Verifying Validity of the Household Dietary Diversity Score: An Application of Rasch Modelling

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Paper prepared for presentation at the EAAE 2014 Congress
'Agri-Food and Rural Innovations for Healthier Societies'

August 26 to 29, 2014
Ljubljana, Slovenia

Abstract:
The Household Dietary Diversity Score (HDDS) was developed to measure household food access, one of the levels of food security. Previous research has shown dietary diversity is related to food security. However, the specific way in which the HDDS measures food security has never been validated. Based on the results of a Rasch model on datasets from Colombia and Ecuador we conclude this indicator in its current form is not internally valid, has limited external validity only in our Colombian data, and is not comparable across cultural settings. More research is warranted into the food groups that make up the indicator as well as the recall period on which it is based.
Key words: HDDS, Rasch modelling, food security indicators, validity, dietary diversity

Introduction

While the definition of food security formed at the 1996 world food summit (FAO, 1996) is widely adopted by consensus, disagreement remains on the indicators that assess, quantify and qualify food security, and on how to operationalize these indicators at national, household or individual level (Jones, Ngure, Pelto, & Young, 2013; Pinstrup-Andersen, 2009; P. Webb et al., 2006). Food security is measured in different ways. For example, anthropometric measures are used to monitor growth of children under five (Pinstrup-Andersen, 2009); recalls of food consumed in past 24 hours or over a longer reference period are recorded to measure intake of macro- and micronutrients (G. Kennedy et al., 2010); and data on food expenditure is used to define food poverty lines (Rose & Charlton, 2002); while experience-based responses such as the Household Food Insecurity Access Score (HFIAS) elicit perceived consequences of not having enough food (Jones et al., 2013). Research institutions and development organisations alike apply such indicators to identify food insecure households or analyse effects of interventions on food security (Jones et al., 2013).

A dietary diversity indicator is a particularly interesting way to measure food security, because it is simple to implement, can be administered at household and individual level, and is a useful outcome in itself (Hoddinott & Yohannes, 2002). There is a shortage of validity studies of survey-based dietary diversity indicators, especially regarding the way questions are posed and how these are handled and interpreted (Ruel, 2003). Particularly pressing issues are the responsiveness of food security indicators to improved food security, their discriminatory power in distinguishing food secure from food insecure households, and their validity across different cultural settings. When measured at an individual level, dietary diversity scores are generally found to be a good proxy for micronutrient adequacy (Arimond & Ruel, 2004; Arimond et al., 2010; Hatloy, Hallund, Diarra, & Oshaug, 1999; G. L. Kennedy, Pedro, Seghieri, Nantel, & Brouwer, 2007; Moursi et al., 2008; Steyn, Nel, Nantel, Kennedy, & Labadorios, 2006). When dietary diversity is measured at a household level, it is considered an indicator of food security (Ruel, 2003). There does seem to be a positive relationship between household dietary diversity and household food security (Faber, Schwabe, & Drimie, 2009; Heady & Ecker, 2013; Hoddinott & Yohannes, 2002; G. Kennedy et al., 2010). However, because of the variety of ways in which dietary diversity is measured in these studies, it is hard to establish a definitive link. In fact, some authors even question what it is that is being measured by these indicators (Ruel, 2003).

This paper aims to test the validity of the Household Dietary Diversity Score (HDDS), which has become a mandatory component of all new USAID-financed *"Title II Multi-Year Assistance Programs (MYAP) with improved household food access as an objective*" (Swindale & Bilinsky, 2006) and is frequently used in other development programs. We check its internal dynamics (i.e. does the score increase with better food access), external dynamics (i.e. does the score increase with higher income and assets), and cross-cultural validity (i.e. can the score be compared over cultures with different food consumption habits). We use data collected from a sample of Colombian and Ecuadorian households, and apply Rasch modelling to define a ‘refined’ household dietary diversity score (HDDS) which is internally valid. This refined HDDS is compared over different income groups and different food cultures.

Household Dietary Diversity Scores

Dietary diversity refers to the variety of foods consumed by individuals or households (Jones et al., 2013; Ruel, 2003). When measured on a household level dietary diversity is related to the socio-economic position of the household and food security, and when measured on an individual level to dietary quality and nutritional status (Ruel, 2002). This relationship makes dietary diversity relevant for food security, which requires access to a nutritionally adequate diet (FAO, 1996). Dietary diversity might not only be linked to dietary quality, but also imply dietary quantity. According to Bennett’s Law, as people become wealthier they switch from starch-dominated diets to more varied diets including vegetables, fruit, dairy products, and meat (Bennett, 1941). Although calorie intake might not increase above a certain level of wealth, Jensen and Miller (2010) suggest people quickly shift to improving the taste of their food bundle when their incomes increase. Their findings are in line with classic economic theories of demand (Maslow, 1943). In other words, households with sufficiently diverse diets can be assumed to at least consume enough food not to be hungry. Therefore, dietary diversity is expected to be an indicator for food security (Ruel, 2003).

