0.74	0.00

[1] Dependent variable MPA, mean probability of adequacy. DDS, Dietary diversity score based on 13 food groups. Period 1 (2007 pre-harvest), Period 2 (2008 post-harvest) [a] Period 2 interaction with DDS.

[§]R square change from 0.637 (model with no dummy) and 0.638(model with dummy).

Table 2.5 shows that period does not modify the association between DDS and MPA. **Table 2.6** shows sensitivity and specificity analysis evaluating the performance of DDS to detect low MPA defined as being ≤40% in Periods 1 and 2.

In both periods, the Youden index indicated a cut-off for DDS ≤4. However, sensitivity was low and total misclassification was relatively high in both periods (**Table 2.6)**.

Table 2.6 Sensitivity and specificity analysis evaluating dietary diversity scores for detecting low MPA (≤40%) among women of reproductive age in Mbooni Division, Kenya

DDS	Sensitivity (%)	Specificity (%)	False positive (%)	False negative (%)	Positive predictive value (%)	Total misclassi-fication (%)
Ability to detect low MPA (MPA≤0.40)						
Period 1						
≤2 (3)[1]	10	100	0	90	100	39
≤3 (14)	33	90	10	67	71	35
≤4 (31)	68	72	28	33	65	32
≤5 (57)	90	23	77	10	47	48
≤6 (67)	100	5	95	0	45	54
Period 2						
≤2 (22)[1]	23	93	7	77	59	28
≤3 (64)	61	78	22	39	55	27
≤4 (124)	86	43	57	14	40	44
≤5 (161)	97	19	81	4	34	57
≤6 (185)	100	2	98	0	31	68

DDS, dietary diversity score; MPA, mean probability of adequacy; Period 1 (2007 post-harvest), Period 2 (2008 pre-harvest) .
[1]Numbers in parenthesis are number of women.

Discussion

This is one of the first studies to examine how season affects dietary diversity, nutrient adequacy and their association. Consistent with findings from other studies from developing countries, the diversity of diets of the women in our study was limited and mainly based on starchy staples with little or no animal source foods [50,51]. Overall nutrient intake of the women was low, as seen from the low mean probability of intake adequacy of the 11 micronutrients considered in the two periods. This is also comparable with results from other studies of women's diets in Africa [23,52-54].

Earlier studies showed fluctuations of energy (and protein) intake and bodyweights due to seasonality in developing countries. Our results also showed that the energy intake of women in the 2008 post-harvest (Period 2) was higher than the 2007 pre-harvest

(Period 1), but the difference is small (~60 kcal) and was not reflected in changes in BMI. The absence of a difference in energy intake and bodyweight might have been due to the onset of post-election violence in Kenya in December 2007. The post-election violence resulted in limited safety and reduced mobility affecting the availability of food in the markets resulting in a sudden increase in food prices. A state of emergency was declared, and people could not engage in their normal daily livelihood activities, as they were not allowed to leave their homes. This affected the resources available and ability to store food after the short rains and to prepare and sow farming land for the 2008 harvest [55-57], impacting household's resilience to revert to normal consumption in the post-harvest season.

Women in our study continued to consume starchy staples irrespective of season, but an overall increased consumption of (dark green) leafy vegetables, vitamin A-rich vegetables and other fruits was observed in the pre-harvest season. In West Africa, however, other seasonal changes were found. Savy et al. [23] showed that in the lean season many other free and cheap foods were available such as legumes, milk or fresh fish, although consumption of purchased foods like meat and oil reduced. Van Liere et al. [58] showed a higher consumption of pulses and of wild foods such as shea nuts and leafy vegetables in a period of food shortage. Consequently, the period of food shortage in both studies did not coincide with lower dietary diversity as was also shown in our study. Despite the reduction of DDS when progressing from pre- to post-harvest season, the MPA increased in an opposite direction with a high MPA in the post-harvest season. Our results may indicate that women in our study area coped by diversifying to non-conventional foods or reducing the amount of foods rather than consuming less food groups. However, the associations between dietary diversity and overall micronutrient adequacy remained significant in both seasons.

Our study does have some limitations. As noted, the data collection in Period 1 coincided with the elections in Kenya in 2007. Due to the post-election violence, we had to stop data collection. The resulting effect was a small sample size, restricting the statistical power of comparison of results from other periods. Limitations are also related to weaknesses inherent to the 24hr-recall. Despite precautions through training of interviewers, impromptu supervision to minimise reporting errors, proper calibration of instruments, random assignment of interviewers to reduce bias, some errors may have

inevitably occurred in recalling dietary intake leading to omission of foods (mainly fruits and snacks), in reporting intakes due to mistakes in recipes, dish ingredients and portion sizes [59]. Subject characteristics may have influenced data quality as obese women who comprised 25% of our study population may have intentionally or unintentionally underreported intakes [7,60]. However, we studied the presence of over- and under-reporting and found that none of the women were in these categories. The data on DDS, MPA and their association in the two seasons were treated as being independent yet they are not. We repeated the above analysis in the sub-group of women for which we had data in all seasons to verify whether such an assumption changed the conclusions. Sub-group analysis showed comparable results (data not shown). The largest source of error with 24hr-recall is the day-to-day variation in intakes. The effect of these errors were minimised in our study using statistical methods to account for intra-individual variation in nutrient intakes [40]. Nutrient variation within foods, food substitution errors, mistakes in applying yield factors and retention factors may have led to imperfections of the food composition data base compiled for this study from different sources [61]. A disadvantage of using the same 24hr-recall data set for calculating the DDS and MPA is that measurement errors may be correlated, leading to inflated associations. However, correlation coefficients between DDS and nutrition adequacy using independent measures in a study in Mali, were slightly lower but still significant [62]. Lastly, our study in general, showed low levels of micronutrient intake resulting in few women above high MPA cut-offs. Therefore, we could not define a cut-off point for DDS to indicate adequate micronutrient intake within our observed distribution [7].

Dichotomous indicators are useful tools to determine prevalence of a problem at population level. In our study, in Period 1 and 2, a DDS of 4 or less indicated inadequate micronutrient intake (MPA ≤40%). Arimond et al. [7] using a comparable standardized definition of MPA and DDS based on 13 food groups, found a best cut-off point for portion size restricted indicators ranging from four to six food groups (MPA cut-off of 0.50). However, arriving at an acceptable balance between sensitivity and specificity was difficult in our study, and the high percentage of false positives might inflate the cost of future interventions [63]. Also defining inadequacy should be treated with caution as there is a tendency to interpret those falling above the cut-off of inadequacy

as adequate. Obviously, having a DDS of more than 4 in our study would indicate an MPA of above 40%, which cannot reflect adequacy.

In this study, we found that women's dietary diversity and probability of adequacy is sensitive to seasonal fluctuations, but the association between dietary diversity and MPA is not affected by season. Hence, dietary diversity may be used as a proxy for micronutrient inadequacy of women throughout the year, with variations in the strength of the association as seasons progress. In our study area, the difference between the post- and pre-harvest seasons is not very large. Changes in BMI and weight of women often reflect seasonal changes, with up to 1.0-2.5 kg lower bodyweights in lean seasons [64-66]. We did not find a significant difference in average BMI and weight between seasons. Although we identified a general reduction of number of women consuming food groups in the post-harvest season, this was not reflected in a meaningful difference in energy intake between seasons. Women's physical activities, being a major contributor to seasonal weight changes in Burkina Faso [23], may also fluctuate less in our study area because of low agricultural load since land sizes are small [67,68]. The resulting absence of large differences between seasons might have weakened our study's ability to detect an effect of seasonality on the association between DDS and MPA. Findings should be confirmed in studies with a larger seasonal contrast in BMI and weight of women. Also, more research is needed to come to a firm cut-off point for creation of a dichotomous indicator of adequate intake.

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Chapter 3

Effect of qualitative and quantitative food data collection methods on the association between dietary diversity and nutrient adequacy among rural Kenyan women.

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(Submitted for publication)

Abstract

Background: There is ample evidence that simple dietary diversity scores are associated with micronutrient adequacy of women's diets. However, the observed associations may be inflated due to correlated measurement errors, as most studies derive both indicators from the same data. This study aimed at comparing dietary diversity scores (DDS: 13 food groups) formulated from a qualitative free-listing 24hr-recall (DDSql) and a quantitative 24hr-recall (DDSqn) in rural Kenyan women and their association with mean probability of adequacy (MPA) based on the same quantitative 24hr-recall.

Methods: Qualitative 24hr-recall was administered at the start of the study followed by the quantitative 24hr-recall within the same week, in the pre- (n=68) and post-harvest (n=132) season. Correlation and Bland-Altman plot analysis, intraclass correlation coefficients, κ statistics and sensitivity/specificity analysis were used to determine the level of agreement between the two dietary diversity scores and their association with MPA.

Results: DDSqn and DDSql showed little agreement with a mean difference (DDSqn-DDSql) of -0.51±1.46 (Period 1) and -0.58±1.43 (Period 2), indicating systematic over-reporting by qualitative free-listing 24hr-recall. In both periods, the correlations between MPA and DDS were lower for DDSql (r=0.14 and 0.19 in Period 1 and 2, $p>0.05$) compared to DDSqn (0.40 and 0.54 in Period 1 and 2, $p<0.01$).

Conclusion: A dietary diversity score formulated based on a qualitative free-listing 24hr-recall is a poor indicator of probability of nutrient adequacy of women's diets in poorresource settings, and needs further refinement to improve its performance to assess women's nutrient adequacy in large-scale surveys.

Introduction

Estimated prevalences of micronutrient deficiencies remain persistently high and of public health concern (1, 2), representing a leading contributor to the global disease burden in sub-Saharan Africa (3). As the consequences especially affect women of reproductive age (4), improving the quality of their diets to obtain adequate amounts of vitamins and minerals is essential (5). Several studies have indicated the usefulness of simple dietary diversity indicators as proxies of micronutrient intake and adequacy among women (2, 3, 5, 6). Especially the Women's Dietary Diversity Project (WDDP) provided evidence that dietary diversity indicators irrespective of food group disaggregation predict micronutrient adequacy of the diets of women with stronger associations when a minimum intake cut-off is applied (2).

In order to validate one measurement instrument against another, measures should be independent, with information collected from two different points in time (7). In most studies and also in the WDDP the same data collection tool was used to assess nutrient intake and to create dietary diversity scores. Measurement errors in both indicators will therefore be correlated, which could have led to inflated correlations leading to inaccurate conclusions (6, 8). To our knowledge, only one study in Mali compared the association of nutrient adequacy with dietary diversity when derived from the same or independent data collection tools. Correlation coefficients ranged from r=0.28 to 0.53 when both indicators were derived from the same data collection tool, but reduced to r=0.24 to 0.36 when derived from independent tools while staying significant (9). Data collection tools used were the food frequency questionnaire (FFQ) and the weighed record, and the obvious differences in the inherent bias presented by both tools, might have influenced the outcome of the study.

Most studies have used quantitative (multiple) 24hr-recall data to assess a dietary diversity score and nutrient adequacy (6, 10-12). The quantitative 24hr-recall will not be suitable for large-scale population surveys as the application of this method is costly, time-consuming, laborious, involves complex data analysis and needs highly skilled personnel. An alternative option is to collect information on dietary diversity through qualitative recalls. However, Martin-Prevel et al. (2010) compared dietary diversity indicators derived from simple qualitative list-based recalls to the same indicators from

quantitative recalls (13). The study showed little agreement between the two types of indicators with large under- and over-reporting, especially of nutrient-dense foods or foods used in small quantities. It was suggested that this misreporting could have lowered the power of dietary diversity based on qualitative list-based recalls to predict nutrient adequacy (5). Increasing the disaggregation of food groups and separating foods known to be consumed in small quantities may improve the performance but also the risk of misreporting and violates simplicity and easiness of data collection (5).

To overcome the limitations of a list-based approach, a qualitative free-listing recall method is suggested. In this method, the interviewer allows the respondent to recall freely and chronologically foods eaten the previous day with the aid of probing and records foods on a list instead of reading the list to the respondent (5, 14). Based on dietary data collected both through quantitative and qualitative free-listing 24hr-recall in two seasons, we examined differences between the two methods and compared the performance in predicting inadequate micronutrient intake in rural Kenyan women.

Material and methods

Study site and population selection

The study was conducted in the post-harvest season (Oct-Nov) of 2007 and the pre-harvest season of 2008 (May-July) at Mbooni division, Makueni district in Eastern Kenya. The district comprised of 16 divisions, 66 locations and 108 sub-locations. It is characterized as semi-arid to arid with low erratic rainfall, which on average is 500 mm annually. The district is prone to frequent droughts and food shortages (15) and mainly subsistence farming is practised. The data used for this survey was obtained in 2 distinct seasonal periods: three repeated 24hr-recalls in October-December 2007 (Period 1, post-harvest) and in April-June 2008 (Period 2, pre-harvest). The seasons of the survey were chosen on the basis of agricultural food circles, with pre-harvest being the period before harvest when there is lack of food while post-harvest refers to the period when the community has an abundance of food after harvest. Kyuu sub-location (having 14 villages) was randomly selected for the survey. In each village 15 households were selected by the random walk method (16) and in each household one woman of reproductive age (15-49 years) having a child aged 2-5 year was selected. In a homestead, where more eligible women were available, only one woman was randomly selected. Additional inclusion criteria were: apparently healthy, no chronic illness, no

known HIV/Aids, not anorexic and not on medication. On obtaining a verbal informed consent from the woman, an appointment for the survey was set. Food consumption data using both qualitative free-listing recall and quantitative recall was obtained from 68 women (from 5 villages) in the 2007 pre-harvest season and from 132 other women (residing in 9 other villages) in the 2008 post-harvest season.

Data collection.

In both seasons, food consumption data was obtained by use of a 3 day non-consecutive quantitative 24hr-recall (DDSqn) method (17) and a single qualitative free-listing 24hr-recall (DDSql) method (14), carried out by well-trained interviewers. The qualitative free-listing 24hr-recall was administered at the onset of the study in both periods, 1 week before the quantitative 24hr-recall in the same women. The repeated quantitative recalls were administered 2-11 days apart from the first recall with all week days represented, except for Saturday due to unavailability of households on Sunday. Interviewers were randomly allocated to recording days in order to avoid repeated household visits by the same interviewer.

In the quantitative recall, food consumption data was collected using the multi-pass method (16, 18). The women were asked to mention all the foods and beverages they had eaten during the preceding 24-hours (from the time they woke up the preceding day to the time they woke up the interview day), including anything consumed outside of the home. They were then requested to describe the foods and beverages consumed, including ingredients and cooking methods of mixed dishes. Amounts of all foods, beverages and ingredients of mixed dishes consumed were in order of preferences estimated: through weighing replicas using a Soehnle electronic kitchen scale (Plateau Art, Germany, Model number 65086, maximum weight 10 kg, to the nearest 2 g (0.1 oz)), in household units, size, volume and monetary value. The total volume of food cooked at the respondents' household and the volume of food consumed by the respondents were measured to determine proportions consumed. The resulting fraction was then multiplied by the total amount of ingredients used in the dish to arrive at the amount consumed by the woman. Standard recipes were developed to take care of all foods consumed outside the home. Conversion factors from household units, size, volume and monetary values to weight equivalent were determined.

The qualitative free-listing 24hr-recall questionnaire consisted of a list of foods categorized per food group including local/indigenous foods particularly used in the region. A trained interviewer asked the women to recall all foods, ingredients and beverages they ate or drank the previous day and night, whether at home or outside. The responses were ticked by the interviewer according to the corresponding food and food group category.

Calculation of DDSqn and DDSql

The DDSql was calculated as the total sum of food groups consumed. The food groups comprised: cereals; white roots and tubers; vitamin A-rich vegetables and tubers; dark green leafy vegetables; other vegetables; vitamin A-rich fruits; other fruits; organ meat; flesh meat; eggs; fish and seafoods; legumes, nuts and seeds; milk and milk products (19). No minimum intake required for a food group to count was applied.

The DDSqn was calculated from the first recall of the 3 non-consecutive 24hr-recalls, based on the same 13 food groups (6) with no food quantity consumption restriction. Every food group consumed in the previous 24 hours, received a score of 1 (irrespective of number or portion size of food items eaten from the same group). The total food score was summed over all food groups to arrive at the DDSqn for each individual.

Computation of micronutrient intake and adequacy of intake

Nutrient intake calculations were based on a food composition table developed specifically for the study, using the national food composition table of Kenya (20) complemented with nutrient values of 5 other food databases (21-25) when foods or nutrients were missing in the Kenya table. USDA retention factors release 6 (26) were applied to raw ingredients and foods to account for nutrient losses during food preparation. Retinol and β-carotene were converted into retinol activity equivalents (RAE) using the IVACG conversion factors (27).

Nutrient intakes were calculated using VBS software version 4 (Bas Nutrition Software, Arnhem, the Netherlands). Intake of energy and the following micronutrients were assessed: iron, zinc, calcium, vitamin C, vitamin A (RAE), vitamin B6 , vitamin B12 , folate, riboflavin, niacin and thiamine, being key micronutrients for women's health (5). Vitamin C was included, because of its role in enhancing the absorption of non-haem

iron (28). All nutrient intakes obtained from the quantitative 24hr-recall (per period) were adjusted for within-person variation using the National Research Council (NRC) adjustment procedure to arrive at the usual intake (29, 30).

The probability of adequate nutrient intake (PA) was calculated for vitamins A (RAE), C, B12, B6, riboflavin, niacin, thiamine, folate, zinc and calcium using their respective estimated average requirements (EARs) and distributions (31-33). The distribution of iron requirement is skewed, so probability of adequacy values derived by the Institute of Medicine (33) were used, but adjusted for 5% bioavailability to reflect the inhibitory nature of the predominantly cereal-based diet in the study area. Similarly, the EAR for zinc was adjusted for low (15%) bioavailability (34). Mean probability of adequacy (MPA), a summary measure of micronutrient adequacy, was computed from PAs of all 11 micronutrients reported in this paper (35).

Statistical Analysis.

All statistical analyses were done using PASW 19 for Windows (IBM SPSS Statistics 19, SPSS Inc., Chicago). All data was visually checked and tested for normality using the Shapiro-Wilk test. Most of the intake data came to near normality after log10 transformation. Mean DDSqn and DDSql were compared using the paired sample t-test. The proportion of women consuming the different food groups using both methods was compared by McNemar's test. Scatter plots were drawn to show the association between DDSqn and DDSql. Spearman's rank correlation between DDSqn, DDSql and PA (MPA) were used to assess associations.