Dietary diversity can be measured by counting the number of foods or food groups consumed over a certain reference period. These groups can be simply counted or a weight can be attached to them based on their nutritional value. Some indicators also take into account the frequency at which the foods were consumed, or specify a minimum portion size required for a food to be counted in the index (see Ruel (2003) for a review of different indicators). Of the food-group indicators, the HDDS analysed in this paper is probably the most widely used. It was developed by the Food and Nutrition Technical Assistance (FANTA) and actively promoted by USAID. Moreover, this index is the basis for the recent FAO "*Guidelines on measuring household and individual dietary diversity*" (FAO, 2012).

The HDDS was developed to measure household food and designed to be an easy-to-use and quick-to-implement index, making it ideal for impact evaluations of development programmes (Swindale & Bilinsky, 2006). It measures dietary diversity by counting the number of food groups that were consumed by the household over the last 24 hours. The indicator consists of twelve food groups: cereals; roots and tubers; vegetables; fruits; meat, poultry, and offal; eggs; fish and seafood; pulses, legumes, and nuts; dairy products; oils and fats; sugar and honey; and miscellaneous, such as condiments. These twelve food groups are based on the groups used to construct the United Nation's Food and Agriculture Organisation (FAO) food balance sheets (Swindale & Ohri-Vachaspati, 2005). The value of the HDDS equals the number of food groups consumed in the last 24 hours. A higher score reflects higher dietary diversity and hence better household food access (Swindale & Bilinsky, 2006).

Although the link between dietary diversity and micronutrient adequacy of individual diets (see Kennedy et al. (2010) and Jones et al. (2013)) is well established, the relation between household dietary diversity and household food security is less clear (Heady & Ecker, 2013; Ruel, 2003). Previous studies were based on indicators differing in regard to their inclusion of individual foods versus food groups, number of food groups, weights, and recall period.

In particular, only two research papers are named on which the conclusion that "*an increase in dietary diversity is associated with socio-economic status and household food security*" is based (FAO, 2012). Of these papers, Hatloy et al. (1999), in a case study in a southern county of Mali, indeed find such an association for socio-economic status. For nutritional status, the association was only found in urban areas. Furthermore, their index for dietary diversity is based on ten food groups, not the suggested twelve. Perhaps the most extensive work on this topic is by Hoddinott and Yohannes (2002). In a very thorough research they study the relationship between dietary diversity and a range of measures of food security using datasets from ten countries, covering a range of incomes. The authors find a robust positive relationship – independent of whether individual foods or food groups are used to measure dietary diversity – which holds over urban and rural areas, seasons, and recall period. However, nowhere in the paper is the HDDS indicator used in the form promoted in the guidelines. Furthermore, the analyses depend on external validation, not specifically taking into account *how* the indicator measures food access, i.e. its internal validity. In this research, we specifically study the internal dynamics of the HDDS, looking at the contribution of the individual food groups to the overall indicator.

Rasch models were used to study the validity of the HDDS. This statistical technique is often applied in educational science to develop indicators such as the Intelligence Quotient or indicators that quantify proficiency in math (Adams, Wu, & Carstensen, 2007; Walker & Beretvas, 2003). These indicators have to provide reliable test scores that are intertemporally valid and independent of cultural differences so they can be used to compare educational performance between countries and over time (e.g. the famous, but controversial PISA test scores). Moreover, test scores need to have sufficient power to detect differences between low and high performing individuals. In many perspectives, indicators of proficiency in math and the HDDS have much in common. Rasch models are typically used to validate indicators that are intended to be summated into an overall score, such as exams and HDDS.

In verifying the internal validity of the HDDS we consider three conditions an indicator of food access should meet in order to be a valid and reliable proxy of the latent trait, which in this case is household food access. First, the probability of a correct (in this study, affirmative) response to an item (food group) needs to be stable over the latent trait, such that each food group contributes positively and significantly to the overall score on the indicator. Second, food groups need to have a hierarchical order, such that households consuming the most difficult item should also consume other, easier, items. Third, the indicator needs to be robust to cultural differences. Hence, conditional on the latent trait, item difficulty should be consistent between countries, cultures, and food habits. These conditions are necessary for the indicator to reliably distinguish households with high food access from households with low food access and to allow cross-cultural and intertemporal comparison of households based on HDDS.

These condition can be tested by using Rasch models. In this paper we do not specifically attempt to establish *what* is measured by the HDDS, but assume it measures household food access. Rather, we will analyse *how* the HDDS measures food access, by verifying for each food group whether it meets the conditions specified above. Applying this novel methodology to analyse the internal validity of the HDDS is the main contribution of this paper to the literature.

In the next section, Rasch models are described in more detail. The data used to analyse HDDS come from Colombia and Ecuador, whose context will be described in the data section. In the results section, we show and discuss the outcomes of the analyses, first for the Colombian, then for the Ecuadorian sample. Subsequently, the external validity of the HDDS will be assessed through studying its correlation with factors commonly associated with food security. For this comparison we will not use the original HDDS, but rather a 'refined' version which meets all internal validity conditions. In that section thresholds below which a households should be considered as suffering from an insufficiently diverse diet will be determined, which is important for setting targets for project impact of development programmes. In the conclusion we give an overall assessment of the appropriateness of the indicator and discuss potential points of concern.

Methodology

Rasch models were developed by Rasch (1960) to measure an individual's level of a latent trait. The models assume that the probability of an individual's response to a question depends only on item difficulty and individual ability. In this study, the latent trait is household food access, which is measured by adding up the food groups consumed in the last 24 hours. These food groups are the items. Rasch models do not depend on *a priori* assumptions about item difficulty. Models are most frequently applied in education and psychology, but commonly used in other human sciences (Bond & Fox, 2001), and increasingly applied to medical research (A. Smith, Rush, Fallowfield, Velikova, & Sharpe, 2008).

Rasch models have been used to study food security indicators before. They have been applied to test experience-based indicators, such as the core food security module (CFSM) developed by the US Department of Agriculture (Derrickson, Fisher, & Anderson, 2000; Opsomer, Jensen, & Pan, 2003), Latin American Household Food Security Measurement Scale (ELCSA) (Toledo Vianna, Hromi-Fiedler, Segall-Correa, & Pérez-Escamilla, 2012), Household Food Insecurity Access Scale (HFIAS) (Deitchler, Ballard, Swindale, & Coates, 2010), and most recently, the Arab Family Food Security Scale (Sahyoun et al., 2014). Coates, Wilde, Webb, Rogers, and Houser (2006) use Rasch models to assess the items that should be included in a food insecurity scale for Bangladesh. Rasch models allow evaluating whether items are equally difficult in different cultural settings because estimated item parameters are not sample specific (Casillas, Schulz, Robbins, Santos, & Lee, 2006; Salzberger, Sinkovics, & Schlegelmilch, 1999).

Its most simple form, the 1PL Rasch model, is based on the assumption that the probability of an affirmative answer to item i (e.g. a food group) of person p is determined by the difference between the person's ability θ_p (e.g. its food access status) and the difficulty of the item, β_i (equation 1). In other words, the higher a person's nutritional status and the less 'difficult' a particular food group is, the more likely it is that this person is consuming that particular food group. Formally, the 1PL model is specified as follows:

$$\ln\left(\frac{P_{pi}}{1-P_{pi}}\right) = \theta_p - \beta_i \qquad (1)$$

This formula states that log odds of the probability of an affirmative response of person p to item i is a linear function of the ability of person p and the difficulty of question i.

The item-specific goodness of fit allows assessing whether each of the items fits the data well for different categories of the latent trait, θ_p, food access. To do so, the expected probabilities are graphically compared to the observed probabilities, using so-called Item Characteristics Curves (ICC) (Bond & Fox, 2001). These curves show whether the predicted probability of a correct response to an item is similar to the actual observed probability in the sample.

A poor item fit might indicate that the item does not measure the same latent trait as the other items, but it might also indicate that the item is not as strongly correlated with the latent trait as the other items. The simple 1PL Rasch model assumes no interaction between a household's ability and food items. The more flexible parameterization of the 2PL model does allow testing the correlation of item i with the latent trait, by adding an interaction term, α_i:

$$\ln\left(\frac{P_{pi}}{1-P_{pi}}\right) = \alpha_i\theta_p - \beta_i \qquad (2)$$

The additional parameter, α_i, determines the discriminatory power of the items, i.e. it measures the extent to which an item helps to distinguish high from low performers. The larger is α_i, the more a small increase in θ increases the probability of an affirmative response to item i.

The three validity conditions necessary for the HDDS to be a valid indicator of food access, explained above, can be tested directly with the 2PL Rasch model. In order to do so, first all food groups consumed by all or none of the households in the sample were removed from the analysis, as estimates are unstable when there are less than ten observations per binary choice alternative (Linacre, 2002). Removing these food groups was justified because food groups consumed by (nearly) all or none of the households do not help in distinguishing households with high from households with low food access.

Next, each condition was tested. Condition 1, regarding stability of the probability of a correct response for different levels of food access, was accepted if $\alpha_i > 0$. If α_i is not significantly different from zero, the probability of a correct response is no longer a function of θ. This implied that an individual with a highly diversified diet could not be distinguished from a household with a less diversified diet. Hence, questions with $\alpha_i = 0$ should not be included in the refined HDDS because they did not contain information and increased measurement error. Even more worrying were items (food groups) with a negative α_i. Such items showed an inverse relationship with the latent trait, implying that the probability of consuming food group i *decreased* with increasing food access. This might occur if a food group was only consumed by the least food-secure households. As the HDDS score equals the number of consumed food groups, food groups with an inverse relation with dietary diversity will bias HDDS downwards. Clearly, such items should not be included in an internally valid indicator.