Bland-Altman plot analysis was used to assess the level of agreement between the indicators, by plotting the differences between the DDSqn and DDSql, against their mean (36, 37). For comparable measurements, differences should be centered around zero and show no systematic variation according to the mean of the measurement pairs (38). Intraclass correlation coefficients (ICC) and κ statistics were used to assess agreement between DDSqn and DDSql (39). As a rule of thumb, κ values of at least 0.6 were required to claim a satisfactory level of agreement (40, 41). Discrepancies in reporting the foodgroups by DDSql were described, using DDSqn as the reference method.

The performance of DDSql and DDSqn using sensitivity/specificity analysis to predict the prevalence of low nutrient adequacy (defined as MPA≤ 0.40) was determined. The Receiver Operating Characteristic (ROC) analysis was used to determine the area under the curve (AUC) for each period. Low MPA was defined based on ROC analysis showing the highest AUC. AUC values were tested whether different from 0.50. The best DDS cut-off for maximising sensitivity/specificity was determined using the Youden index (42, 43). Sensitivity/specificity analyses reflected the full extent of misclassification and also investigated the proportions of all women who would be classified as 'false positives' and 'false negatives', and the 'positive predictive value' reflecting the true likelihood of having low MPA among those who were true positive. For all statistical tests we considered values of $p<0.05$ to be statistically significant (44).

Results

Mean age of the women in Period 1 and 2 was 33.6±8.1 years and 35.4±8.7 years respectively (**Table 3.1**). The mean BMI of the women ranged between 23 – 25 kg/m^2 with about a quarter being obese (BMI> 25kg/m^2) in both periods. As expected, the mean energy intake of the women was slightly but significantly lower (1960 ±380 kcal) in Period 1 compared to 2090 (±22) kcal in Period 2. DDSql was not significantly different from DDSqn in Period 1 (5.2±1.2 versus 5.2±1.2), while in Period 2 DDSql was significantly higher than DDSqn (4.7±1.3 versus 4.3±1.4 in Period 2, $p<0.05$).

DDSqn and DDSql were significantly but weakly correlated at $r=0.25$ in Period 1 and $r=0.31$ in Period 2 ($p<0.05$). The MPA was significantly lower in Period 1 (0.41±0.1) compared to Period 2 (0.43±0.1). In both periods, the correlations between MPA and DDS were lower for DDSql ($r=0.14$ and 0.19 in Period 1 and 2, $p>0.05$) compared to DDSqn (0.40 and 0.54 in Period 1 and 2, $p<0.01$).

For both DDS indicators, 50% or more of the women consumed cereals, other vegetables, legumes and nuts, milk and milk products and dark green leafy vegetables in both periods (**Table 3.2**). The proportion of women consuming milk and milk products and other fruits (both periods), and dark green leafy vegetables and vitamin A-rich vegetables and tubers (Period 2) is higher and consumption of white roots and tubers (Period 1) and other vegetables is lower (Period 2) for DDSql compared to DDSqn.

Hardly any women consumed eggs, vitamin A-rich fruits, organ meats, flesh meats and small fish eaten whole with bones.

Table 3.1. Nutrition status indicators, mean probability of adequacy, the dietary diversity score and their association among women of reproductive age per period in Mbooni Division, Kenya[f].

Demography	Period 1 2007 Pre-harvest (n=68)	Period 2 2008 Post-harvest (n=132)
Age (in years)[z]	33.6±8.1	35.4±8.7
Weight (kg)[z]	56.9 ± 10.0	56.3 ± 11.2
Height (cm)[z]	154.6 ± 13.2	157.5 ± 6.3
BMI (kg/m^2)[z]	25.4 ± 16.9	22.6 ± 4.1
BMI>25 (%)	27.7	23.9
BMI<18.5 (%)	4.6	12.0
Energy intake (kcal, SD)[y]	1960(±380)[a]	2090(±22)[b]
DDSqn	5.18[a]±1.2	4.28[b]±1.4
DDSql	5.19[a]±1.2	4.68[b]±1.3
MPA	0.41[a]±0.1	0.43[b]±0.1
Spearman correlation with MPA DDSqn		
DDSql	0.40[x]	0.54[x]
	0.14	0.19

[f]Values are in means±SD unless stated otherwise. [y]Geometric mean (SD).
[x]Correlation is significant at the 0.01 level (1-tailed).
[ab]Values with shared superscript in a row are not significantly different (p<0.05).
[z]Period 1, n=73 and Period 2, n=134.
DDSqn, Quantitative 24hr-recall, n=68; DDSql, Qualitative 24hr-recall, n=132, PA, probability of adequacy; MPA, mean (PA).

Table 3.2. Proportion of women (of reproductive age), who consumed various food group categories in two periods in Mbooni Division, Kenya

Food groups	Period 1 Pre-harvest season (2007)		Period 2 Post-harvest season (2008)	
	DDSqn,% (n=68)	DDSql,% (n=68)	DDSqn,% (n=132)	DDSql,% (n=132)
Cereals	98.5	100	99.2	100
Other vegetables	92.6	97.1	83.3[a]	74.2[b]
Legumes and nuts	70.6	70.6	62.1	65.2
Milk and milk products	70.6[a]	80.9[b]	75.0[a]	83.3[b]
Dark green leafy vegetables	77.9	88.2	48.5[a]	78.0[b]
White roots and tubers	29.4 [a]	14.7 [b]	22.0	20.5
Other fruits	10.3[a]	47.1[b]	14.4[a]	32.6[b]
Vitamin A-rich vegetables and tubers	5.9	8.8	0[a]	4.5[b]
Flesh meat	8.8	8.8	4.5	4.5
Eggs	2.9	1.5	0.8	0
Vitamin A-rich fruits	0	1.5	0	3.0
Organ meat	0	0	0	1.5
Small fish eaten whole with bones	0	0	0	0

[ab]Values sharing superscript in a row are not significantly different p<0.05
DDSqn, Quantitative 24hr-recall; DDSql, Qualitative 24hr-recall

Table 3.3 indicates that using the DDSql, women reported to have consumed 0.5 and 0.6 more food groups compared to DDSqn in Period 1 and 2, respectively. **Figure 1** shows the distribution of food groups, which are over- and under-reported by DDSql against DDSqn in Period 1 and Period 2. Most misreported food groups were legumes and nuts, other fruits, dark green leafy vegetables, white roots and tubers, and dairy (milk and milk products).

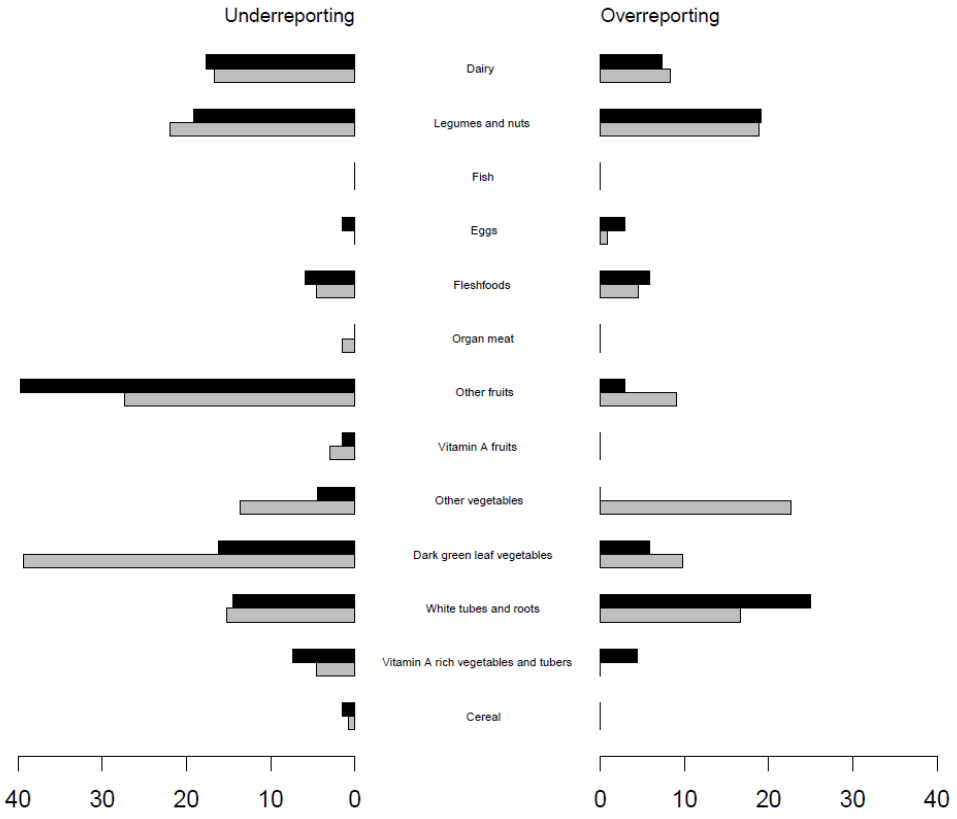

Figure 1. Proportion of women who over- and under-reported food groups in Period 1 and 2**.**
Legend: Black ; Period 1 , Grey; Period 2

In Period 1, 44.1% of the women and in Period 2 55.3% of the women over-reported food groups in DDSql compared to DDSqn. Under-reporting was done by 19.1% (Period 1) and 20% (Period 2) of women in DDSql compared to DDSqn (Figure 2 A, B). The Bland-Altman plots (**Figure 2** C,D) show that the limit of agreement between the two DDS indicators is wide in both periods and that the mean differences between the indicators do not depend on the level of the dietary diversity score.

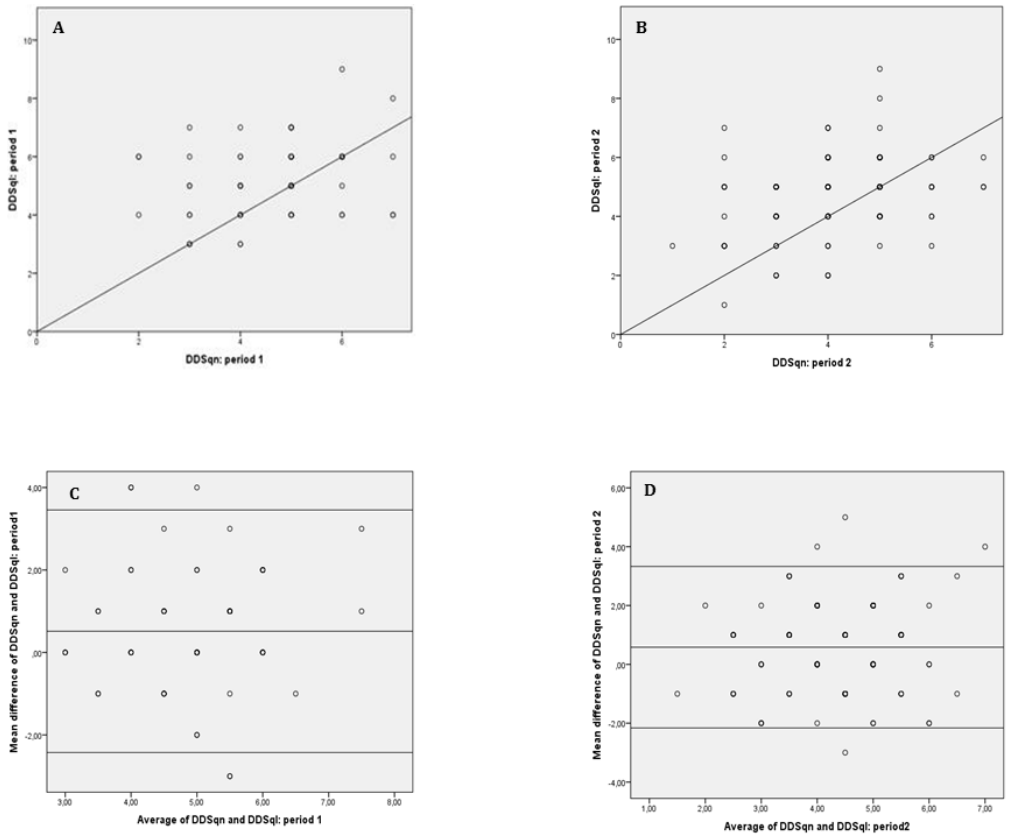

Figure 2. Distribution of DDSqn against DDSql (A, B) and the mean difference against the average of DDsqn and DDSql in (C, D) in Period 1 (A, C) and Period 2 (B, D), among women of childbearing age, Mbooni district, Kenya.

The intraclass correlation coefficient (ICC) values are low at 0.42 and 0.46 in Period 1 and 2, respectively. None of the κ statistics reached the value of 0.6, showing that the 2 indicators are different (**Table 3.3**).

Table 3.3. Actual differences between women's dietary diversity scores based on quantitative 24hr-recall or qualitative 24hr-recall in Mbooni district, Kenya

Season	DDSqn-DDSql				
	Mean	SD	p[1]	ICC[2]	κ statistics simple
Period 1	-0.51	1.46	0.01	0.42	0.19
Period 2	-0.58	1.43	0.00	0.46	-0.02

[1] paired sample t-test ($p < 0.05$); [2]ICC: Intraclass correlation coefficient
DDSqn, Quantitative 24hr-recall; DDSql, Qualitative 24hr-recallPeriod 1: n=68 and Period 2: n=132.

Table 3.4 shows sensitivity and specificity analysis evaluating the performance of DDSqn and DDSql to detect low MPA defined as being ≤40%. The AUC ranged from 0.58 to 0.82 and was only significantly different from 0.5 for DDSqn in Period 1 and 2 showing low predictive power for DDSql in Period 1 and 2. In both periods, the Youden index indicated a cut-off for DDS ≤4 maximizing sensitivity and specificity. However, sensitivity was low and total misclassification was relatively high for both indicators in both periods.

Discussion

To our knowledge, this is the first study that compared dietary diversity indicators derived from a qualitative free-listing 24hr-recall tp a quantitative 24hr-recall and their association with mean probability of nutrient adequacy. Our study found that, contrary to the quantitative indicator, the qualitative dietary diversity score is a poor indicator of the mean probability of nutrient adequacy of women's diets. The avoidance of correlated measurement errors by using two independent data collection tools resulted in a reduced association of the qualitative dietary diversity score with nutrient adequacy. In addition, the qualitative dietary diversity score underreported food groups compared to

Table 3.4. Sensitivity and specificity analysis evaluating dietary diversity scores based on Quantitative 24hr-recall or Qualitative 24hr-recall for detecting low MPA (≤40%)[1] per period among women of reproductive age, Mbooni District, Kenya

DDS	Sensitivity (%)	Specificity (%)	False positive (%)	False negative (%)	Positive predictive value (%)	Total misclassification
Period 1: Pre-harvest season						
Ability to detect low MPA (MPA≤0.40) (AUC = 0.75)						
DDSqn						
≤2 (3)	10	100	0	90	100	39
≤3 4)	13	100	0	87	100	38
≤4 (16)	37	87	13	63	69	35
≤5 (39)	80	62	39	20	62	30
≤6 (64)	100	13	87	0	47	49
≤7 (69)	100	0	100	0	44	57
Ability to detect low MPA (MPA≤0.40)(AUC = 0.58)						
DDSql						
≤2 (0)	0	100	0	100	0	43
≤3 (5)	10	95	5	90	60	42
≤4 (22)	40	74	26	60	55	41
≤5 (42)	68	44	56	33	48	46
≤6 (62)	93	13	87	8	45	52
≤7 (67)	100	5	95	0	45	54
≤8 (68)	100	3	97	0	44	55
Period 2:Post-harvest season						
Ability to detect low MPA (MPA≤0.40) (AUC = 0.82)						
DDSqn						
≤2 (17)	25	92	8	75	59	30
≤3 (35)	58	86	14	43	66	23
≤4 (63)	88	67	33	13	56	27
≤5 (96)	100	33	67	0	42	45
≤6 (119)	100	6	94	0	34	64
≤7 (122)	100	2	98	0	33	66
Ability to detect low MPA (MPA≤0.40) (AUC = 0.60)						
DDSql						
≤2 (7)	10	96	4	90	57	31
≤3 (17)	20	89	11	80	47	33
≤4 (52)	48	61	39	53	37	44
≤5 (91)	88	33	67	13	39	49
≤6 (118)	95	5	95	5	32	66
≤7 (122)	100	2	98	0	34	66
≤8 (123)	100	1	99	0	33	67

MPA, mean probability of adequacy. AUC: Area under the curve

[1]Numbers in parenthesis are the number of women having a dietary diversity score below the given cut-off point.

DDSqn, Quantitative 24hr-recall; DDSql, Qualitative 24hr-recall

the quantitative dietary diversity score leading to a further weakening of performance of the qualitative dietary diversity score to predict the probability of nutrient adequacy.

Both the qualitative and quantitative DDS were calculated based on food consumption data of a single day. Savy et al. (2007) showed in a study among Burkinabe women, that the DDS increased with increasing recall days, but that more recall days were prone to memory bias (45). A single-day DDS is therefore assumed to be adequate to assess dietary patterns at the population level (45, 46).

To avoid dependency of data leading to correlated measurement errors, we separated data collection for the qualitative DDS from that of the quantitative DDS, with the qualitative study taking place 1 week prior to the quantitative study, on different days. Resulting intra-individual variation in intake across days might have attenuated measures of association of the two DDS indicators (47). A difference of one week between data collection was considered short enough to avoid changes in food consumption, as the variation in foods is generally poor in the study area (48), and to avoid effects of seasonality. The qualitative free recall took place before the quantitative recall introducing the possibility of systematic over-estimating of food intake data in the quantitative recall due to the effect of learnt responses (48). However, we think a period of 1 week between the two data collection session is sufficient to avoid respondents recalling what was asked previously (49).

Both the qualitative and the quantitative DDS were calculated with no restriction on the minimum amount of food consumed as to keep data collection simple. Studies have shown that the diversity scores are stronger associated with nutrient adequacy when consumption of trivial amounts (<15 g) of a food group did not count in the scores (17, 50). Including foods that are only eaten in small quantities might have weakened the associations observed in our study. However, including assessment of quantities consumed would be more difficult to operationalize and would go against the need for a simple tool that can be used in large surveys.