Condition 2, the hierarchical ordering of food groups, could visually be checked from the ICC curves, which showed the predicted versus the actual probability of consumption of a food group conditional on the latent variable. These curves visualised whether households consuming difficult items also consumed easy items, i.e. the implied hierarchical ordering of food groups.

Finally, condition 3, robustness to cultural differences, was checked using Differential Item Functioning (DIF), which allows testing whether items respond differently between groups (Osterlind & Everson, 2009). For example, fish consumption might be common in coastal areas, but indicates a highly diversified diet in rural areas. To verify this condition, prior knowledge of dietary patterns in the region was required.

Each of these conditions was checked for all food groups using Rasch analyses performed using R version 2.12.1, with packages irtoys and eRm (Mair & Hatzinger, 2007; Partchev, Partchev, & Suggests, 2009). After checking the internal validity conditions and constructing a refined HDDS which included only those items (food groups) meeting all internal validity conditions, the external validity of the HDDS was checked by comparing it to several factors commonly associated with household food access, such as income and wealth. Finally, its cross-cultural validity was verified by checking whether food groups contributed equally to the overall index for each country.

Data

The validity of the HDDS was tested using data from a cross-border agricultural development project in Colombia and Ecuador. These countries are culturally close and economically similar. Both countries are considered upper-middle income countries according to the World Bank classification, yet have high inequality and poverty rates. In 2006, Ecuador had a Gini-coefficient of 0.46. The Amazon basin, where our data was collected, is one of the poorest regions of Ecuador, with 59.7% of the population living below the national poverty line (INEC, 2006). In 2011 the Gini-coefficient in the province of Nariño in Colombia, our research area, was estimated at 0.50. Nariño is one of the poorest departments of Colombia, with 50.6% of the population living below the national poverty line (DANE, 2011). Although culturally and economically similar, the agro-climatic conditions in the research areas are very different. Households interviewed in Colombia live in the Andes mountain range, whereas households interviewed in Ecuador live in the tropical rainforest.

In total, 509 households were randomly selected for interviewing in Colombia, and 506 households in Ecuador. All interviewed households were poor smallholder farmers, with large families, few assets, and low incomes.

Structured personal interviews were used to collect data on household and farm characteristics and income, as well as the HDDS and months of adequate household food provisioning (MAHFP) as indicators of food security and the country-specific progress out of poverty (PPI) index developed by the Grameen Foundation. The used HDDS surveys were made more specific for each country by adding commonly consumed foods to the specification of the food groups (appendix). For example, food group 1, cereals, was specified for the Ecuador survey as as 'In the last 24 hours, did you consume any kind of cereal like rice, maize, or wheat, or any product made from cereals, such as bread, cookies, humitas, etc?'[1].

MAHFP is a count of the number of months in the last year the household had insufficient food to feed the entire family. PPI is an index consisting of ten items which are intended to give a rapid assessment of the likelihood the household is below the poverty line (appendix). It contains closed questions on family composition, housing quality, and household assets. A score is attributed to each answer and the total score determines the likelihood a household is below the poverty line. Based on data from the PPI, about 53.4% of Colombian households and 71.3% of Ecuadorian households in our sample were living below the national poverty line.

Results

For each country, the three internal validity conditions were verified using Rasch analysis. For the Ecuadorian data, two separate analyses were done based on the results of Differential Item Functioning, which showed the existence of two groups with distinct dietary patterns. Such a difference was not found in the Colombian sample. After discussing the results of the internal validity verification for both countries, the external validity of a 'refined' HDDS – which contained only those food groups that met all internal validity conditions – was checked. Finally, the suitability of the HDDS to set target levels of dietary diversity for monitoring and evaluation purposes was analysed by determining and comparing several food security thresholds.

Internal validity: Colombian sample

Food groups consumed by nearly all or very few households reduce the variation of the HDDS indicator and hence its efficiency. In the Colombian sample, this lack of variation is clearly a concern: 99% of households consumed the food groups ‘cereals’, ‘ roots or tubers’, ‘sugar or honey’ and ‘other’ during the 24 hours before the survey (table 1). Hence these food groups did not provide any information on differences in food access between households and were excluded from subsequent Rasch analyses.

The results of the 2PL Rasch model are graphically represented in figure 1 with Item Response Functions (IRFs). Estimates of α and β for each item are given in table 2. IRFs showed the probability of a correct response for each item as a function of household food access. To fulfil condition 1, the higher the ability (on the horizontal axis) the higher should be the probability of a correct response (on the vertical axis). The numbers on the different curves correspond to the item numbers (food groups) provided in table 2.

[1]En las últimas 24 horas, comía algún cereal como el arroz, el maíz o el trigo, o algún producto elaborado con estos granos, como el pan, la galleta, la humita, etc.?