The DDS in our study was calculated based on 13 food groups. Studies have shown that further disaggregation of food groups leads to better associations with nutrient adequacy (5). Our study population, however, consumed a limited number of foods (56 foods) and hardly any women consumed 9 food groups. Only 2% of the women

consumed 8 food groups or more, and most of the women had a dietary diversity score of less than 6. Further disaggregation beyond 13 food groups was therefore not considered to be useful in the context of our study. The study population in general had a low mean probability of nutrient adequacy and none of the women had an mean probability of nutrient adequacy greater than 0.70. The general lack of food variety and low adequacy of nutrient intake in this community could have contributed to the limited ability to show strong associations. It might not be possible to generalise the level of associations observed in such disadvantaged populations to those with a full distribution of the dietary diversity score and adequacy of intake, making our found associations context-specific.

Our study shows that the quantitative DDS was but the qualitative DDS was not associated with the mean probability of adequacy of intake of Kenyan women. The correlation of the quantitative DDS and MPA (0.40 and 0.54 in Period 1 and 2, respectively) was within the range of correlations of 0.2-0.6 found in other studies (47, 51). However, the association of the qualitative DDS and MPA was much lower (0.14 and 0.19 in Period 1 and 2, respectively) and was not significant.

One of the main reasons for the low agreement between the qualitative and quantitative DDS and their association with nutrient adequacy may be the likelihood of misreporting in the qualitative recall. Misreporting of food groups was high in the qualitative recall as compared to the quantitative recall, mostly concerning the consumption of dairy (milk and milk products), dark green leafy vegetables, other fruits and white roots and tubers. This misreporting could be intentionally or unintentionally. Intentional misreporting happens when food is being eaten but deliberately not reported, or food is not eaten but deliberately reported, often with hypothesized reasons related to perceived cultural norms (52) or trying to convey a better image (53). The unintentional misreporting happens when food being eaten is genuinely forgotten (for example foods that are infrequently consumed or in small quantities), or when foods are 'normally' or frequently consumed but, by chance, not during the recall day. This misreporting may be due to, for example, poor memory, poor attention, illness, irregular eating patterns, effects of being observed, and is often beyond the control of the respondent (54). The reasons for misreporting in the qualitative free-listing 24hr-recall in our study are not known, however, inquiring about the amounts of foods consumed by the respondent

might have reduced the possibility and extent of misreporting as it represents a way of confirming whether food is actually consumed. The misreporting in the qualitative free-listing 24hr-recall assessed in our study is relative to the quantitative 24hr recall. We do not know to what extent the quantitative recall is inducing misreporting compared to the actual intake.

The absence of a strong association of a dietary diversity score with nutrient adequacy when a qualitative free-listing 24hr-recall is used (as often done in large-scale studies), indicates the necessity to further refine the dietary diversity score. There are several suggestions that could improve the performance of the dietary diversity score to predict nutrient adequacy. First, the dietary diversity score could focus on those (nutrient-dense) foods in a food group that contribute most to nutrient intake or variation in nutrient intake. Consuming those foods would make a difference in reaching nutrient adequacy, and as such would avoid the inclusion of foods in the score that do not or hardly contribute to nutrient intake. However, these foods are context-specific and hamper universality of the developed dietary diversity score. In addition, too much disaggregation of food groups might increase misreporting (55).

Secondly, a simple way to exclude foods that are consumed in small quantities should be found. Some studies suggest to use domestic or local measuring units, taking into consideration eating habits (56). It has also been argued that more research is needed to accurately determine whether exclusion of small amounts of foods consumed would not compromise the precision of the indicator score (55).

Thirdly, assigning weights to food groups to count in the dietary diversity score or taking into account frequency of consumption could improve performance of the indicator. Concerning dietary diversity indicators of household-level food security, results on the effect of weighting systems are contradictory: some studies do show a better prediction of availability of dietary energy at the household level (57), others show no improvement in correlations with calorie consumption per capita (58), in classification of households being food-insecure (59). However, not much research has been done on the effect of including weighting or frequency of consumption on the performance of individual dietary diversity scores. In addition, the accruing advantages of incorporating frequency into the indicator should, however, be balanced against

additional survey requirements, as this implies additional burden in data collection and analysis both at the side of enumerators and respondents (15, 55).

The performance of a qualitative free 24hr-recall in predicting mean probability of adequacy was poor. However, its limitations can be overcome by inclusion of nutrient-dense foods, or including portion sizes or frequency, but more research needs to be done to study whether these modifications will result in improved associations with dietary nutrient adequacy. Such studies would support the development of a simple tool that can be used in large-scale studies. Results from the study analysis would inform policy makers on timely action to take, especially towards strategies to improve the micronutrient adequacy of women's diets.

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Chapter 4

Performance of informative food-based compared to food group-based dietary diversity scores to predict micronutrient adequacy among rural Kenyan women.

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(under preparation for submission)

Abstract

Background: The food group-based dietary diversity score is a good proxy for adequacy of micronutrient intake for women. However, found associations are moderate and limiting the score construction to informative foods may improve performance. The objective of this study is to compare the performance of informative food -based with food group-based dietary diversity scores to predict micronutrient adequacy of diets of women of reproductive age in Mbooni District, Kenya.

Methods: Repeated non-consecutive 24hr-recalls were collected during pre-harvest (Period 1, Oct 2007, n=73) and post-harvest (Period 2, April 2008, n=203) seasons. Mean probability of adequacy (MPA) was calculated for 11 micronutrients. A dietary diversity score (DDS) was constructed based on 13 food groups with a minimum intake threshold per food group of 15 g. Six diversity indicators were constructed based on informative foods selected on the contribution to intake and to variance of intake of micronutrients. Correlation analysis tested associations between the dietary diversity scores and MPA, and Steigers' equation was used to test differences in performance between the dietary diversity indicators.

Results: Only 20 and 25 foods contributed to 90% of intake and explained 90% of variance of intake of selected micronutrients respectively. Correlation of the informative-food-based scores and MPA were moderately higher (r=0.54-0.59 in pre-harvest; r=0.37- 0.45 in post-harvest) than that of the foodgroup-based dietary diversity score (r=0.40 and 0.38 in Period 1 and 2) but differences were only significant in Period 1 and only when not adjusted for energy intake.

Conclusion: Informative food-based dietary diversity scores did not lead to an indicator that predicted nutrient adequacy better than the food group-based dietary diversity score, and therefore the latter should be preferred in large-scale studies.

Introduction

Micronutrient malnutrition is a widespread nutrition challenge faced by women in developing countries, having consequences not only for their own health but also for that of their offspring. One of the most important causes leading to micronutrient deficiency is a poor diet lacking diversity (1). Because of the costs and complexity of conventional quantitative dietary assessments, very little information on women's diet and micronutrient intake in developing countries is available. Dietary diversity scores (DDS) as developed by FANTA are proposed as proxy indicators of micronutrient intakes of women. Defined as a simple count of foods or food groups consumed over the past 24 hours, the indicator has been validated through a multi-country study and a strong association between DDS and the micronutrient adequacy of the diets of women was found (2). The indicator is now increasingly being used in large-scale studies like demographic health surveys and in impact assessments of nutrition-sensitive agriculture.

The correlations between the dietary diversity score and nutrient adequacy found in the multi-country study were rather moderate, ranging from r=0.21 to r=0.53, reducing to r=0.12-0.46 when adjusted for energy intake (2). To be useful as proxies to assess micronutrient intake at the population level in large-scale studies, there is a need for further efforts to improve the performance of the dietary diversity indicators to predict micronutrient adequacy of the diet of women. Applying a minimum amount required for a food group to count, improved the performance of the indicator, as the dietary diversity score with a 15 g minimum requirement performed consistently better than ones with a 1 g minimum requirement (2). However, operationalizing of such a minimum requirement is challenging and misreporting was shown to be much higher when applying the 15 g compared to the 1 g minimum requirement (3). Increasing the number of food groups in the score would likely improve the performance of the indicator, but results are not consistent across different studies (2, 3, 4) and too much disaggregation might increase misreporting especially for nutrient-dense foods (3).

Another option that may improve performance is limiting the score construction to informative foods. Current dietary diversity scores comprise food groups categorizing foods according to the type of food. These food groups may therefore comprise foods that do not or hardly contribute to nutrient intake, because they are not regularly

consumed, are consumed in small quantities or have a low nutrient profile. Consuming those foods would increase the DDS but not nutrient adequacy, weakening the association between the two. A focus on informative foods may potentially overcome this limitation. Informative foods are consumed regularly, contributing substantially to intake of nutrients of interest, and are able to rank individuals according to their intake, i.e. varying in use between persons (5, 6). Three different procedures can be used to select informative foods (6). A simple procedure identifies food items with a high nutrient content based on published food composition tables. However, this method may lead to a selection of foods that are consumed infrequently or in small quantities. A second procedure selects food on the basis of their percentage contribution to nutrient intake of a population (7). A third approach identifies foods based on the contribution to the variance of nutrient intake (8), a simplified alternative to forward regression, predicting the foods that explain most variance, taking the covariance between nutrient intakes of foods into account (5, 9). Molag et al. (2010) automated the selection of food items using the above procedures in a computer system with the aim to compile and process tailored food frequency questionnaires (9).

We used the above computer system to construct dietary diversity scores on the basis of informative foods selected on their contribution to micronutrient intake and to the variance of micronutrient intake. The aim of this study was to test the performance of these new indicators to predict adequacy of micronutrient intake compared to that of the conventional food group-based dietary diversity score, using food intake data of rural Kenyan women.

Materials and methods

Study site and sample selection

The study was conducted in pre-harvest 2007 (Oct-Nov) and post-harvest 2008 (Apr-Jun) seasons at Mbooni division, Makueni district, in Eastern Kenya. The Makueni district comprises of 16 divisions, 66 locations and 108 sub-locations. It is characterized as semi-arid to arid with low erratic rainfall, which on averages is 500 mm annually. The district is prone to frequent droughts and food shortages(10). Mbooni division (with 4 sub-locations) has a distinct seasonality and experiences two rainy seasons; long rains in March/April and short rains in November/December. Subsistence farming is practised with most crops harvested after the short rains. Kyuu sub-location (having 14 villages) was randomly selected for the survey.

In each village 15 households were randomly sampled using the random walk method (11). One non-pregnant, non-lactating woman of reproductive age with the youngest child between 2-5 years was selected from each household. When more eligible women were available (at a household), only one woman was randomly selected. When no eligible woman was available in the household, the next household was visited through the random walk method until 15 women were selected. Other inclusion criteria for the women were: apparently healthy, no chronic illness, no known HIV/Aids, not anorexic and not taking medication. Verbal informed consent was obtained from the subjects after a written consent form was read to them, and an appointment was made for the survey date. Due to the post-election violence in Kenya in 2007, data collection had to be stopped and only 73 women were selected for the first data collection round. For the second data collection round, 210 women were selected.

At the time of the study, there was no Institutional Review Board or Ethics Committee at the University of Nairobi. In consultation with the Ethics Committee at Wageningen University, The Netherlands, no other Ethical Review Board was consulted, as according to the Kenyan Government rules in 2007, the study was not entitled to ethical clearance as it did not involve feeding of participants nor withdrawing any bodily fluids. The study was registered with and approved by the Kenya Ministry of Education, Science and Technology. Verbal approval was obtained from the Mbooni District officials and the community authorities.

Data collection

Food intake data were collected through a repeated quantitative 24hr-recall carried out by well-trained interviewers. The first round of data collection took place during the short rains period in October-December 2007, characterised by food shortage just before the harvest starting from December onwards (referred to as Period 1, pre-harvest season). The second round took place in the long rains period in April-June 2008, when short rains harvest was still available and the long rains started (referred to as Period 2, post-harvest season). In both data collection rounds 3 repeated 24hr-recalls were carried out on non-consecutive days with 2-11 days apart. All days of the week were represented except for Saturday due to unavailability of households on Sunday. Women were randomly allocated to day of the week, interviewers were randomly allocated to households and repeated household visits by the same interviewer were avoided. The 24hr-recall was administered using the multiple-pass method (12). Women were asked to mention all foods and beverages consumed during the preceding 24 hours (from the time they woke up the preceding day, to the time they woke up the interview day), including anything consumed outside of the home. Next, they were requested to describe the foods and beverages consumed, including ingredients and cooking methods of mixed dishes. Duplicate amounts of all foods, beverages and ingredients of mixed dishes consumed were weighed to the nearest 2 g (0.1 oz) using a Soehnle electronic kitchen scale (Plateau Art, Germany, Model number 65086, maximum weight 10 kg). When not available, amounts were estimated either in household units, size, volume (measured by water) or in monetary value. Plate sharing was not practised in the study area. The total volume of food cooked at the respondents' household and the volume of food specifically consumed by the respondent were measured to determine the proportion consumed. The resulting proportion was multiplied by the total amount of ingredients used in the preparation of the dish to determine amount of ingredients consumed by the respondent. Standard recipes were generated to take care of all foods consumed outside the home. Conversion factors from household units, size, volume and monetary values to weight equivalent were determined.

Nutrient intake, probability of adequacy (PA) and mean PA (MPA)

Nutrient intake calculations were based on a food composition table developed specifically for the study using the national food composition table of Kenya as the primary data source for nutrient values of foods (13). Foods and nutrient values missing in this table were selected, in order of priority from food composition tables from East Africa (14), Mali (15), South Africa (MRC) (16), International Minilist (IML) (17) and the United States Department of Agriculture database (USDA) (18). USDA retention factors release 6 (19) were applied to raw ingredients and foods to account for nutrient losses during food preparation. Vitamin A, β-carotene and retinol were converted into retinol activity equivalent (RAE) using the standard conversion factors (20, 21).

Nutrient intakes were calculated using Compl-eat (version 1.0. Wageningen University, The Netherlands). Intake of energy and the following micronutrients were assessed: iron, zinc, calcium, vitamin C, vitamin A (RAE), vitamin B6, vitamin B12, folate, riboflavin, niacin and thiamine being key micronutrients for women's health (1). Vitamin C was included because of its role in enhancing the absorption of non-haem iron (22). All nutrient intakes obtained from the 24hr-recall (per period) were adjusted for within-person variation using the National Research Council (NRC) adjustment procedure to arrive at the usual intake (23). The probabilities of adequacy (PA) for vitamins A (RAE), C, B12, B6, riboflavin, niacin, thiamine, folate, zinc and calcium were calculated based on their respective estimated average requirements (EARs) and distributions (20, 24, 25), (see Supporting Information Table S1), using the PROBNORM function in SPSS (PA=PROBNORM [(adjusted individual intake-EAR)/SD], where PROBNORM is the statistical function that clarifies whether the probability of the individual intake is above the EAR. The distribution of iron requirement is skewed, so the probability of adequacy values derived by the Institute of Medicine (20) were used (See Supporting Information Table S2), but adjusted for 5% bioavailability to reflect the inhibitory nature of the predominantly cereal-based diet in the study area. Similarly, the EAR for zinc was adjusted for low (15%) bioavailability (11). The mean probability of adequate micronutrient intake (MPA) for each individual, a summary measure of micronutrient adequacy, was computed as the average of the PA for the 11 micronutrients considered in this study.

Informative food-based diversity scores

Dietary intake data for both seasons were combined into one data file. Informative foods were selected by two methods: (1) based on the percentage contribution to micronutrient intake (MOM1) and (2) based on the percentage contribution to the variance of micronutrient intake (MOM2) (7, 8). Detailed procedures for both selection processes are described in Molag et al. (2010) (9).In the first procedure, foods are selected on the basis of their percentage contribution to nutrient intake in a population. It is a simple and suitable selection procedure for the purpose of estimating the absolute level of intake in a population. The second procedure simply selects foods based on their contribution to the variance in nutrient intake. This procedure does not take the covariance in nutrient intake of different food items and their estimated regression coefficients into account, and tests only one combination of food items. For both methods, foods selected were ranked according to their contribution to the selected micronutrients and six food lists were created; three based on foods contributing respectively 90%, 70% and 50% to nutrient intake, and three based on foods contributing respectively 90%, 70% and 50% to variation in nutrient intake. Accordingly, six informative food-based diversity scores were made: for each list and for each period, every women received a score of 1 for every food consumed and the scores were totalled to arrive at three diversity scores derived from foods selected based on contribution to nutrient intake (IDS50, IDS70, IDS90) and at three diversity scores derived from foods selected based on the contribution to the variance in nutrient intake (VDS50, VDS70, VDS90).

Food group-based dietary diversity score

The dietary diversity score (DDS) was calculated based on 13 food groups as described by Arimond et al. (2) using a minimum quantity intake of 15 g for a food group to count. The thirteen food groups comprised: all starchy staples, all legumes and nuts, all dairy, organ meat, eggs, small fish eaten whole with bones, all other flesh foods and miscellaneous small animal protein, vitamin A-rich dark green leafy vegetables, vitamin A-rich deep yellow, orange and red vegetables, vitamin C-rich vegetables, vitamin A-rich fruits, vitamin C-rich fruits, all other fruits and vegetables (2). The DDS was constructed based on the 24hr-recall from the first observation day; this in recognition that the score

is meant for use in large-scale surveys where only one household visit would be possible (2, 26). Every food group consumed in the previous 24 hours received a score of 1 (irrespective of number of food items eaten from the food group), when consumed in quantities of 15 g or more. The total food scores were summed up to arrive at the total DDS for each individual.

Statistical analysis

All statistical analyses were done using PASW 19 for Windows (27). Complete datasets were available for 73 women (Period 1) and 203 women (Period 2) while 67 women had data for both periods. The nutrient and dietary diversity data was visually checked and tested for normality using the Shapiro-Wilk test. Non-normally distributed data was log transformed to obtain normality. For each period, Spearman's rank correlation (for non-normally distributed indicators) (28) and partial correlations (adjusted for energy intake) between the diversity scores and probability of adequate nutrient intake (PA, MPA) were calculated and differences between the informative food-based diversity scores and the food group-based diversity score were tested using Steiger's equation (29).

Results

The average age of the women was 35 years (range 20-49), about 82% were married and 63% attained primary education. More than half of the women were subsistence farmers (58%), (**Table 4.1**). Mean daily energy intake of the women was slightly but significantly higher in Period 2 (2097 SD 151 kcal) compared to Period 1 (2039 SD 162 kcal).

In general, the PAs of nutrients in Period 1 were significantly lower compared to those in Period 2 (**Table 4.2**), except for PA of vitamin C intake. The PA of vitamin B12, calcium, riboflavin and folate intake were below 10% in both periods. The PA of iron, thiamin, zinc, vitamin B6 and vitamin C intake were over 70% in Period 1 and 2. The MPA was significantly lower in Period 1 (41%) compared to Period 2 (44%). In total, the women in our study consumed 56 different food items. Only 20 and 7 foods contributed 90% and 50% respectively to intake of the 11 micronutrients considered (**Table 4.3**),

and only 25 and 16 foods explained 90% and 50% respectively to the variance of nutrient intake (**Table 4.4**).

Table 4.1. Demographic characteristics of women of reproductive age (N=203) in Mbooni Division, Kenya[1].

Demography	Value
Age (in years)[×]	34.9 (SD 9.0)
Relationship to Head of households (%)	
Wife	81.5
Daughter	8.3
Other relative	10.2
Marital Status (%)	
Married	82.4
Single	12.2
Divorced/Widowed	5.4
Level of Education (%)	
Primary	63.4
Secondary or higher	30.7
Literate (read/write)	2.9
Illiterate	2.9
Occupation (%)	
Farmer	58.3
Housekeeper	24.0
Trader	10.3
Other	7.3

[1] Data collected at the start of the study in Period 1(n=73) and Period 2 (n=130)
[×] Mean (SD)

Table 4.2. Probability of adequacy of intake of 11 micronutrients of women in reproductive age, Kenya

Nutrients	**Period 1 (n=73)**	**Period 2 (n=203)**
	%PA[1]	**%PA**
Iron (mg)	77.1[a]	80.4[b]
Zinc (mg)	70.7[a]	76.8[b]
Vitamin C (mg)	98.5[a]	90.9[b]
Vitamin A(µg)	11.7[a]	17.4[a]
Calcium (mg)	0.07[a]	0.22[a]
Thiamin (mg)	99.9[a]	99.9[a]
Riboflavin (mg)	5.1[a]	9.8[b]
Niacin (mg)	14.2[a]	18.9[b]
Vitamin B_6 (µg)	75.9[a]	84.4[b]
Vitamin B_{12} (µg)	0.0	0.0
Folate (µg)	0.01	0.14
Mean Probability of Adequacy	41[a]	44[b]

[1] PA: probability of adequacy; data sharing superscript in a row are not significantly different ($P<0.05$)

The food groups starchy staples (especially white maize grain), dairy (cow milk) and vitamin A-rich dark green vegetables (Sukuma wiki) contributed most to intake and explained the largest part of the variance of intake of the micronutrients considered. In addition, arrow roots contributed 50% of total folate intake and red beans explained 20% of variance in folate intake. Beef meat and cowpeas contributed 23% and 19% of total vitamin B_{12} and iron intake, respectively. White maize flour contributed to 19% of total iron intake and covered 25% and 17% of the variance in intake of iron and vitamin B1 (**Table 4.3 and 4.4**). The 20 foods contributing to 90% of intake and the 25 foods explaining 90% of the variance in intake covered 6 and 7 out of the total 13 food groups respectively.

However, none of the women consumed all the foods included in the diversity scores in the 24 hours for which food consumption data was collected and the maximum number of foods consumed was 12 for IDS scores and 11 for VDS scores (**Table 4.5**). As expected, the scores increased from 3.6 to 5.6 for IDS and from 4.7 to 5.1 for VDS when a larger percentage of the contribution to intake or to the variance of intake was covered. Overall, for all scores values in Period 1 were higher compared to Period 2.

Table 4.3. Contribution of foods to intake of micronutrients in women's diets, Mbooni District, Kenya

Foods	Vitamins (%)								Minerals (%)		
	B1	B2	B6	B12	C	Folate	Niacin	Vit A (RAE)	Calcium	Iron	Zinc
All starchy staples											
Flour maize white	17.2	6.0				7.4	8.0		2.5	24.7	14.7
Maize grain white	39.4	26.4	27.2			19.6	32.0		8.6	21.3	42.4
Nzenga[1]	4.7	1.6				3.2	3.7			3.3	7.0
Rice white									5.3	1.8	3.0
Cassava			16.4			1.8	1.6			0.8	
Sweet potatoes		1.5	2.2		7.8	8.7	2.3		1.0	3.0	
Banana ripe					1.1					0.7	
Arrow root						5.0					
Flour porridge wimbi		0.3				0.4	1.3		0.1		0.6
All legumes and nuts											
Beans red	3.8	6.3				20.8	3.2		3.5	9.6	9.8
Peas white									1.2	2.6	1.7
Beans white		1.4				4.2				1.6	1.7
Peas pigeon										1.5	
All dairy											
Milk cow whole	2.1	28.0		90.0	0.7	2.4		10.2	18.6		4.1
Vitamin A-rich dark green leafy vegetables											
Sukuma wiki[2]	15.7		40.9		57.7		32.2	70.6	35.7	9.9	5.9
Pumpkin leaves		2.7	2.9		1.0	2.2	1.4	4.1		1.6	
Vitamin C-rich vegetables											
Cabbage		2.0			12.1	2.0			1.6		
Cowpea leaves	2.0	9.5			5.6	10.2	3.6	3.4	12.4	8.3	
All other fruits and vegetables											
Avocado	2.7	2.0			1.3		2.0				
Tomato	2.9	3.5			3.1	2.6		3.8			
Total percentage contribution to intake	90.5	90.6	91.3	90.0	90.4	90.1	90.0	92.1	90.4	90.6	90.6

[1]Nzenga: dehulled, pounded maize; [2] Sukuma wiki: Kales – dark green leafy vegetables

Table 4.4. Contribution of foods to the variance of the intake of micronutrients in women's diets, Mbooni District, Kenya

Foods	Vitamins (%)								Minerals (%)		
	B1	**B2**	**B6**	**B12**	**C**	**Folate**	**Niacin**	**Vit A (RAE)**	**Calcium**	**Iron**	**Zinc**
All starchy staples											
Flour maize white	8.0									19.0	5.7
Maize grain white	53.5	19.5	26.1			3.9	24.5			18.1	60.6
Nzenga	3.0		2.2								6.6
Rice white									6.9	1.7	4.1
Sweet potatoes					8.4	12.2	2.0			5.5	
Cassava		1.4	20.0				1.7				
Arrow root			7.2			50.3					
Flour porridge wimbi	0.4						0.8				
White wheat flour						0.2	0.5			0.2	
Banana raw		0.1	1.2				0.1	0.1	0.2	0.2	
Banana ripe	0.7	0.1			0.3	0.1	0.1	0.2		0.4	
All legumes and nuts											
Beans red		3.5				13.6				11.4	10.0
Beans white											
Peas white										4.0	
Peas pigeon										3.3	
Cowpeas						4.4					2.7
All dairy											
Milk cow whole		42.4		77.1				10.3	12.1		
Flesh foods and small animal proteins											
Beef meat				22.9							
Vitamin A-rich dark green leafy vegetables											
Sukuma wiki	19.7		36.2		68.2		58.4	71.9	55.1	9.1	2.7
Pumpkin leaves		3.1						3.4			
Vitamin C-rich vegetables											
Cowpea leaves		17.8				7.4	2.2	3.0	19.9	19.2	
Cabbage					15.5						
Spinach								1.6			
All other fruits and vegetables											
Arrow root leaves											
Avocado	5.8	2.5					1.7				
Total percentage contribution to variance of intake	90.0	90.2	90.7	100	92.0	91.8	90.5	90.2	94.0	91.3	92.0

Table 4.5. Foods included in the diversity scores based on contribution to the intake and to the variance in intake of 11 micronutrients among women of reproductive age, Kenya[1]

Food items included in diversity score	No. of food items	Contribution to intake (I) and to variance of intake (V)		Diversity score			
		% (SD)	Minimum - maximum	Period 1		Period 2	
				Mean (SD)	Minimum-maximum	Mean (SD)	Minimum-Maximum
IDS50							
flour maize white, maize grain white, arrowroot, beans red, milk cow whole, sukuma wiki, leaves cowpea	7	52.0 (5.9)	43.9-58.5	3.6 (1.3)	0-5	3.4 (1.2)	1-6
IDS70							
IDS50 + nzenga, potatoes sweet cabbage, cassava	11	73.1 (5.0)	66.5-77.0	4.4 (1.6)	0-7	3.9 (1.3)	1-8
IDS90							
CFV70 + flour porridge wimbi, rice white, banana ripe tomato, leaves pumpkin	20	98.5 (7.5)	90.1-104.5	5.6 (1.6)	1-8	5.0 (1.6)	2-12
VDS50							
flour maize white, maize grain white, arrowroot, cassava, potato sweet, nzenga, beans red, beans white, peas cow, peas white, milk cow whole, sukuma wiki, leaves cowpea, avocado, cabbage, spinach	16	62.7 (4.8)	57.2-66.0	4.7 (1.7)	0-8	4.3 (1.3)	2-9
VDS70							
VDS 50 + meat beef, rice white	18	77.5 (13.8)	67.7-87.2	4.9 (1.7)	0-8	4.3 (1.4)	2-9
VDS90							
VDS 70 + leaves pumpkin, leaves arrow root, flour porridge wimbi, flour wheat white, peas pigeon, banana ripe, banana raw	25	118.9 (25.1)	92.1-141.9	5.1 (1.6)	1-8	4.7 (1.5)	2-11
DDS							
starchy staples, legumes/nuts, dairy, organ meat, eggs, small fish eaten whole with bones, all other flesh foods and small animal protein, vitamin A-rich dark green leafy-, vitamin A-rich deep yellow, orange and red-, vitamin C-rich vegetables, vitamin A-rich-, vitamin C-rich fruits, all other fruits and vegetables	13	NA	NA	4.5±1.2	1-7	4.0±1.3	1-7

[1]IDS: Diversity score based on foods contributing 50%, 70% or 90% to intake of11 micronutrients ; VDS: Diversity score based on foods contributing 50%, 70% or 90% to variance in intake of 11 micronutrients; DDS: Diversity score based on 13 food groups consumed in restricted quantities (15 g or more); NA: not applicable

The correlations between diversity scores and mean probability of adequacy (MPA) were higher in Period 1 (r=0.54-0.59) than in Period 2 (r=0.37 -0.45). After adjusting for energy intake the correlations for all diversity scores in both periods reduced (r=0.18 – 0.25) but stayed significant. All correlations of IDS and VDS with mean probability of nutrient adequacy were higher compared to that of the DDS in both periods, but only significant for Period 1 and only when not adjusted for energy intake (**Table 4.6**).

Table 4.6. Comparison of association of disaggregated informative food scores and dietary diversity scores with mean probability of nutrient adequacy among Kenyan women[1]

Food scores	Period 1 (n=73)		Period 2 (n=203)	
	2007 Post-harvest		2008 Pre-harvest	
	Spearman correlation	Partial correlation[2]	Spearman correlation	Partial correlation[2]
IDS 50	0.57*	0.21*	0.43*	0.28*
IDS 70	0.54*	0.18	0.39*	0.25*
IDS 90	0.55*	0.21*	0.45*	0.23*
VDS 50	0.58*	0.23*	0.39*	0.25*
VDS 70	0.54*	0.18	0.37* §	0.21*
VDS 90	0.54*	0.25*	0.42* §	0.24*
DDS	0.40* †	0.20*	0.38*	0.22*

[1] IDS: Diversity score based on foods contributing 50%, 70% or 90% to intake of 11 micronutrients ; VDS: Diversity score based on foods contributing 50%, 70% or 90% to the variance in intake of 11 micronutrients; DDS: Diversity score based on 13 food groups consumed in restricted quantities (15 g or more);
[2] All Partial correlations were adjusted for energy intakes. PA: probability of adequacy
* Correlation is significant at 0.01 level (1-tailed);
†DDS is significantly different from IDS 50, 70, 90 and VDS 50, 70, 90 ($p<0.05$)
§VDS 70 and VDS 90 are significantly different ($p<0.05$)

Discussion

To the authors' knowledge, this is the first study in a rural development setting, that used diversity scores based on informative foods contributing to the intake or to the variance in intake of 11 micronutrients and evaluated whether these scores better predict mean probability of adequacy than food group-based scores. The results show that the use of the developed informative food-based scores improved the associations with mean probability of adequacy compared to the food-group based dietary diversity score. However, the associations were still moderate and did not exceed r = 0.60. There was no difference in level of association between informative food-based scores and mean probability of nutrient adequacy whether the score was formulated derived from foods selected based on the percentage contribution to the intake or to the variance in intake. Similarly, no difference in the level of association between the score and mean

probability of nutrient adequacy were observed whether the cumulative percentage used to select the foods was set at 50%, 70% or 90%.

Our study had several limitations that are typically related to the use of retrospective dietary recall methods with inherent systematic (over- and under-estimation) and random (imprecise estimates) errors (30). Errors could be related to misreporting of foods consumed (like omission of fruits and snacks), mistakes in recipes and listing dish ingredients (31), or over- or under-estimation of portion sizes. The use of food composition data, although carefully compiled using a standardized procedure (31; 32), remains challenging, particular in developing country settings. In our study, only a few foods contributed most to intake and mistakes in nutrient composition of these foods might have a large effect on total nutrient intake. We correlated single-day diversity scores with estimated usual nutrient intake, in recognition that in large surveys often only one household visit is possible, but precise estimates of intakes require many repeated recalls. High intra-individual variation in intake could have attenuated found associations, but this was analytically addressed by using the National Research Council (NRC) procedure (23; 24) allowing adjustment of individual intake in studies comparable to ours with small sample sizes and equal numbers of observations per subject (33). Lastly, the same data collection tool was used to assess nutrient intake and to create the dietary diversity scores leading to correlated measurement errors resulting in inflated associations. Despite the careful precautionary efforts taken to minimise these errors, some errors may have inevitably occurred but we are of the opinion that these errors will be mainly random, contributing to an increase of variance and hence reducing the ability to find strong associations, but this will very unlikely change our main conclusions.

Results show that women in our study consumed diets with low diversity reflected by a small number of total foods and of informative foods consumed. Only 7 foods contributed to 50% of nutrient intake, while only 16 foods explained 50% of the variance in nutrient intake. Maize (either as flour in ugali or as grain), cow milk and sukuma wiki (kale) were the largest contributors. We also found large gaps between intakes and requirements across most micronutrients with a mean probability of adequacy of 40-45%, indicating that with poor diets it is not possible to fulfil the necessary nutrient requirement for human survival (34; 35). This confirms results of

earlier studies showing poor women's diets (1) and underscores the need to improve diets and the micronutrient intake of women of reproductive age.

Use of informative foods to derive a dietary diversity score resulted in an improved association with micronutrient adequacy of women's diets, although the improvement is modest and associations stay moderate at a level of below r=0.6. In general, correlation values of r ≥0.7 show good performance (6), although in food consumption studies correlation values of r≥0.4 are considered acceptable (6). Also previous research indicated, that an increase in the number of nutrients in an indicator provided limited benefit in predicting overall diet quality (36). The dietary diversity scores and MPA being at the lower end of the distributions, typical for resource poor settings (2), might have contributed to a limited ability to show stronger associations. Is it worth the investment then to develop informative food-based diversity scores in such settings if the improvement of the association with nutrient adequacy is moderate?

The informative food-based diversity scores have some advantages. The selection of informative foods as done in our study using computer based software, avoids the dilemma of operationalizing a minimum consumption requirement for a food or food group to count in a diversity score. Dietary diversity scores applying this minimum requirement perform consistently better in predicting MPA than ones without a minimum requirement (2; 37; 38). Practically, identification of foods that are consumed in small quantities through questionnaires remains challenging. Including food groups at a high level of disaggregation and identifying and separating foods known to be consumed in small quantities is suggested but may result in long lists of food and food items, increasing the risk of misreporting (3). Using the identification of informative foods as done in our study, foods that are consumed in small quantities are not selected as they do not contribute meaningfully to nutrient intake or to the variance in some nutrients intake. Secondly, as data were collected in two seasons, seasonal foods with a high nutrient profile are also included when they contribute to intake or to the variance of intake.

However, using informative foods also has obvious limitations. To identify the informative foods, good knowledge on the main types of foods consumed in the area and on the ways they are usually prepared is essential. Hence, prior to large-scale studies, quantitative food consumption data should be collected on a sub-sample of the target

population, preferably in more than one season. This may be out of scope as it is time consuming and costly. Secondly, a more serious disadvantage is that the selection of informative foods depends on the dietary habits and foods consumed in the study population. These differ between countries and even vary within countries, making the informative food-based diversity score context-specific seriously hampering cross and within country comparisons.

Therefore, based on the moderate improvement of associations with micronutrient adequacy and on the limitations of selecting informative foods, the use of a food group-based dietary diversity score should be preferred above an informative food-based diversity score in resource poor settings in developing countries. Other options for improving performance may be considered like weighting of foods, although studies using weighted scores in household level indicators are not consistently showing a better predictive performance (39) (40). Additional research to confirm whether weighting would improve the performance of individual dietary diversity scores is needed.

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Chapter 5

Evaluation of the Minimum Dietary Diversity score for Women (MDD-W) to predict nutrient adequacy among rural Kenyan women.

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(under preparation for submission)

Abstract

Background: The Minimum Dietary Diversity score for Women (MDD-W) was recently launched to be used as a global indicator of prevalence of acceptable adequate nutrient intake. Women consuming at least five out of ten food groups are assumed to have a greater likelihood of meeting their micronutrient needs. Performance of this indicator should be evaluated in different settings. The objective of this study is to investigate the ability of the Minimum Dietary Diversity score for Women to predict micronutrient adequacy and the prevalence of acceptable adequacy in rural women of reproductive age in Mbooni District, Kenya.

Methods: Food consumption data was collected in 2 seasons, using 3 non-consecutive quantitative 24hr-recalls from 203 women. MDD-W was constructed based on 100 food groups, using a minimum consumption of 15 g for a food group to count. For each season, correlation analysis tested the association of MDD-W with the mean probability of nutrient adequacy (MPA) of intake for 11 micronutrients. Proportions of women consuming 5 or more food groups and of women with an MPA above 0.60 were compared, and proportions of women consuming different food groups were compared between those consuming less than 5 and consuming 5 or more food groups. Sensitivity/specificity analysis at MPA > 60% were used to assess performance of the MDD-W cut-off of 5 food groups or more.

Results: The mean of the Minimum Dietary Diversity score for Women was higher in Period 1 (5.2±0.9) compared to Period 2 (4.8±1.1) with 73% and 64% of women consuming 5 food groups or more. Only 1.4% and 2.5% had an MPA>0.60. The MDD-W was significantly but moderately associated with MPA with higher correlations in Period 1 (r=0.53) than in Period 2 (r=0.45). Using an MDD-W of 5 or more resulted in high total misclassifications with a low positive predictive value of below 5% in both periods.

Conclusion: The MDD-W is a good proxy for nutrient adequacy but using the cut-off of 5 or more is a poor indicator of prevalence of acceptable nutrient adequacy in rural Kenyan women of reproductive age consuming low diverse diets.