Table 1. Food group consumption in the Colombian sample

	Food group	By % of households
1	Cereals	99
2	Roots and tubers	99
3	Vegetables	49
4	Fruits	50
5	Meat	67
6	Eggs	66
7	Fish	6
8	Legumes	62
9	Milk/diary	23
10	Oils/fat	86
11	Sugar/honey	99
12	Other	99

Note: food groups that were excluded from further analysis are underlined.

If two items had similar discriminatory power, α, but differed with respect to their difficulty, β, the curve of the most difficult item (higher β) was plotted towards to the right-hand side of the graph. For instance, vegetables (item 3) and fish (item 7) had similar discriminatory power (α equaled 1.006 and 0.858 respectively), but fish was a considerably more difficult item compared to vegetables (β equaled 3.552 and 0.069, respectively). Hence, the IRFs of fish and vegetables were almost parallel, but the curve of fish was located to the right of the curve of vegetables.

The α's determine the slope of the IRFs: items with high discriminatory power have steeper slopes. For instance, meat (item 5) and legumes (item 8) had similar β's, but the slope of the IRF of meat was steeper than the slope of the IRF of legumes, because the latter had a smaller α. In other words, the food group meat had more power in differentiating between households with high and low food access.

The IRF of food group 6 (eggs) was rather flat, which implied the probability of consuming eggs was independent of the latent trait. This is confirmed in table 2: the discriminatory power of food group 6 was low and not significantly different from zero (P=0.22), violating the stability condition. This finding corresponds with the observation of Dufour, Staten, Reina, and Spurr (1997) that eggs are an important component of the daily diet in Colombia, independent of the socio-economic status of the household. It was consumed by two-thirds of the interviewed households. All seven remaining food groups had a significantly positive α, satisfying condition 1.

Condition 2 (hierarchy) was verified by visual inspection of the Item Characteristic Curves (ICCs) for each of the seven remaining items. ICCs are similar to IRFs and show the probability of an affirmative response to an item (i.e. the probability of consuming the food group) (vertical axis) as a function of the household's ability (horizontal axis). However, ICCs also show the predicted probability of a correct response with its 95% confidence interval and the actual observed probability of a correct response represented by a dot. Item-specific fit is high when predicted probabilities are close to expected probabilities. For the food group meat (Figure 2), predicted probabilities corresponded well to actual observations. Results for other food groups were similar, suggesting that condition 2 held.

Condition 3 – intra-cultural comparability – was not formally tested because sampled households were from a confined region and all shared the same ethnicity. Therefore there was no *a priori* reason to expect differential item functioning.

Table 2. Results of the 2PL model in the Colombian sample

	Food group	α	β
3	Vegetables	1.006	0.069
4	Fruits	1.129	-0.007
5	Meat	0.538	-1.369
6	<u>Eggs</u>	<u>0.110</u>	-5.898
7	Fish	0.858	3.552
8	Legumes	0.316	-1.651
9	Milk/diary	1.191	1.293
10	Oils/fat	0.565	-3.479

Note: we underline the food groups that were excluded from further analysis

In sum, in the Colombian sample seven food groups met all three internal validity conditions: vegetables, fruits, meats, fish, legumes, diary, and oils. Of those, oils and fats were most likely to be consumed, while fish was only consumed by the households with the most nutritionally diverse diet.

<u>Differential Item Functioning: Ecuadorian sample</u>

The amazon basin where the Ecuadorian data was collected has two ethnic groups with distinct dietary patterns. Originally the region was inhabited by the indigenous tribe of the Kichwa, but since the oil boom of the 1970s large groups of mestizo migrants have also settled in the region and currently make up almost half the population (Lobao & Brown, 1998; Witt, Kakabadse, Ortiz, & Maldonado, 1999). A glance at the summary statistics for food groups consumption shows marked differences in diet between these groups (table 3). Milk and dairy products were, for instance, consumed by only 7% of Kichwa households, while 27% of migrant households reported having consumed this food group in the previous day. This suggested that our sample in Ecuador did not satisfy condition 3.

A formal test confirmed the occurrence of Differential Item Functioning between the ethnic groups ($P<0.001$), implying that a single index for the Ecuadorian case did not meet condition 3 of cultural robustness. When the items showing the strongest DIF were removed one by one until they no longer showed any DIF ($P=0.352$), only five food groups were left in the final model: 1, 3, 8, 9 and 11. Such a small number of groups is not very meaningful, as the resulting indicator can take only five values and therefore is not very sensitive to changes in food access. By not pooling the data, valuable within-group information on specific diets was preserved. Hence, the subsequent analysis was performed separately for each of the two cultural groups. The presence of two different subgroups confirms that good knowledge on regional dietary patterns is essential for constructing a reliable indicator.