Introduction

Consuming low diversity diets is considered as one of the major causes of micronutrient deficiencies in low and middle income countries, particular of women in reproductive age (15-49 years) who are more vulnerable because of their greater micronutrient needs. However, due to the time-consuming and costly nature of dietary intake assessment methodology, accurate information on women's diets is often missing, which hampers the identification of (sub)populations at increased risk. The dietary diversity score, being a simple count of food groups consumed on the previous day, is suggested as a good proxy for micronutrient adequacy of the diet [1, 2, 3]. In large-scale studies and impact assessments of nutrition-sensitive interventions, particular in agriculture, currently a 9-point food group score is used [4]. This score was validated as one of the six diversity indicators in a multi-country study, using a common analytical protocol and harmonized definitions, as an acceptable indicator for micronutrient adequacy of women's diets, especially when consumption of trivial amounts (<15g) of a food group did not count in the dietary diversity score [2]. However, the study did not recommend a validated dichotomous indicator based on a standard number of food groups as none of the studied indicators or cut-off points yielded an acceptable balance of sensitivity, specificity, and misclassification across sites [5]. Instead, reporting results by the mean population score was recommended [4]. However, it is statistically incorrect to calculate the mean population score, as the DDS is an ordinal variable assumed to be quasi-continuous.

Dichotomous indicators are useful tools for screening for vulnerability within populations and to determine the prevalence of a problem at the population level. Recently, the Minimum Dietary Diversity score for Women (MDD-W) was endorsed by the United Nations (UN) to be used as the global indicator. This indicator specifies that out of 10 food groups (all starchy staple foods, beans and peas, nuts and seeds, dairy, flesh foods, eggs, vitamin A-rich dark green leafy vegetables, other vitamin A-rich vegetables and fruits, other vegetables and other fruits) a woman should consume at least 5 groups with a minimum amount of 15 g, to have a greater likelihood of meeting her micronutrient needs [6]. To support evidence of robustness of the MMD-W, the indicator should be validated in different settings. It is against this background that our

study set out to investigate the ability of the Minimum Dietary Diversity score for Women to predict micronutrient adequacy in rural Kenyan women of reproductive age.

Methods

Study site and sample selection

The study was conducted in 2007 (pre-harvest) and 2008 (post-harvest) at Mbooni division, Makueni district in Eastern Kenya. Makueni district comprises of 16 divisions, 66 locations and 108 sub-locations. It is characterized as semi-arid to arid with low erratic rainfall. which on average is 500 mm annually. The district is prone to frequent droughts and food shortages. Mbooni division (with 4 sub-locations) has a distinct seasonality and experiences two rainy seasons; long rains in March/April and short rains in November/December. Subsistence farming is practised with most crops harvested after the short rains. Kyuu sub location (having 14 villages) was randomly selected for the survey and the community is rural with cultural homogeneity, since all people are from the Kamba ethnic group.

In each village 15 households were randomly sampled using the random walk method [7]. One woman of reproductive age (non-pregnant and non-lactating) having a last borne child between 2-5 years was selected from each household. When more eligible women were available (at a household), only one woman was randomly selected. Other inclusion criteria were: apparently healthy, no chronic illness, no known HIV/Aids, not anorexic and not taking medication. In total, 210 women were selected. An appointment was made for the survey date in the selected household after obtaining verbal, informed consent from the woman. Due to the post-election violence in Kenya in 2007, data collection had to be stopped and only 73 women were selected for the first data collection round. For the second data collection round, 210 women were selected.

At the time of the study, there was no Institutional Review Board or Ethics Committee at the University of Nairobi. In consultation with the Ethics Committee at Wageningen University, The Netherlands, no other Ethical Review Board was consulted, as according to the Kenyan Government rules in 2007, the study was not entitled to ethical clearance as it did not involve feeding of participants nor withdrawing any bodily fluids. The study was registered with and approved by the Kenya Ministry of Education, Science and

Technology. Verbal approval was obtained from the Mbooni District officials and the community authorities.

Data collection

The mean daily food intake of the women was assessed using a repeated quantitative multi-pass 24hr-recall method, carried out by well-trained interviewers [8, 9]. Data was obtained in 2 distinct seasonal periods: three repeated 24hr-recalls in October-December 2007 (Period 1, pre-harvest) and in April-June 2008 (Period 2, post-harvest). The seasons of the survey were chosen on the basis of agricultural food circles, with pre-harvest being the period just before harvest when food availability is low while post-harvest refers to the period when short rains harvest was still available. The repeated recalls were from non-consecutive days with 2-11 days apart. All days of the week were represented except for Saturday due to unavailability of households on Sunday. Households were randomly allocated to day of the week, interviewers were randomly allocated to households and repeated household visits by the same interviewer were avoided. Women were asked to mention all foods and beverages they had eaten during the preceding 24 hours (from the time they woke up the preceding day, to the time they woke up the interview day), including anything consumed outside of the home. They were then requested to describe the foods and beverages consumed, including ingredients and cooking methods of mixed dishes. Duplicate amounts of all foods, beverages, ingredients of mixed dishes consumed were weighed to the nearest 2 g (0.1 oz) using a Soehnle electronic kitchen scale (Plateau Art, Germany, Model number 65086, maximum weight 10 kg). When not available, amounts were estimated either in household units, size, volume (measured by water), or monetary value. Plate sharing is not practised in the study area. The total volume of food cooked at the respondents' household and the volume of food specifically consumed by the respondent were measured to determine the proportion consumed. This proportion was multiplied by the total amount of ingredients used in the preparation of the dish to determine the amount of ingredients consumed by the respondent. Standard recipes were generated to take care of all foods consumed outside the home. Conversion factors from household units, size, volume and monetary values to weight equivalent were determined.

Nutrient intake, probability of adequacy (PA) and mean PA (MPA)

Nutrient intake calculations were based on a food composition table specifically developed for the study. The primary data source for nutrient values of foods was the national food composition table of Kenya [10]. Foods and nutrient values missing in this table were taken, in order of priority, from food composition tables from East Africa [11], Mali [12], South Africa (MRC) [13], International Minilist (IML) [14] and the United States Department of Agriculture database (USDA) [15]. USDA retention factors release 6 [15] were applied to raw ingredients and foods to account for nutrient losses during food preparation. Retinol and β-carotene were converted into retinol activity equivalent (RAE) using the standard conversion factors [16, 17].

Nutrient intakes were calculated using Compl-eat (version 1.0. Wageningen University). Intake of energy and the following micronutrients were assessed: iron, zinc, calcium, vitamin C, vitamin A (RAE), vitamin B6, vitamin B12, folate, riboflavin, niacin and thiamine, being key micronutrients for women's health [18]. Vitamin C was included because of its role in enhancing the absorption of non-haem iron [19]. All nutrient intakes obtained from the 24hr-recall (per period) were adjusted for within-person variation using the National Research Council (NRC) adjustment procedure to arrive at the usual intake [20]. The probabilities of adequacy (PA) for vitamins A (RAE), C, B12, B6, riboflavin, niacin, thiamine, folate, zinc and calcium were calculated using their respective estimated average requirements (EARs) and distributions [21, 22, 16] (see Supporting Information Table S1), using the PROBNORM function in SPSS (PA=PROBNORM [(adjusted individual intake-EAR)/SD], where PROBNORM is the statistical function that clarifies whether the probability of the individual intake is above the EAR. The distribution of iron requirement is skewed, so probability of adequacy values derived by the Institute of Medicine [20]were used (see Supporting Information Table S2), but adjusted for 5% bioavailability to reflect the inhibitory nature of the predominantly cereal-based diet in the study area. Similarly, the EAR for zinc was adjusted for low (15%) bioavailability [23]. Mean probability of adequacy (MPA), a summary measure of micronutrient adequacy, was computed as the average of PAs of all 11 micronutrients reported in this paper.

Dietary diversity score

The Minimum Dietary Diversity score for Women (MDD-W) was calculated based on 10 food groups as described by a consensus meeting convened by the Food and Agriculture Organisation (FAO) and the Food and Nutrition Technical Assistance [6], using a minimum quantity intake of 15 g for a food group to count. The MDD-W was constructed based on the 24hr-recall from the first observation day; this in recognition that the score is meant for use in large-scale surveys where only one household visit would be possible[2]. Every food group consumed in the previous 24 hours received a score of 1 (irrespective of number of food items eaten from the food group), when consumed in quantities of 15 g or more. The total food scores were finally summed up to arrive at the total MDD-W for each individual. The ten food groups comprised: all starchy staples foods, beans and peas, nuts and seeds, dairy, flesh foods, eggs, vitamin A-rich dark green leafy vegetables, other vitamin A-rich vegetables and fruits, other vegetables and other fruits [6].

Anthropometric measurements

Body weight and height were measured according to WHO standardized procedures [24]. A microtoise (Bodymeter 208; Seca GMbH, Hamburg, Germany) was used to measure the height of women to a precision of 0.1 cm. Weight was measured with a platform spring balance scale with a 150 kg maximum and 0.5 kg graduation (Seca 761; Seca, Hamburg, Germany). For both weight and height the average of two measurements was taken. The ages of women were determined by use of the National Identification cards, local calendar of events and memory. Based on Body Mass Index (BMI – kg/m2), women were divided into 3 categories: underweight BMI < 18.5 kg/$m^{2,}$ normal weight 18.5 ≥ BMI ≤ 24.9 kg/m^2, and overweight or obese ≥ 25 kg/m^2 [25]. Demographic data were collected on the relationship with the household head, marital status, level of education and occupation.

Statistical analysis.

All statistical analyses were done using PASW 19 for Windows (IBM SPSS Statistics 19, SPSS Inc., Chicago). Complete datasets were available for 73 women (Period 1) and 203 women (Period 2) while 67 women had data for both periods. The nutrient and dietary

diversity data was visually checked and tested for normality using the Shapiro-Wilk test. Non-normally distributed data was log transformed to near normality. The proportion of women being underweight or overweight and women consuming the different food groups in the two periods was compared by use of the Chi-square test. For each period, Spearman's rank correlation (for non-normally distributed indicators) [26] and partial correlations (adjusted for energy intake) between MDD-W and PA (MPA) were calculated to verify linear associations. Mean MPA was compared between women who consumed < 5 food groups and women who consumed ≥ 5 food groups using a independent sample t-test. Proportions of women with an MPA>0.60, and a MDD-W of 5 or more were calculated and compared with a Chi-square test. We tested the ability of the dietary diversity score to detect the prevalence of acceptable mean nutrient adequacy (defined as MPA>0.60) using the Receiver Operating Characteristic (ROC) analysis. The best DDS cut-off for maximising sensitivity/specificity was determined using the Youden index [27, 28]. Sensitivity/specificity analyses reflected the full extent of misclassification and also investigated the proportions of all women who would be classified as 'false positives' and 'false negatives', and the 'positive predictive value' reflecting the true likelihood of having an acceptable MPA among those who were true positive. For all statistical tests we considered values of $p<0.05$ to be statistically significant.

Results

The average age of the women was 35 years (range 20-49). About 82% were married and 63% attained primary education. More than half of the women were subsistence farmers (58%), **Table 5.1**.

Table 5.1. Demographic characteristics of women of reproductive age in Mbooni Division, Kenya[1].

Demography	Value
Age (in years)[2]	34.9 (SD 9.0)
Relationship to Head of household, (%)	
Wife	81.5
Daughter	8.3
Other relative	10.2
Marital Status (%)	
Married	82.4
Single	12.2
Divorced/Widowed	5.4
Level of Education (%)	
Primary	63.4
Secondary or higher	30.7
Literate (read/write)	2.9
Illiterate	2.9
Occupation (%)	
Farmer	58.3
Housekeeper	24.0
Trader	10.3
Other	7.3

[1] N=203
[2] Mean (SD)

The mean BMI of women was 23 kg/m^2 with no significant differences between periods (**Table 5.2**). The percentage of overweight women (BMI>25) ranged from 16-23% with the lowest value in the 2008 post-harvest season though not significant. The percentage of underweight women ranged from 5-10%, with the highest percentage in the 2007 pre-harvest season but the differences were not significant. Mean daily energy intake of the women was significantly different in both periods, with the highest energy intake in Period 2 (2097 ± 151 kcal) and the lowest in Period 1 (2039 ± 162 kcal).

Table 5.2. Nutrition status indicators, mean probability of adequacy, the dietary diversity score and their association among women of reproductive age per season in Mbooni Division, Kenya[1]

	Period 1 2007 Pre-harvest (n=73)	**Period 2 2008 Post-harvest (n=203)**
Weight (kg)	56.2 ± 9.5	56.6 ± 8.4
Height (cm)	156.0 ± 4.7	157.4 ± 5.8
BMI (kg/m^2)[2]	23.0 ± 4.1	22.8 ± 3.7
Obese: BMI>25 (%)	23.1	16.1
Underweight: BMI<18.5 (%)	5.0	9.7
Energy intake (kcal, SD) [3]	2039(±162)[a]	2097(±151)[b]
MMD-W	5.2 (±0.9)	4.8 (±1.1)
Minimum-maximum	2-7	2-8
MDD-W≥5 (%)	72.6	63.5
MPA	0.41 (±0.1)	0.44 (±0.1)
MPA>0.60 (%)	1.4	2.5

[1] Values are in means±SD unless stated otherwise, BMI body mass index (kg/m^2); MDD-W: womens dietary diversity score based on 10 food groups with 15 g restriction; MPA, mean probability of adequacy.
[2] Only for weight, height and BMI, Period 1:n=60, Period 2:n=62
[3] Geometric means (SD).
[ab]Values not sharing superscript in a row are significantly different, P<0.05

In both periods, almost all women consumed starchy staples (**Table 5.3**). However, hardly any or no woman consumed nuts and seeds, eggs and other vitamin A-rich vegetables and fruits. Over 60% of the women consumed the food groups: beans and peas, dairy, vitamin A-rich dark green leafy vegetables and other vegetables. Flesh foods and other fruits were consumed by less than 10% of the women. More women consumed vitamin A-rich dark green leafy vegetables and other vitamin A–rich vegetables and fruits in Period 1 (78.1% and 5.5% respectively) compared to Period 2 (58.6% and 0.5% respectively), while less women consumed other fruits (13.3% in Period 1 and 5.5% in Period 2).

Table 5.3. Proportion of women of reproductive age consuming various food groups per period and per MDD-W category in Mbooni Division, Kenya[1]

Food group	Period 1 2007 Pre-harvest (n=73)	Period 2 2008 Post-harvest (n=203)	Period 1 2007 Pre-harvest		Period 2 2008 Post-harvest	
			<5 FG (n=20)	≥5 FG (n=53)	<5 FG (n=74)	≥5 FG (n=129)
All starchy staples	98.6[a]	100.0[a]	97.5	100	100	100
Beans and peas	68.5[a]	63.5[a]	50.0[a]	90.9[b]	53.3[a]	95.2[b]
Nuts and seeds	0.0[a]	0.5[a]	0	0	0.7	0
Dairy	72.6[a]	75.4[a]	52.5[a]	97.0[b]	66.7[a]	100.0[b]
Flesh foods	8.2[a]	5.4[a]	2.5	15.2	4.7	7.5
Eggs	2.7[a]	0.5[a]	2.5	3.0	0	1.9
Vitamin A-rich dark green leafy vegetables	78.1[a]	58.6[b]	65.0[a]	93.9[b]	46.0[a]	94.3[b]
Other vitamin A-rich vegetables and fruits	5.5[a]	0.5[a]	0[a]	12.1[b]	0	1.9
Other vegetables	93.2[a]	86.2[a]	87.5[a]	100.0[b]	81.3[a]	100.0
Other fruits	5.5[a]	13.3[b]	5.0	6.1	8.0[a]	28.3[b]

[1]Values in %
[ab]Proportions sharing superscript in a row are not significantly different $p<0.05$

The MDD-W significantly decreased as the periods progressed, from 5.2 (SD 0.9) in Period 1, to 4.8 (SD 1.1) in Period 2 (**Table 5.4**) with a minimum score of 2 and a maximum of 7 (Period 1) or 8 (Period 2). The MDD-W and probability of nutrient adequacy were significantly correlated for all nutrients in both periods, with correlation coefficients ranging from r=0.43 – 0.58 in Period 1 and r=0.24 – 0.50 in Period 2 with higher correlations in Period 1 compared to Period 2. After controlling for energy intake the correlations reduced with some nutrients remaining significant. Higher and significant correlations of MDD-W with MPA were observed in Period 1 (r= 0.54) than Period 2 (r=0.45). After adjusting for energy intake, the correlations (Period 1: r= 0.34, Period 2: r=0.30) decreased but remained significant (**Table 5.4**).

Table 5.4. Probability of adequacy of intake of 11 micronutrients and their association with the minimum dietary diversity score (restricted 15 g) among rural Kenya women.

Nutrients	**Period 1 (n=73)**		**Period 2 (n=203)**	
	2007 Post-harvest		**2008 Pre-harvest**	
	Spearman correlation	**Partial correlation[1]**	**Spearman correlation**	**Partial correlation[1]**
Iron (mg)	0.43**	0.16	0.28**	0.07
Zinc (mg)	0.51**	0.43**	0.37**	0.20**
Vitamin C (mg)	0.47**	0.27**	0.39**	0.31**
Vitamin A(µg)	0.48**	0.13	0.50**	0.23**
Calcium (mg)	0.53**	0.03	0.36**	-0.17**
Thiamin (mg)	0.44**	0.13	0.41**	0.06
Riboflavin (mg)	0.58**	-0.01	0.24**	-0.17**
Niacin (mg)	0.44**	0.03	0.40**	0.13**
Vitamin B_6 (µg)	0.46**	0.19*	0.39**	0.23**
Vitamin B_{12} (µg)	0.44**	0.25**	0.33**	0.08
Folate (µg)	0.52**	-0.08	0.24**	-0.08
MPA[2]	0.54*	0.34**	0.45**	0.30**

[1]All partial correlations were adjusted for energy intake

[2]MPA: mean probability of adequacy of nutrient intake

*Correlation is significant at the 0.05 level (1-tailed);** Correlation is significant at the 0.01 level (1-tailed)

For Period 1, 73 % of women consumed 5 or more food groups out of 10, while in Period 2 64% of women consumed 5 food groups or more. With regard to mean probability of adequacy, 1.4% of women had a MPA >0.60, while in the second period 2.5% of women had a MPA>0.60 (**Table 5.2**). In both periods, a higher percent of women consumed beans and peas, dairy, vegetables and fruits (both vitamin A-rich or not) at or above the cut-point of 5 for MDD-W (**Table 5.3**). In both periods (**Table 5.5**), the MPA for those consuming 5 or more groups was significantly higher (Period 1: 0.42±0.06; Period 2: 0.46±0.07) compared to those consuming less than 5 food groups (Period 1: 0.37±0.08; Period 2: 0.39±0.08).