<u>Internal validity: Ecuadorian sample</u>

Condition 1 held for all food groups in the Ecuador data because all food groups were consumed by fewer than 95% of the households in both ethnic groups (table 3). Results of 2PL Rasch models for both ethnic groups are shown in table 4 and 5. Results for the Kichwa households are also graphically represented with IRFs (figure 3). In order to meet condition 1, α's needed to be non-negative and non-zero. Contrary to the results for the Colombian sample, the likelihood of consuming some food groups decreased with an increase in the

Table 3. Food group consumption by Ecuadorian households across different ethnic groups

	Food group	% of Kichwa HHs (n=209)	% of migrant HHs (n=297)
1	Cereals	80	95
2	Roots and tubers	87	81
3	Vegetables	15	37
4	Fruits	26	40
5	Meats	52	66
6	Eggs	46	50
7	Fish	49	29
8	Legumes	18	56
9	Milk/diary	7	27
10	Oils/fat	40	38
11	Sugar/honey	52	77
12	Other	54	86

Note: HH stands for Households

latent trait, food access. In this case α was negative. For instance, for Kichwa households the predicted likelihood of consuming fish decreased from 80% for households with little dietary diversity to less than 20% for households with a highly diversified diet. Fish (food group 7) was therefore clearly violating condition 1. Fish was an important part of the diet in Kichwa communities and consequently its consumption was common, although more so in rural communities than in towns (J. Webb et al., 2004). No sources were found mentioning an inverse relationship between income and fish consumption, although a possible reason could be a development project of the provincial government of Napo which donated fish ponds to indigenous households in the region. Such a project was mentioned by respondents in a second survey round conducted in summer 2013[2]. If only poor households were eligible for this programme, it would explain the observed inverse relationship of fish consumption with overall dietary diversity.

Results suggest that the responses to food group 2, roots and tubers, were also in violation of condition 1. Even though the coefficient was statistically significant, it was very small. This is also evident from figure 3, where the IRF of this group is a flat line. Its low discriminatory power combined with its very low item difficulty, resulted in a horizontal line, which suggests that the group added no explanatory power to the overall indicator. In our sample, 80% of the households reported having consumed roots or tubers the previous day. It is, however, likely that this food group was consumed by all households on a regular but not daily basis and therefore its consumption had no power in explaining its food access status.

Although the discriminatory power of food groups 3 and 4, vegetables and fruits, was statistically insignificant, these groups were not excluded from the indicator because they added some explanatory power to the HDDS indicator (figure 3). Moreover, when food groups 2 (roots and tubers) and 7 (fish) were dropped, the p-values of group 3 (vegetables) and 4 (fruits) decreased to 0.14 and 0.11, respectively, which is close to the 10% statistical threshold level.

[2] We were not able to identify the project. Respondents could be referring to the "Piscicultura Sostenible para la Amazonía" project ran by the Centro Lianas (www.centrolianas.org).

Table 4. Results of the 2PL model for the Ecuadorian data of Kichwa households

	Food group	α	β
1	Cereals	1.252	-1.444
2	Roots and tubers	0.04	-48.006
3	Vegetables	0.213	8.295
4	Fruits	0.225	4.737
5	Meats	0.494	-0.143
6	Eggs	0.507	0.342
7	Fish	-0.400	-0.074
8	Legumes	0.438	3.568
9	Milk/diary	1.064	2.825
10	Oils/fat	1.076	0.482
11	Sugar/honey	2.499	-0.047
12	Other	0.804	-0.23

Note: food groups that were excluded from further analysis are underlined.

For migrant households, two different food groups were found to violate the stability condition. Legumes had a negative coefficient, violating condition 1, and food group meats had a small coefficient, not adding explanatory power (table 5).

Table 5. Results of the 2PL model for the Ecuadorian data of migrant households

	Food group	α	β
1	Cereals	0.41	-7.178
2	Roots and tubers	0.396	-3.752
3	Vegetables	0.954	0.645
4	Fruits	0.79	0.6
5	Meats	0.011	-58.523
6	Eggs	0.193	0.034
7	Fish	0.309	2.91
8	Legumes	-0.148	1.612
9	Milk/diary	0.407	2.584
10	Oils/fat	1.397	0.491
11	Sugar/honey	1.997	-0.979
12	Other	1.096	-1.963

Note: food groups that were excluded from further analysis are underlined.

Upon inspection of the ICC curves for migrant households, food group 2 (roots and tubers) and 7 (fish) were found to have low item fit. Many more households than predicted consumed roots and tubers at the lower tail of the food access distribution. Consumption of roots and tubers was common among all households and did not increase considerably with higher levels of food access. Similarly, fish consumption remained relatively stable with increasing food access (figure 4). Both food groups therefore violated the hierarchy condition.