Table 5.5. Mean MPA at or above versus below the cut-off of 5 food groups among rural Kenyan women of reproductive age

Period	**MDD-W**	
	< 5 food groups	**≥ 5 food groups**
Period 1 2007 (Pre-harvest)	0.37[a] (SD 0.07)	0.43 [b] (SD 0.07)
Period 2 2008 (Post-harvest)	0.39[a] (SD 0.09)	0.46 [b] (SD 0.07)

[ab]Proportions sharing superscript in a row are not significantly different p<0.005

Using MPA>0.60 as acceptable nutrient adequacy of intake, the ROC analysis showed that the AUC for MDD-W was 0.76 in both periods, being significantly greater than 0.50 only in Period 2 (p=0.045). **Table 5.6** shows the sensitivity and specificity analysis evaluating the performance of the MDD-W to detect women with an acceptable nutrient adequacy. The false positive rates were 28% and 62% in Period 1 and 2, while the false negative rates were 100% and 0%, respectively. In total, 29% and 62% of women were misclassified with positive predictive values of 0% and 4% in Period 1 and 2, respectively. The Youden index indicated a cut-off for DDS ≥6 in Period 1 and for DDS ≥5 as cut-points maximizing sensitivity and specificity for classifying women having an acceptable nutrient intake.

Table 5.6. Sensitivity and specificity analysis evaluating the minimum dietary diversity for women (restricted 15 g) for detecting acceptable MPA (>0.60) among rural Kenyan women of reproductive age.

DDS	Sensitivity (%)	Specificity (%)	False positive (%)	False negative (%)	Positive predictive value (%)	Total misclassi-fication (%)
			MPA>0.60			
Period 1 (AUC=0.76)						
≥3 (72)	100	1	99	0	1	97
≥4 (70)	100	4	96	0	1	95
≥5 (53)	100	28	72	0	2	71
≥6 (33)	100	56	44	0	3	44
≥7 (2)	0	72	3	100	0	4
Period 2 (AUC=0.76)						
≥3 (200)	100	2	98	0	3	96
≥4 (178)	100	13	87	0	3	85
≥5 (129)	100	37	62	0	4	61
≥6 (53)	60	75	25	40	6	26
≥7 (8)	20	97	4	80	13	5

MDD_W, minimum dietary diversity -women; MPA, mean probability of adequacy; AUC=Area Under the Curve; Period 1 (2007 pre-harvest), Period 2 (2008 post-harvest) . [1]Numbers in parenthesis: number of women.

Discussion

This study aimed to evaluate the performance of a recently launched MDD-W to estimate the prevalence of women reaching a minimum dietary diversity reflective of an acceptable micronutrient adequacy across the 11 micronutrients studied. Results indicate that the 10 food groups score is significantly but moderately associated with micronutrient adequacy, in both seasons studied. However, the proportion of women consuming 5 food groups or more overestimated the prevalence of acceptable nutrient adequacy (defined as MPA>0.60) having low specificity with high number of misclassifications.

The present study has inevitable limitations. Those inherent to the use of the 24hr-recall may have introduced some errors, both systematic (over- and under-estimation) and random (imprecise estimates) errors [29], related to for example omission of foods (mainly snacks and fruits) or misreporting of portion size consumed [30]. The used food composition database was based on the Kenya food database, which is old and lack nutrient values which may have introduced errors. However, we are of the opinion that through the precautions taken like implementation of a standardized methodology,

thorough training of enumerators, and a careful update of the food composition database using standardized procedures [31, 32] these errors will be mainly random, contributing to an increase of variance and hence reducing the ability to find strong associations. In addition, the existence of correlated measurement errors as both the MDD-W and the MPA were derived from the same food intake data, may have inflated the found associations [33].

The diversity of food groups consumed by our study population was limited and mainly consisted of starchy staples, beans and peas, cow milk and vegetables. This did not differ much between seasons, although the percentage of women consuming vitamin A-rich dark green leafy vegetables was higher in Period 1. Accordingly, the mean probability of adequacy for the 11 micronutrients studied is low, being 41% and 44% in pre- and post-harvest season. The percentage of women having an MPA above 0.60, considered as reflecting an acceptable adequacy, is very low at 1.4% and 2.5 % respectively. This confirms earlier studies showing poor women's diets [18] putting them at risk of micronutrient deficiencies and underscoring the need to improve their diets and micronutrient intakes.

The correlations between the Minimum Dietary Diversity score for Women and mean probability of nutrient adequacy in this study were statistically significant, although moderate, and show that there is a definite relationship between a greater dietary diversity and a greater probability of micronutrient adequacy. The ROC analysis provided the basis of the assessment of the performance of the MDD-W to predict micronutrient adequacy. In both seasons, the Area Under The Curve was greater than 0.50, being 0.76, showing an indicator with reasonable potential. This confirms that the MDD-W is a good proxy of micronutrient adequacy among women, although the MDD-W uses different food-groupings than earlier studies [2, 34].

The sensitivity/specificity analysis showed that the MDD-W (≥ 5 food groups consumption) had a high sensitivity of 100%, but specificity below 40% and a total misclassification of above 60%, indicating a poor performance of the score in both seasons. This confirms that the score cannot be used to screen individuals. At the population level, the presence of substantial misclassification is less serious especially when the percentage of false positives is comparable with that of false negatives [2]. In our case, however, false positive far outnumbered false negatives leading to an

overestimation of the prevalence of adequacy using the suggested cut-point of 5 food groups. As the MDD-W is proposed to be used to determine the prevalence of acceptable micronutrient adequacy, we compared the prevalence of women consuming 5 or more food groups with that of women having an MPA of above 0.60. At the very best, these prevalences would be equal and in the worst situation there would be no relationship between the two. Our results show that the prevalence based on the MDD-W cut-off of 5 food groups is much higher than the one based on an MPA>0.60. However, both indicators increased in the same direction going from Period 1 to Period 2. Also, the mean MPA of the group of women at or above the cut-point of 5 was higher than that of the women below 5 food groups. Another way of looking at the performance of the indicator was through the consumption of specific food groups. Among the women consuming 5 or more food groups, a higher percentage consumed the food groups beans, dairy and (vitamin A rich) vegetables compared to the women consuming less than 5 food groups. Hence, although the use of the cut-point of 5 food groups would overestimate the prevalence of acceptable nutrient adequacy, it still indicates that the closer a woman is to the threshold, the better the situation is likely to be in terms of micronutrient adequacy. Although the MDD-W is proposed to be used to determine the prevalence of acceptable micronutrient adequacy in a population, evaluation of the performance of the indicator in our study population shows that interpretation of the prevalence should be in relative rather than in absolute terms.

Results from our study, highlights some challenges in using the MDD-W. It is questionable whether a MPA > 60%, considered as quite low, reflects an adequate intake or even an acceptable intake. As very few women had a diet covering an MPA of 70% or more in our study, comparable to the studies based upon which the MDD-W was validated (FAO, 2014), a cut-point reflecting a higher level of MPA could not be evaluated. Even when considering a MPA>60 as acceptable, it does not mean that all women reaching or exceeding the minimum have an adequate intake of all 11 micronutrients. Furthermore, limitations of the MDD-W are that it cannot be used as a dietary guideline, it is not reflective of all aspects of diet quality and it is not reflective of the intake of fortified foods. Lastly, the MMD-W was evaluated in our study for estimating prevalence of adequate intake, however, we do not know how sensitive the indicator is to change over time. Results do indicate that the MDD-W changes through seasons, but the association with MPA remains consistent in the different seasons. We

also do not know whether the indicator is responsive to changes especially in populations with a very low baseline of dietary diversity. Although these challenges request for further studies, the MDD-W seems a promising tool to assess micronutrient adequacy at the population level in resource poor settings, although the prevalence of adequacy determined using the suggested cut-point of 5 should be interpreted with care especially in populations with low dietary diversity and nutrient adequacy.

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Chapter 6

General discussion

Micronutrient malnutrition is still of public health concern in developing countries, especially among women of childbearing age. The key cause of micronutrient deficiencies is a low intake due to monotonous diets, but food consumption data of women is often lacking. Collection of high-quality food consumption data often rely on expensive and time-consuming methods, which are usually not suitable for use in developing countries. Resource poor settings need data collection tools, which are cheap, simple and easy to use in largely illiterate populations, yet still give valid and accurate results. The dietary diversity score being a count of food groups consumed has gained interest as a simple tool that can be used in such settings to collect data in large surveys. The dietary diversity score has been found to be a good proxy indicator for micronutrient adequacy of women's diets. However, there are still outstanding methodological questions impeding interpretation of the score. The main objective of this thesis is to evaluate the dietary diversity score as a simple tool to assess nutrient adequacy in the diets of rural Kenyan women of reproductive age. This chapter reviews the main findings, discusses limitations of the methods used, proposes areas for further research and finally puts the findings into the larger context of relevance to public health.

Study Findings

The main findings of this thesis are summarized in **Table 6.1**. Both the dietary diversity score and nutrient adequacy were low in this study setting, indicating a monotonous cereal-based diet. The dietary diversity score derived from a quantitative 24hr-recall showed a consistent, positive relationship with mean probability of nutrient adequacy in the diets of rural Kenyan women of reproductive age. These associations were consistent in both seasons studied. However, the dietary diversity score calculated from food data collected by a qualitative free-listing 24hr-recall formed a poor indicator for the prediction of mean probability of nutrient adequacy. This suggested that further refinement of the indicator is needed especially for its use in large surveys. Use of informative foods to calculate a dietary diversity score led to a moderately improved correlation between the dietary diversity score and mean probability of adequacy. The recently FAO /FANTA/UN suggested Minimum Dietary Diversity Score for Women was moderately correlated with mean probability of adequacy of the diet of rural Kenyan

Table 6.1: Main findings by chapters

Summary of findings	
Chapter 2; What impact does seasonality have on the association between the dietary diversity score and nutrient adequacy and its determinants?	
Mean DDS is 4.5±1.2 (Period 1) and 4.0±1.3 (Period 2). Mean MPA is 0.41±0.07 (Period 1) and 0.44±0.08 (Period 2) Correlation is r=0.40 (Period 1) and r=0.38 (Period 2) Season is not an effect modifier (p=0.45)	**The dietary diversity score can be used to predict nutrient adequacy in the diets of rural Kenyan women independent of season.**
Chapter 3; What is the effect of using different methodologies of determining dietary diversity on this association?	
The mean difference of qualitative versus quantitative dietary diversity score is -0.51 ±1.46 (Period 1) and -0.58 ± 1.43 (Period 2). The correlation of the qualitative dietary diversity score and MPA is r=0.14 and 0.19 for Period 1 and 2. The correlation of the quantitative dietary diversity score and MPA is r=0.40 and 0.54 for Period 1 and 2.	**A dietary diversity score based on a qualitative free-listing 24hr-recall is a poor predictor of nutrient adequacy**
Chapter 4: Does a dietary diversity score based on informative foods predict nutrient adequacy better than a dietary diversity score based on food groups?	
The informative food-based score is moderately but significantly correlated with MPA; r=0.54 – 0.59 (Period 1) and r=0.37 – 0.45 (Period 2). These correlations were significantly different from those with the food group-based dietary diversity score in Period 1 but not Period 2 ($p<0.05$).	**Calculation of the informative food-based diversity score did not lead to an indicator that out-performed the food group-based dietary diversity score in predicting nutrient adequacy**
Chapter 5: How does the Minimum Dietary Diversity score for Women (MDD-W) predict nutrient adequacy in a rural poor resource setting?	
Period 1 Women consuming ≥ 5 food groups = 73%, MPA >0.60 =1.4%: False positives =28% MPA for women consuming ≥ 5 = 0.42±0.1. Correlation between MDD-W and MPA is r=0.54 (Period 1) and r=0.45 (Period 2) Period 2 Women consuming ≥ 5 food groups = 64%, MPA >0.60 =2.5% False positives =62% MPA for women consuming ≥ 5 =0.46±0.1.	**The Minimum Dietary Diversity score for Women is a good proxy for nutrient adequacy, but using the cut-off of 5 or more makes it a poor indicator of prevalence of acceptable nutrient adequacy in rural Kenyan women of reproductive age consuming low diverse diets.**

women (of reproductive age), but using the cut-off of consuming 5 or more food groups to reach acceptable adequacy of nutrient intake led to high levels of misclassification.

INTERNAL VALIDITY

The methodological considerations for the cross-sectional study in chapters 2-5, which may potentially influence the validity of the results, such as selection bias, information bias and confounding, are discussed below.

Selection bias

The study setting was at Mbooni district, Kenya, which is a typical rural setting, depending on rain-fed agriculture for a livelihood. The district has a bimodal climate with distinct short (October – December) and long rains (April – June). The area lacks infrastructure, people live in poverty and lack modern amenities like running tap water and electricity (1). The foods available to the population are either homegrown or accessible through markets on market days. The women selected in this area for our study were considered typical of most rural women in Kenya, who are part-time farmers, petty traders and housewives with most of them being semi-literate.

A multistage cluster sampling procedure was used to select the women in our study. Makueni district has 16 divisions, out of which Mbooni division was chosen randomly. Mbooni division has one location and 5 sub-locations. Kyuu sub-location was chosen randomly out of the 5 sub-locations. All the 14 villages in the Kyuu sub location were included in the study sample, and 15 households in every village were selected. The local administration in our study area did not have a census list for all the households in the 14 villages. Therefore, we chose the random walk method to select our study population, which is assumed to be a proxy for the random sampling method where no household census or the list of households are available (2). There could have been a possibility that households near the starting point had a higher chance of being sampled, and that those away from the starting point could have been underrepresented (1). If this occurred and underrepresented households had different characteristics related to the outcomes of our study, this could have influenced our findings, which could have reflected, for example, in an increased or reduced dietary diversity score. However, households in our study area were rather homogenous. Also, the boundaries and central

point of the villages were carefully defined followed by a strictly standardized selection procedure. We, therefore, are of the opinion that it is not likely that the used selection procedure resulted in a selection bias influencing our study results.

Within the households, non-pregnant non-lactating women were selected. In a household with more than one eligible women, one non-pregnant non-lactating woman was randomly selected. To determine the women's physiological status, the eligible women were asked whether they were pregnant or not. No pregnancy test was performed to confirm this response. It is possible that some pregnant women in the first trimester were included in our study as they may have been reluctant to reveal their pregnancy at an early stage (3). However, studies indicate that it is not likely that women change their food patterns in the first trimester (4) nor that their requirements are yet strongly increased in the first trimester (5). We, therefore, expect that inclusion of these women did not affect the dietary diversity score or probability of nutrient adequacy (4). Women were only selected when they had a child older than 2 years, because at that age the majority of children (about 80%) has stopped breastfeeding (6). This ensured that the selected women were non-lactating (7). However, even if the women had one child >2 years and a younger child of < 2 years, who was not breastfed, the woman was eligible for the study. The choice of women with children >2 years might have resulted in somewhat older women being selected for the study. However, it is not likely that the dietary patterns were influenced by the age of the women (8).

The women were given information about the study and a request to participate. When they consented they signed an informed consent form. A large number of women refusing to participate may introduce selection bias as there is a possibility that they are different from the ones consenting. Refusal to participate is generally low in developing countries (9). In our study, all women agreed to participate and so refusal did not affect our study results.

Due to the post-election violence in 2007, the study sampling and administration process had to be stopped temporarily because of insecurity. The first 73 women who were chosen, were from 5 villages, which were located near the main shopping centre in Mbooni division. This first sub-set of women could have been different from the rest of the women sampled 4 months later, after the country had settled from the post-election violence. However, the dietary diversity scores and mean probability of nutrient

adequacy were compared between the first set of 73 women and the second set of 135 women, who were selected after the election violence subsided, revealing no apparent differences. In addition, sub-group analysis for the 67 women who were interviewed during both seasons revealed no difference in results from our studies. Therefore, the conflict did not result in a study population in the first season differing from that of the second season.

Information bias

Potential sources of information bias in the described household field studies are mainly related to the collection of food consumption data: errors accruing from 24hr-recall data, adjusting for day-to-day variations, correlated measurement errors, and food composition table data, which will be discussed below.

Errors associated with 24hr-recall data

During food consumption data collection there is the possibility of introducing random and systematic errors into the data. These errors may be related to the equipment, the interviewer and the respondent.

Concerning equipment, duplicate portions of food consumed by our respondents had to be weighed and water volumes measured when food was not available. Use of weighing scales that were not calibrated or reading the scales improperly could have contributed to the random errors. These errors were avoided as much as possible by calibrating weighing scales every day with known weights. The enumerators were thoroughly trained on how to take readings of food weights, measure water volumes and leftover foods and determine the right portion sizes.

With respect to interviewer bias, not implementing interviewing procedures in a standardised way is another source of random error. The enumerators were first trained thoroughly on the standardised interviewing procedure (involving probing), and on the anticipation and recognition of potential sources of distortion and errors. Proper training of enumerators reduced random errors, which, if occurred, may lead to poor estimates of food portion sizes (2) and may reduce the associations between the dietary diversity score and nutrient adequacy. In addition, introduction of systematic bias by interviewers was avoided in our study by allocating interviewers to different

households every time. The process ensured that an interviewer did not interview the same household twice. If the interviewers were assigned to the same household, they may develop familiarity with the respondent and assume answers from previous interviews. The precautious enumerator training and the avoidance of repeated household interviews by the same interviewer reduced the likelihood of introducing these errors in our study.

Respondents tend to intentionally or unintentionally recall information differentially during a 24hr-recall (10). Some respondents may deliberately give answers they think are desirable, or give them a better image (11). Some respondents may genuinely not remember what they ate, because of relying on their memory to give the answers. Poor reporting by respondents is worse if they have complicated diets or the questionnaire is complicated (12). Also during the 24hr-recall methodology, people systematically tend to omit single food items, especially fruits or snacks, leading to poor estimation of food and nutrient intakes (2). Omission of foods will affect the calculation of dietary diversity scores, by lowering its value and hence weakening the associations studied. However, the effect of the systematic errors was reduced by implementing a standardized multi-pass, probing interviewing technique (13). The multi-pass probing technique itself also helped respondents to remember what was consumed. Furthermore, the actual weighing of duplicate foods might have helped the respondents to improve their ability to indicate portion sizes consumed.