In conclusion, data in Ecuador could not be pooled, because there were significant differences in dietary patterns between Kichwa and migrant households. Hence, the HDDS was analysed separately for each group. For Kichwa households, food groups roots and tubers and fish violated the stability condition, such that only ten food groups met all the validity conditions. For migrant households, food groups roots and tubers and meats, failed to meet the stability condition, and the food groups fish and legumes violated the hierarchy condition. Therefore, for migrant households only eight food groups met all internal validity conditions.

Considering that for neither country all original 12 food groups met the internal validity criteria, the HDDS was not found to be internally valid. The additive nature of the indicator suggests that consumption of each food group should contribute positively to overall household food access, which clearly was not the case. Therefore, to check the external validity of the HDDS, the refined HDDS was used, which included only those food groups meeting all internal validity conditions.

<u>External validation</u>

External validity refers to whether the indicator measured what it was supposed to measure: food access. To assess this external validity of the HDDS its association with factors commonly associated with food access will be studied. For this comparison not the original HDDS, but rather a 'refined' version was used, consisting only of food groups that met all internal validity conditions. In the Colombian sample, the correlation between this refined HDDS and the HDDS was high (94%), which is not surprising since four of the five excluded food groups were consumed by nearly all households. However, the refined HDDS was still preferred because it contained no redundant food groups and therefore was more efficient.

To examine the external validity of the refined HDDS, it was compared to household and farm characteristics (table 6). All indicators commonly associated with food access, such as income per household member, land assets, progress out of poverty index (PPI) and years of education were positively associated with dietary diversity as measured by the refined HDDS. Moreover, the number of months households did not have enough to eat, as measured by the MAHFP, decreased with increasing dietary diversity. These findings were in line with the positive relationship between income and the likelihood of consuming each of the food groups included in the refined HDDS (figure 5). For instance, 30% of the households in the lowest tercile consumed food group 3 (vegetables) compared to 65% in the highest tercile. Hence, there is suggestive evidence that the refined HDDS was externally valid.

Table 6. External validation of the refined HDDS for the Colombian sample

Refined HDDS[a]	Income/AE[b]	Land (ha)	PPI	Education (years)	MAHFP	n
1	2611625	1.43	44.56	3.86	3.71	41
2	2758047	1.80	47.46	4.38	3.98	92
3	3487642	1.78	45.96	4.31	2.08	131
4	4027938	2.26	48.49	4.92	1.12	140
5	4304248	2.03	50.45	4.95	0.78	67
6	7730467	3.53	55.14	5.41	0.72	29
7	12660239	3.24	68.78	8.21	0	9

[a] Four households consumed none of the food groups that are included in the refined HDDS of Colombian data, but were attributed a score of 1 in this analysis.

[b] Adult equivalence scales were used using the formula $AE=(A+\mu K)^{\gamma}$, where A refers to adults, K to children, and μ and γ are weights. Given the developing-country context, $\mu=0.3$ and $\gamma=0.9$ were chosen as weights (Deaton, 1997; Deaton & Muellbauer, 1986).

Although there was a suggestive association between HDDS and income, this relationship was too weak to use HDDS as an instrument to set target levels of dietary diversity for monitoring and evaluation purposes in development interventions. A cross-tabulation between groups of households based on the refined HDDS and income terciles showed that only 45% of the households in the lowest tercile of dietary diversity also belonged to the lowest income tercile, while 22% belonged to the highest income tercile (table 7). If the HDDS was a perfect targeting instrument, we would expect only observations on the diagonal. It is clear HDDS is an approximate indicator at best.

Table 7. Cross-tabulation between income and refined HDDS in the Colombian sample (number of households in categories of refined HDDS and income)

	Refined HDDS		
	0-3	4	5-7
Poorest tercile	119	34	17
Middle tercile	85	56	28
Richest tercile	60	50	60

For the Ecuadorian data, for neither of the two ethnic groups a relationship was found between the refined HDDS and income (figure 6). Hence, the data did not allow concluding that higher income households had a more diverse diet as measured by the HDDS. Also none of the other factors commonly associated with food security correlated with the refined HDDS. More specifically, for hardly any of the food groups the likelihood of consuming a particular food item increased with income. More generally, it questions the usefulness of the HDDS as an indicator of food security in this particular context.

Threshold values

The FANTA project team recommends using the average dietary diversity score of the richest 33% of households as the threshold value of having a sufficiently diversified diet (Swindale & Bilinsky, 2006), which for our Colombia sample was equal to 8.76. Because the score of an individual household is always an integer number, either a score of 8 or 9 could be chosen as the threshold. Using the unrefined HDDS and a score of 8 as a threshold, 60%, 25% and 20% of the households in the first, second and third income tercile were food secure (figure 7). These figures drop to 30%, 20% and 10% with 9 as the cut-off value. These substantial differences were partially caused because the variation in the HDDS was almost completely determined by 7 food groups instead of 12 as shown above.

When income data are not available, FANTA recommends using the average score of the 33% of households with the most diverse diet as threshold, which equaled 10.5 in our sample. However, a target above 10 would imply that only 10% of the households in the first income tercile enjoyed a sufficiently diverse diet.