Adjustment for day-to-day variations

Determination of usual intakes of respondents from dietary data was done by statistically adjusting day-to-day variation using the approach proposed by the National Research Council (NRC) (14) developed further by Nusser et al. (15). We preferred to use the NRC method because it is particularly appropriate for adjusting of individual intakes and can be used with a small samples size with equal number of observations per subject, typical of our study (16). To adjust intake distributions using the NRC approach, at least two independent days or three consecutive days of dietary intake data are needed for a representative sub-sample of individuals in the group. Other day-to-day adjustment methods, such as the Iowa University State method (ISU), Multiple Source Method (MSM), and the National Cancer Institute (NCI) method, are specifically suitable

for intakes in populations with a large sample size and repeated intake data for a subsample only (17). These methods were shown to have a similar mean bias and a variability of usual intake that increases with small sample sizes, especially when data is not normally distributed (8). If intake distributions are not properly adjusted for both within-person variation and survey-related effects, such as interview method and interview sequence, the prevalence of nutrient inadequacy will be estimated incorrectly no matter which of the approaches discussed above is chosen. Use of the most suitable method reduced the possibilities of introducing errors that could have affected the results of our study.

Correlated measurement errors

In order to validate one measurement instrument against another, measures should be independent, with information collected from two different time points (18). When the dietary diversity score and nutrient adequacy are calculated from the same food intake data, there is a possibility of getting correlated measurement errors (19). This might have led to inflated associations between the dietary diversity scores and nutrient adequacy (20) reported in chapter 2, 4 and 5. In chapter 3, we studied the association between dietary diversity and nutrient adequacy derived from different data collection tools implemented at different time points, which were one week separated. Results indeed revealed a reduced association between the dietary diversity score with nutrient adequacy, although we could not attribute the reduction solely to the absence of correlated measurement error, as the data collection tools also differed and parallel collection of data with different tools also leads to uncorrelated errors.

Food composition table data

The food intake data obtained from the women had to be converted to nutrient intake data to be used in the various analyses. Calculation mistakes during conversion of food intake data into nutrients may introduce errors into the database. For our study, the Kenyan (21) food composition table was preferred as the main country-specific source of nutrient data, because nutrient values of foods can vary across geographic areas. However, the table was old or outdated (6, 22). The food composition table lacked nutrient values analysed by modern food analytical techniques, thus increasing the possibility of introducing errors into the nutrient intake data (23). This necessitated the

compilation of a food composition table that was systematically developed for this study. The compilation method was clearly documented and other food composition tables, preferably from the region, otherwise from the African continent and lastly the USDA tables, were referred to where necessary (24-28). Some respondents reported foods as cooked. Thus, to account for the nutrient losses that occur during cooking, nutrient retention factors were used for the conversion process (29). During the retention factor calculations, errors might have been incorporated into the nutrient intake database. Although all the conversion calculations were done very carefully to reduce systematic error and bias, it is still possible that they eminently were introduced, which may have affected our associations with the dietary diversity score by decreasing or increasing nutrient adequacy estimations.

Potential confounders

In our study, dietary energy could have confounded the association between the dietary diversity score (exposure) and nutrient adequacy (outcome) (30). The dietary diversity score and nutrient intake both increase in value as total dietary energy increase. It is important to ascertain that the resulted correlations are not due to increasing energy intake. The total dietary energy intake was controlled for in our study by adjusting for it, in the association between the dietary diversity score and mean probability of adequacy. The results of the association between the two remained significant and positive, though the absolute values were reduced. The reduction in value means that mean probability of adequacy is related in part to increasing dietary energy and also to a separate effect on probability of adequacy by increasing the number of food groups consumed (9).

Body Mass Index (BMI) may be a possible confounder as obese people might underreport foods consumed (31). In this study, we had only overweight (20%), but no obese women. In this study, over- and underreporting was calculated using the basal metabolic rate (BMR), energy intake and physical activity level. The cut-off of low (< 0.9* BMR) and high (> 3* BMR) energy intake was used to assess over- and underreporting (32, 33). However, no woman was found to have been below or above these cut-off points (34-36). Therefore, it is not likely that BMI was a confounder in this study (36-38).

Only studies in children have found age as a confounding factor (9). A study in Mali found age and height not to be significant determinants of mean probability of nutrient accuracy (9). It is highly unlikely that the above-mentioned potential confounders affected the association between dietary diversity score and nutrient adequacy.

EXTERNAL VALIDITY

In this section our main findings are reviewed in the context of results from other studies. The aspects that will be discussed below are related to methodological questions that impede the development and use of the dietary diversity score, addressing seasonal effects, food intake methods, selection of foods and the cut-off for estimating the prevalence of acceptable nutrient adequacy.

Seasonality and dietary diversity score

Changes in food patterns, which occur with seasonal changes affect the dietary diversity score and nutrient adequacy. In our study, the dietary diversity score fluctuated from one season to the other. Other studies also show seasonal effects on the dietary diversity score or nutrient adequacy (39-42). The change in nutrient adequacy is usually consistent as it is lower in the lean season compared to the season of food plenty. However, the direction of the change in the dietary diversity score with season is not consistent. This could indicate that there is some food coping mechanism employed by the women. Food coping mechanisms are the households efforts to keep a stable food supply by using a set of strategies to deal with major or minor food stresses (43). Food coping mechanisms can be different in various areas, meaning that the dietary diversity score is affected differently depending on which strategy was adapted. Some coping strategies of reducing meals does not affect the dietary diversity, but only the nutrient adequacy. Turning to consumption of indigenous foods may increase the dietary diversity score, but not necessarily the nutrient adequacy. If the indigenous foods consumed are nutrient-dense, then the nutrient adequacy will probably increase. But more often than not the foods consumed as alternative foods are not nutritious and thus the nutrient adequacy usually decreases (16, 39-41). Although the dietary diversity score and nutrient adequacy changed across seasons, the association between the dietary diversity score or nutrient adequacy remained consistent. This might imply that

the changes in the dietary diversity score or nutrient adequacy are not pronounced enough to affect the association.

However, in our study the seasons were not very distinct. It is possible that in areas with clearly contrasting seasons, the differences in the dietary diversity score could be larger, leading to weaker associations. This could decrease the association between the dietary diversity score and nutrient adequacy. To study the dietary pattern of a resource poor setting, it is important to assess food consumption per season, to observe changes in the dietary diversity score. However, in every season, the dietary diversity score is a good proxy of nutrient adequacy.

Qualitative method for collection of food consumption data

Large studies, such as the demographic health surveys, use a qualitative 24hr-recall to collect food consumption data. The dietary diversity score is validated based on quantitative 24hr-recall methods (34). Validation of the dietary diversity score should be done using a qualitative method. So far, only one study in Mali has compared the dietary diversity scores derived from a list-based qualitative 24hr-recall method against those based on the 24hr-recall quantitative method. The study recommended the use of free-listing qualitative 24hr-recall methods suggesting that it might overcome the problems associated with the list-based method (44). Our study found that the association between the dietary diversity score derived from a qualitative assessment method and nutrient adequacy was low and not significant ($r=0.14$ and $r=0.19$ in Period 1 and 2, respectively).

These findings raise doubts about the ability of an indicator derived from free-listing 24hr-recall to predict micronutrient adequacy. Use of a 15 g quantity food restriction for the food to count as food group could improve the qualitative 24hr-recall derived dietary diversity score. Using a qualitative 24hr-recall in large surveys like the demographic health survey is still useful, because it provides useful information on the diversity of the diets. But usefulness of qualitative methods to derive a dietary diversity score is weakened to predict nutrient adequacy. Further improvement of the qualitative indicator is necessary and could be done by excluding foods consumed in small quantities, however further research in this aspect is recommended.

Food group-based indicator versus informative food-based score

In the dietary diversity score, food groups are categorised according to the type of foods. The foods in these groups might not necessarily contain foods that contribute to intake of micronutrients and they might not be consumed regularly or in large quantities. Such foods may increase the dietary diversity score, but not nutrient adequacy, weakening their associations. Focusing on informative foods may potentially overcome the above-mentioned limitation. Informative food scores are derived from foods that are consumed by the majority of the women and contribute most to the intake of micronutrients and to the variance of intake of micronutrients. The food group-based dietary diversity score is a count of food groups consumed within a given period in time, irrespective of the foods consumed within a food group. Indeed our study shows that the informative food score improves the correlation between the dietary diversity score and the nutrient adequacy indicating to be a better predictor of nutrient adequacy. However, the improvement is moderate. To derive the informative food score, the researcher needs to know the types of foods (including indigenous foods) and the usual portion sizes, consumed in the setting. The need for prior knowledge of foods consumed will increase the time and costs needed for a survey, which is not normally available. In addition, the indicator is context-specific. Maillot et al (2007) also stated that the informative food score is a context-specific indicator (45). Given the limitations of informative food-based scores listed above, it would be recommended to continue the use of the food group-based score in large-scale surveys.

Global Minimum Dietary Diversity for Women (MDD-W)

The Minimum Dietary Diversity score for Women for global use was recommended in 2014. Few studies, if any, have yet evaluated this indicator. The development of MDD-W stems from the need for a dichotomous indicator to determine the prevalence of women with adequate micronutrient intake, defined as being a mean probability of adequacy of above 0.60, corresponding with a consumption of 5 or more food groups; MDD-W ≥5. A positive indicator was chosen, because it aligns with the minimum dietary diversity score for children recommended by WHO and this positive indicator has a threshold sufficiently high that those at or above the threshold could be labelled as more likely to have an acceptable mean probability of adequacy (46). Our study evaluated the indicator

at the individual level, but concluded at the population level. We found that the Minimum Dietary Diversity score for Women was a moderate predictor of nutrient adequacy. However, it was still slightly better than the dietary diversity score based on 13 food groups, which aligns with earlier studies indicating that increasing food groups will not improve the indicator (9).

A dichotomous indicator is a necessity to enable researchers to estimate prevalence of women meeting dietary criteria, which makes global comparison easier (46). Arimond, et al. (2010) studied women's diets in five sites and with same indicators, and attempted to derive a cut-off point for setting a dichotomous indicator for assessing prevalence of nutrient inadequacy. This cut-off point was not found, because it was not possible to balance sensitivity and specificity. Another study in Madagascar on children 6 to 23 months also showed that it is difficult to balance sensitivity and specificity. In an effort to increase sensitivity while using the dietary diversity score, they ended up with high misclassification, reduced specificity and more false positives (47). Arimond, et al. (2010), suggested that at the population level a certain amount of misclassification of a dichotomous indicator could be acceptable. When at population level the false positives are equal to the false negatives, the found prevalence would reflect the proportion in a population having an acceptable nutrient adequacy. However, in our study the false positives far outnumbered the false negatives. Our study setting had hardly any women with an MPA above 0.60. Yet, there was a large number of women with a dietary diversity score of ≥5. This indicates that the dietary diversity score ≥5 as cut-off in a rural setting like our study area does not correctly indicate the prevalence of acceptable mean probability of nutrient adequacy. However, the MDD-W is a good indicator for predicting nutrient adequacy, but the cut-off ≥ 5 and mean probability of adequacy of > 0.6 might not be very suitable in our study population. More studies should be carried out on sensitivity and specificity to support development of a dichotomous indicator to assess micronutrient inadequacy or adequacy.

Conclusion

Although dietary diversity changes with season, the dietary diversity score is still a good proxy for nutrient adequacy irrespective of season in an area with low to moderate seasonality. The free-listing qualitative 24hr-recall makes a poor indicator of nutrient

adequacy, requiring validation for use in large surveys in poor resource settings. Although an informative food-based score is a moderate predictor of nutrient adequacy, its advantages do not outway advantages of food group-based scores. Of the two, the food group-based score is therefore preferred. Our study, to the authors' knowledge, is the first to evaluate the ability of the Minimum Dietary Diversity score for Women to predict nutrient adequacy. The Minimum Dietary Diversity score for Women formed a good indicator for predicting nutrient adequacy in our study settings. However, the Minimum Dietary Diversity score for Women using a cut-off of the dietary diversity score of ≥5, does not meet the acceptable mean probability of nutrient adequacy of >0.6 in our resource poor population.

Future research

Further studies are needed to determine how dietary diversity scores change over time to provide evidence for validity of use of the indicator in monitoring and evaluating nutritional interventions. Specifically, how the score responds to actual change in the probability of adequate nutrient intake, for example how the score changes due to nutritional interventions. The study on the effects of seasonality is part of this, and although our study did not find a seasonal effect on the association between the dietary diversity score and nutrient adequacy, further studies are needed in areas with more distinct seasons to confirm our results. A study of the robustness of the association between the dietary diversity score and nutrient adequacy in unimodal climates (or more contrasting seasons) is needed to provide evidence of the indicator for use through-out the year.

The dietary diversity score has been validated by quantitative studies. However, in poor resource settings, food consumption data are collected by use of qualitative 24hr-recall. Validation of qualitative 24hr-recall for deriving the dietary diversity scores has not been done yet, especially not for assessing micronutrient adequacy of women's diets. This could be carried out by performing a study using several qualitative food consumption methodology tools in different seasons (to take care of the effect of seasonality on the dietary diversity score and comparing their ability to predict nutrient adequacy).

The validity of the cut-off of the Minimum Dietary diversity score for Women for global use of ≥5 should be studied in different settings. In poor resource settings, where the diversity of the diet is low with little variation of foods, use of a cut-off of ≥5 will probably not reflect mean probability of nutrient adequacy of >0.6. Search for a cut-off for a dichotomous indicator that can be used globally in different types of settings should be continued. In addition, it should be considered whether in resource poor settings with low dietary variety, a validated negative indicator would be more applicable for indicating poor nutrient adequacy.

Public health significance

In Kenya, the only current policy for complementary feeding is for infants and young children on appropriate feeding practices (IYCF), which is recommended by WHO. Concerning dietary diversity, it states that for a child (6 to 24 months) who is still breastfed, consumption of food groups ≥4, (i.e. a Minimum Dietary Diversity score for Women of ≥4) indicates adequate nutrient intake. The current position in Kenya is that there is no policy on how to determine the micronutrient adequacy in the diets of women.

Kenya Demographic Health National Surveys (KDHS), (supported by the USAID-funded MEASURE DHS program), which are designed to assist developing countries to collect data on fertility, family planning, and maternal and child health is an entry point where the Minimum Dietary Diversity Score for Women could be used to assess nutrient adequacy for women in the country. KDHS collect data every 5 years, in the entire country. This would provide an important source of information on women's diets to be used by decision makers, non-governmental organisations that are already working on health and nutrition issues, the nutrition community and governments for advocacy, identification and location of vulnerable groups in countries for the creation of awareness and for sensitisation of women to eat nutritious foods, hence leading to adequate micronutrient intake.

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Supporting Information

SI Table. Estimated Average Requirements (EAR) to be used for assessing Probability of Adequacy[ab] for adult women

	Females 19-65 years		Females 15-18 years		Pregnant women		Lactating women	
	EAR	**SD[c]**	**EAR**	**SD[c]**	**EAR**	**SD[c]**	**EAR**	**SD[c]**
Vit A (RAE/d) [d]	270 [e]	54	365 [e]	73	370[e]	74	450 [e]	90
Vit C (mg/d)	30 [e]	3.0	30 [e]	3.0	40 [e]	4.0	55 [e]	5.5
Thiamin (mg/d)	0.9 [f]	0.09	0.9 [f]	0.09	1.2 [f]	0.12	1.2 [f]	0.12
Riboflavin (mg/d)	0.9 [f]	0.09	0.8 [f]	0.08	1.2 [f]	0.12	1.3 [f]	0.13
Niacin (mg/d)	11 [f]	1.65	12 [f]	2	14 [f]	2.1	13 [f]	1.95
Vit B_6 (mg/d)	1.1 [f]	0.11	1.0 [f]	0.1	1.6 [f]	0.16	1.7 [f]	0.17
Folate (µg/d)	320 [e]	32	330 [e]	33	520 [e]	52.0	450 [e]	45.0
Vit B_{12} (µg/d)	2.0 [e]	0.2	2.0 [e]	0.2	2.2 [e]	0.22	2.4 [e]	0.24
Calcium (mg/d)[g]	1000	-	1300	-	1000		1000	
Iron (mg/d)	See Table S2	-	-	-	22 [h]	2.07	10% bioavail: 11.7 [i] 5% bioavail: 23.40	3.51 7.02
Zinc (mg/d)	50% bioavail: 2.00 [j] 30% bioavail: 3.33 15% bioavail: 6.67	0.50 0.83 1.67	50% bioavail: 2.90 [f] 30% bioavail: 4.80 15% bioavail: 9.60	0.7 1.2 2.4	50% bioavail: 3.00 [k] 30% bioavail: 5.00 15% bioavail: 10.00	0.75 1.25 2.50	50% bioavail: 3.40 [k] 30% bioavail: 5.67 15% bioavail: 11.3	0.85 1.42 2.83

[a] All values are taken from WHO/FAO (2004) unless otherwise stated.

[b] Values for EAR are adjusted for an assumed bioavailability (WHO/FAO, 2004). Thus, EAR refers to intake of the nutrients and not the physiological need for the absorbed nutrient.

[c] All SDs were calculated based on EAR and CV (SD=CV*EAR/100). CV is assumed to be 10% for all micronutrients except 15% for niacin (IOM, 2002), 20% for vitamin A (IOM, 2002), 25% for zinc (WHO/FAO 2004) , 9.4% and 30% for iron, for pregnant and lactating women, respectively (IOM, 2002).

[d] One µg retinol equivalent (RE) is equal to 1 µg all-trans-retinol, 6 µg β-carotene and 12 µg α-carotene or β-cryptoxanthin (WHO/FAO 2004) . Note also the EAR for vitamin A refers to intake adequate to prevent the appearance of deficiency-related syndromes (WHO/FAO 2004).

[e] EAR taken from WHO/FAO (2004)

[f] EAR back-calculated from RNI (Recommended Nutrient Intake) (WHO/FAO, 2004) .

[g] This is not an EAR, but rather Adequate Intake (AI) from IOM (1997). Following Foote et al. (2004) we calculate probabilities of adequacy to be: 0% when intake ≤ ¼ of the AI; 25% for intakes > ¼ and ≤ ½ of the AI; 50% for intakes > ½ and ≤ ¾ of the AI; 75% for intakes > ¾ and ≤ AI; and 100% for intakes above the AI.

[h] EAR for iron intake, as presented in IOM (2000, page 347). IOM estimates that bioavailability is 18% in the 1st trimester and 25% in the 2nd and 3rd. As information on month of pregnancy will not be available in most datasets, a weighted average of 23% bioavailability should be used for all pregnant women.

[i] Gives EAR on iron for two levels of absorption for lactating women, based on IOM (2002). According to WHO/FAO (2004), either a very low (5%) or low (10%) absorption level can be assumed in a developing country setting.

[j] This is the median requirement of zinc required given three levels of bioavailability: high (50%), moderate (30%) or low (15%) bioavailability. The researcher should choose one of these levels of bioavailability based on criteria given by WHO/FAO (2004). For non-pregnant non-lactating women, the WHO/FAO EAR (1 mg/d) is adjusted for bioavailability.

[k] To estimate EAR for zinc for pregnant and lactating women, the following method was used: RNIs were back-calculated to find EAR for each trimester/three months of lactation. The three EARs each for pregnant women and for lactating women were averaged, since in our datasets we will not know trimester or number of months since child's birth.

S2 Table. Probabilities of Adequate Iron Intakes (mg/d) and Associated Ranges of Usual Intake in Adult Women Not Using Oral Contraceptives[a]

Probability of adequacy	Total absorbed iron	10% bioavailability	5% bioavailability
0	<0.796	<7.96	<15.91
0.04	0.796-0.879	7.96-8.79	15.91-17.59
0.07	0.880-0.981	8.80-9.81	17.60-19.65
0.15	0.982-1.120	9.82-11.20	19.66-22.42
0.25	1.121-1.237	11.21-12.37	22.43-24.76
0.35	1.238-1.343	12.38-13.43	24.77-26.88
0.45	1.344-1.453	13.44-14.53	26.89-29.08
0.55	1.454-1.577	14.54-15.77	29.09-31.56
0.65	1.578-1.734	15.78-17.34	31.57-34.69
0.75	1.735-1.948	17.35-19.48	34.70-38.98
0.85	1.949-2.349	19.49-23.49	38.99-47.01
0.92	2.350-2.789	23.50-27.89	47.02-55.79
0.96	2.790-3.281	27.90-32.81	55.80-65.63
1	>3.28	>32.81	>65.63

[a] This table was adapted from Table I-7 in IOM (2000) which gives probability of adequacy (PA) for various levels of iron intakes, using an iron bioavailability of 18%. Based on those figures, the PA for various levels of *absorbed* iron has been calculated, adjusted for a bioavailability of 10% and 5%.

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Summary

The major cause of micronutrient deficiencies are low intake due to monotonous diets, especially among women of childbearing age. Due to costly and time- consuming food intake assessment methods, there is generally lack of information on women's diet quality and nutrition. The dietary diversity score was proposed and validated to be a good, simple and proxy indicator for micronutrient adequacy. However, there are still outstanding methodological questions related to seasonal effects, food intake methods, selection of foods and the cut-off for estimating the prevalence of acceptable nutrient adequacy. By addressing these questions, there will be further development and global use of the dietary diversity score. This thesis evaluated the performance of this simple dietary diversity indicator for assessing nutrient adequacy in the diets of rural women in Kenya.

The study was conducted in Mbooni division of Makueni district. It is semi-arid to arid land with low erratic rainfall of, on average, 500 mm annually. The actual field work was in Mbooni division with a population of 55,984 persons. The division experiences two rainy seasons, long rains occur in March/April and short rains occur in November/December. Subsistence farming is practiced with most crops being harvested after the short rains. Kyuu sub-location (having 14 villages) was randomly selected and in each village 15 women of reproductive age (non-pregnant, non-lactating), having a child between 2-5 years, were selected using the random walk method.

Food consumption data was collected by well-trained interviewers using a quantitative multi-pass 24hr-recall on 3 non-consecutive days separated by a minimum of 2 and a maximum of 11 days. A qualitative free-listing 24hr-recall was carried out within the same week using a questionnaire consisting of a list of local/indigenous foods used in the region, categorized per food group. Responses were ticked by an interviewer, according to the corresponding food and food group category. Data collection was done in pre-harvest (Period 1, October 2007, n=73) and post-harvest (Period 2, April 2008, n=203) seasons. Dietary diversity scores (DDS) were derived based on 13 food groups (in chapter 2, 3 and 4) and 10 food groups (chapter 5). For a food to count, a minimum intake threshold per food group of 15 g was applied (chapter 2, 4 and 5). There was no minimum restriction used in the study described in chapter 3. The intakes (adjusted for day-to-day variance) and the probabilities of adequate intake (PA) were calculated for vitamins A (RAE), C, B_{12}, B_6, riboflavin, niacin, thiamine, folate, zinc and calcium based on

their respective estimated average requirements (EARs) and distributions. Mean probability of nutrient adequacy (MPA) was computed as the average PA of the 11 micronutrients, which was consistently used for all the studies reported in this thesis.

In **Chapter 2,** seasonal variations in dietary diversity, nutrient adequacy, and their association were examined based on the quantitative 24hr-recall in the two seasons using correlation and regression analysis. The dietary diversity score was significantly higher in Period 1 (4.5 ± 1.2) compared to Period 2 (4.0± 1.3), indicating low diverse diets, based on starchy staples and low or no consumption of animal source foods. Mean probability of adequacy was significantly lower in Period 1 (0.41 ± 0.07) compared to Period 2 (0.44 ± 0.08). The dietary diversity score and mean probability of adequacy were significantly, but moderately associated in both seasons with r=0.40 (Period 1) and r=0.38 (Period 2) reducing to r=0.20 and r=0.20 after adjusting for energy intake. DDS cut-off of 4 or less maximised sensitivity and specificity, detecting low micronutrient adequacy of intake (defined as MPA≤0.40) in both periods, but the level of misclassification was high. The association between dietary the diversity score and micronutrient adequacy was found to be independent of season (p=0.45). We concluded that although the dietary diversity score and nutrient adequacy vary per season, the dietary diversity score can be used as a good proxy for nutrient adequacy in each season. However, a firm cut-off point for creating a dichotomous indicator of inadequate intake could not be determined.

Most large-scale studies use qualitative methods to derive a DDS, while the DDS is validated using quantitative dietary assessment methods. In **Chapter 3**, the performance of a dietary diversity score derived from a qualitative free-listing (DDSql) and from the quantitative (DDSqn) 24hrrecall were compared. Correlation and Bland-Altman plot analysis, intra-class correlation coefficients and κ statistics were used to determine the level of agreement between the two dietary diversity scores and their association with MPA. Sensitivity/specificity analysis was used to detect cut-off values of DDS indicating low nutrient adequacy in both seasons. The DDSqn and DDSql showed little agreement with a mean difference (DDSqn-DDSql) of -0.51±1.46 (Period 1) and -0.58±1.43 (Period 2), indicating systematic over-reporting by qualitative free-listing 24hr-recall. In both periods, the correlation with MPA was lower for DDSql (r=0.14 and 0.19 in Period 1 and 2 respectively, p>0.05) than for DDSqn (r=0.40 and 0.54 in Period 1

and 2 respectively, p<0.01). The Bland-Altman plots show that the limit of agreement between the two indicators is wide in both periods. The intra-class correlation coefficient (ICC) values are low at 0.42 and 0.46 in Period 1 and 2, respectively. The dietary diversity score derived from qualitative free-listing 24hr recall method was a poor indicator and needs further refinement to improve its performance for global use.

In order to improve performance of the dietary diversity score, we evaluated a score based on informative foods and compared it with the food group-based score in **Chapter 4.** Foods for the informative food-based scores were selected on the basis of percentage contribution to intake and to variance of intake of the 11 selected micronutrients. Six indicators were developed, based on 90%, 70% and 50% contribution to intake (three indicators) and to variance in intake (three indicators). Association of these indicators with mean probability of adequacy were compared with that of the food group-based dietary diversity score using Spearman and partial (adjusted for energy intake) correlations. Differences between the indicator correlations were tested using Steiger's equation. Informative food-based scores and food group-based dietary diversity scores were significantly, but moderately associated with mean probability of adequacy (r=0.54-0.59 in Period 1; r=0.37-0.45 in Period 2). Correlations of informative food-based scores were higher than those of food group-based score in both seasons, but only significantly different in Period 1 and only when not adjusted for energy intake. In view of the practical difficulties in implementing informative food-based scores and the moderate improvement of the performance of the indicator to predict nutrient adequacy, we advised to give preference to the use of a food group-based dietary diversity score in resource poor settings.

In **Chapter 5**, we investigated the ability of the recently launched Minimum Dietary Diversity score for Women (MDD-W) to predict micronutrient adequacy and prevalence of acceptable adequacy in rural poor resource settings. Based on the quantitative 24hr-recall, MDD-W was constructed based on 10 food groups, using a minimum consumption of 15 g for a food group to count. In each season, correlation analysis tested the association of MDD-W with the mean probability of nutrient adequacy (MPA) of intake for 11 micronutrients. Proportions of women consuming 5 or more food groups and of women with MPA above 0.60 were compared, and proportions of women consuming different food groups were compared between those consuming less than 5 and

consuming 5 or more food groups. Sensitivity/specificity analysis at MPA > 60% were used to assess performance of the MDD-W cut-off of 5 food groups or more. The mean of MDD-W was higher in Period 1 (5.2 ±0.9) compared to Period 2 (4.8 ±1.1) with 73% and 64% of women consuming 5 food groups or more. Only 1.4% and 2.5% had an MPA>0.60. The MDD-W was significantly, but moderately associated with MPA with higher correlations in Period 1 (r=0.53) than in Period 2 (r=0.45). Using MDD-W of 5 or more resulted in high total misclassifications with a positive predictive value of below 5% in both periods. We concluded that the Minimum Dietary Diversity score for Women is a good indicator of nutrient adequacy, but using the cut-off of 5 or more is a poor indicator of prevalence of acceptable nutrient adequacy in rural Kenyan women of reproductive age consuming low diverse diets.

Chapter 6 discusses the main findings and conclusions of this thesis by putting these in a public health perspective, including recommendations for possible future research. Overall, our study was carried out in an area with a bimodal climate showing moderate seasonal variations, weakening our ability to detect an effect of season on the associations of the dietary diversity score and adequacy of intake. In addition, due to post-election violence, data collection in the first period had to be discontinued resulting in a smaller sample size restricting statistical power to compare seasons. Based on our study we conclude that the food-group based dietary diversity score is a good proxy for nutrient adequacy of the diet of women of reproductive age in poor resource settings. Using free listing qualitative 24hr-recall to derive the dietary diversity score does seriously reduce the performance of the indicator to predict nutrient adequacy. Replacing a food group-based score by an informative food-based score is not recommended, although the performance is improved but practical limitations hamper implementation of such a score. We also conclude that the minimum dietary diversity score for women is a good proxy for nutrient adequacy, but the dichotomous indicator based on the consumption of 5 food groups or more is a poor indicator of prevalence of acceptable nutrient adequacy. Further studies should be carried out in areas with more distinct seasons to investigate the differential effect of season on the performance of the dietary diversity score. Also, the qualitative derived scores need to be further refined to improve performance to predict nutrient adequacy among women. Lastly, research is needed to come to a good dichotomous dietary diversity indicator to assess prevalence of acceptable adequate intake. It is advised to include the dietary diversity score in

future National Kenya Demographic Health Surveys in order to assess and evaluate diets of women of reproductive age in Kenya.

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About the author

Curriculum Vitae

Sophia Ngala was born on 23rd January, 1961 in Kenya. She graduated from Kenya Polytechnic with a Higher National Diploma in 1989. The Applied Nutrition Programme, Department of Food Science, Nutrition and Technology gave her a scholarship to study for a degree in Food Science at Michigan State University, in 1994, graduating with a BSc. in Food Science High Honours in 1996. On returning to Kenya, she was again sponsored by The Applied Nutrition Programme, Department of Food Science, Nutrition and Technology for an MSc. in Applied Human Nutrition at the University of Nairobi, graduating in 2003. After the master's degree she continued to work at the University of Nairobi, and has carried out various researches and consultancies in the field of Nutrition. In February 2007, Sophia joined the Division of Human Nutrition, to pursue a PhD in Nutrition and Health, sponsored by NUFFIC, Netherlands under supervision of Dr. Frans Kok, Dr Inge D. Brouwer and Dr. Alice M. Mwangi. She is still a Lecturer at the University of Nairobi, Department of Food Science, Nutrition and Technology in the Applied Nutrition Unit. She has a daughter, Sally Akoth Omondi.

List of publications and posters

Publications

- Oiye S.O, Konyoles S and Ngala S. A. (2012). Effects of Rosemary Spice (Rosmarinus Officinalis L.) and nitrite Picking Salt combination of Keeping and Organoleptic quality of Beef sausages. Journal of Basic and Applied Scientific Research. 2(4) 4008-4015. ISSN 2090-4304.
- Ngala, S., Ambula, M., Mwanza, R., Gitika, P., Mburugu, G., Mwaniki, J., Onyango, C., Shiluli, M. (2006). Water for the Thirsty: a case study of Katulani Location water situation, in Kitui District, Kenya. ICRA / KARI: Netherlands, 2006.

Conference posters

- Poster presentation – Ngala, S., (2005). Coping strategies of Drought prone Areas-Kitui and Mwingi Districts: INNC Congress, Kenya, 2005.
- Poster presentation – Duijzer, G., Ngala, S., Mwangi, A. M., Brouwer, I. (2009). The effect of food groups on the association between dietary diversity and nutrient adequacy. Wageningen Nutritional Sciences Forum 2009. Too much – too little, 4th to 6th March , 2009 ; Arnhem, The Netherlands . Abstract in European Journal of Clinical Nutrition pg. S23 Volume 63 Supplement 3 June 2009.
- Poster presentation – Bollemeijer, I., Ngala, S., Mwangi, A. M., Brouwer, I. (2010). Cut-off points for dietary diversity for under-fives in Mbooni-Kenya. 4th African Nutritional Epidemiology Conference. 4th to 8th October 2010, Safari Park Hotel, Kenya.
- Poster presentation – de Cock, M., S., Ngala, S., Mwangi, A. M., Brouwer, I. (2010). Dietary diversity and nutrient adequacy: Comparing methods. 4th African Nutritional Epidemiology Conference. 4th to 8th October 2010, Safari Park Hotel, Kenya.
- Poster presentation – Asare, E., Ngala, S., Mwangi, A. M., Brouwer, I. (2012). Differences in dietary diversity and its association with nutritional status between women of child-bearing age and non-breast feeding children (2-5 years) in rural Kenya. Nutrition congress Africa 2012. 1-4 October 2012, University of Free State, Bloemfontein, South Africa.
- Poster presentation – de Greve, S., Ngala, S., Mwangi, A. M., Brouwer, I. (2012). Dietary diversity as an indicator for nutrient adequacy and nutritional status

among children 2 to 5 years in Mbooni Division, Kenya. Nutrition congress Africa 2012. 1-4 October 2012, University of Free State, Bloemfontein, South Africa.

Poster presentation – Kogi-Makau, W., Kaindi, D. W. M., Mwangi, A. M., Ngala, S., Andago, A. A., Mbera, G., Mwangi, M., Andango, P. (2012). Towards small and medium entrepreneurs micronutrient capacity development in knowledge and product formulation in Kenya. Nutrition congress Africa 2012. 1-4 October 2012, University of Free State, Bloemfontein, South Africa.

Overview of completed training activities

Discipline specific activities

Courses

- 8th International advanced course on nutritional and lifestyle epidemiology. Wageningen University, The Netherlands 2007.
- Applied data analysis in nutrition and health research. Wageningen University, The Netherlands 2007
- Food composition data collection training and use of VBS-KOMEET, Wageningen University, The Netherlands, 2007
- The complexity of impact monitoring on MGD 1. Wageningen University, The Netherlands 2009
- National workshop on monitoring tools for assessing food access and dietary diversity EC/FAO. Safari park hotel, Nairobi, Kenya 2009
- Nutrition in Emergencies Colloquium. Nutrition works/Emergencies Nutrition Network/University of Nairobi, Lodwar, Kenya 2010
- International course on the production and use of food composition data in nutrition. Pretoria, South Africa 2010
- Mobile technology for Nutrition. Wageningen University, The Netherlands 2014.
- NL for NIL malnutrition! The Lancet Nutrition Series 2013: What's their message – what's our action? Ministry of Foreign Affairs. The Hague, The Netherlands 2013

Conferences and meetings

- Food Sovereignty: Promoting or Undermining Food Security? Seminar, Wageningen University, The Netherlands 2007
- Nutritional Science Forum Wageningen University, The Netherlands 2009
- Nutrition Congress Africa. Safari Park hotel, Nairobi, Kenya 2009
- National workshop on monitoring tools for assessing food access and dietary diversity EC/FAO. Safari park hotel, Nairobi, Kenya, 2009
- Nutrition Congress Africa 2012. University of Free State, Bloemfontein, South Africa 2012
- Nederlandse Academie van Voedingswetenschappen (Dutch Nutrition Society Conference) Wageningen University, The Netherlands 2014
- Mini-symposium (INSTAPA, WIAS, VLAG) Nutritional iron, anaemia and infectious diseases. Wageningen University, The Netherlands 2014

General courses

- VLAG PhD week – 17th edition. Bilthoven, The Netherlands 2007
- Information Literacy for PhD including Endnote program. Wageningen University, The Netherlands 2007
- SME TOT Materials Testing Course – INSTAPA, Maseno Agricultural Training Centre. Kenya 2010
- National Nutrition Action Plan Workshop. Ministry of Public Health, Bontana Hotel Nakuru. Kenya 2011
- Africa Day – Wageningen, Organised by African Study Center – Leiden University and Wageningen University, The Netherlands 2012
- Introduction to Data Analysis. Erasmus University, Rotterdam, The Netherlands 2009
- Regression Analysis. Erasmus University, Rotterdam, The Netherlands 2009
- Scientific Writing for publication. Bloemfontein, South Africa 2012

- Scientific writing and presentation. Wageningen University, The Netherlands 2012
- WGS PhD Workshop Carousel Visualising Science; Finding and acquiring small grants; Writing propositions; Scientific Publishing. Wageningen University, The Netherlands 2014

Optional courses and activities

- Research proposal development, Wageningen University, The Netherlands 2007
- Staff Seminars, Wageningen University, The Netherlands 2007
- International PhD tour to Mexico and South West USA. Wageningen University. The Netherlands 2011