In the Ecuadorian sample, average dietary diversity of the richest tercile in the entire sample was 6.77, while average dietary diversity of the 33% households with the most diversified diet was 8.75. As for the Colombian sample, the percentage of households that could be considered as having a sufficiently diversified diet was not robust to the choice of the threshold. Almost 60% of the richest households had a sufficiently diversified diet when a threshold of 6 was used, while this percentage dropped to 35% if a threshold of 7 was chosen. Based on a threshold of 6, 89% of Kichwa households had an unsatisfactorily diversified diet compared to 67% of migrant households. Clearly, these figures would be lower if separate thresholds were chosen for each cultural group, although this is not common practice.

Discussion

In this paper the household dietary diversity score (HDDS) developed by the Food and Nutrition Technical Assistance (FANTA) project was analysed using Rasch models. In particular, it was verified whether the HDDS met several conditions required for it to be a valid indicator of food security (Swindale & Bilinsky, 2006). Rasch models allow differentiation between the discriminatory power and difficulty of items, revealing the relative importance of individual food groups in differentiating between levels of food access. In our data, this importance differed markedly between countries. Therefore, in its current form the HDDS was found not to be internally valid. To test its external validity, a refined HDDS was used which included only those food groups that met the internal validity conditions. In the Colombian data, seven food groups made up the refined indicator: vegetables, fruits, meats, fish, legumes, diary, and oils. These results correspond well with the literature as the refined index mainly contains foods with high nutritional values such as fruits, vegetables, and animal source products.

The results for the Ecuadorian data were less convincing. For the group of Kichwa households, the food groups roots and tubers, and fish were excluded from the final index and for migrant households the groups roots and tubers, meats, fish, and legumes did not meet the conditions. Especially the non-inclusion of meats and fish in the overall index for both groups is cause for concern, as animal source foods are of crucial importance for macro and micro nutrient intake in developing countries (Murphy & Allen, 2003). Moreover, as there appears to be a direct link between consumption of animal source foods and dietary diversity (Brown, Peerson, Kimmons, and Hotz (2002), as cited in Ruel (2003)), the exclusion calls into question what the HDDS really measures. Unfortunately, without a more thorough external validation, ideally based on a 'gold standard' for food security, this question cannot be answered.

There were substantial differences in the importance of each food group in the overall index between countries and even within a country. This holds even though two culturally similar neighbouring countries were studied. Results of the employed DIF-analysis make clear that in its current form, the HDDS has no cross-cultural validity, a problem previously mentioned but not tested by Ruel (2003). This lack of cross-cultural validity is problematic as it prevents direct interpretation of the value of the overall indicator. Before interpreting this value, it is essential to have a thorough understanding of local dietary patterns, even when a survey or project concerns only a small area within a single country. Clearly, requiring extensive knowledge before being able to interpret a simple, easy-to-use indicator defeats its usefulness for deployment in the rapid assessments required by development projects.

The HDDS could not be translated directly into some degree of food access. However, as an indicator of food access it was expected to correlate with factors commonly associated with food security, such as income and wealth (Barrett, 2010; L. C. Smith, El Obeid, & Jensen, 2000). Our results indicate a weak association in the Colombia data, and almost none in Ecuadorian data. These results were contrary to expectations as such direct links between improved dietary diversity with increases in income were previously found in studies in Germany (Thiele & Weiss, 2003) and Bangladesh (Rashid, Smith, & Rahman, 2011). Of these, the latter study used the same indicator of dietary diversity as employed in this paper. Even though a significant link was found, their t-statistic of 4.17 is not impressive given their sample size of 7440 households. It appears the relationship between dietary diversity and income might be weaker than expected based on classic theories of demand (Maslow, 1943). Indeed, for the Ecuador data, no link at all could be established. This phenomenon might be partly explained by habit formation (Atkin, 2013). Households might prefer those foods consumed as a child even when alternative food baskets become affordable. If that were to be the case, income increases result in increased quantities of foods consumed, rather than increased variety. Unfortunately, in its current form the HDDS does not take consumed quantities into account.

The limited external validity and inaccuracy as a targeting tool strongly suggest the scale is not reliable at the household level, which might be caused by basing the index on only the foods consumed in the last 24 hours before the survey (Swindale & Ohri-Vachaspati, 2005). In that case, a straightforward way to overcome this inaccuracy is to increase the recall period. In a study using a 15 day recall period for dietary diversity, Drewnowski, Henderson, Driscoll, and Rolls (1997) noted diversity increased steeply over the first three days of recall, after which increases became small until a recall of 10 days. In other words, 24h recall might significantly underestimate true diversity when measuring dietary diversity at an individual or household level. Although this reduced accuracy at an individual level is no problem for group averages, it does makes attribution of project benefits more problematic and reduces the usefulness of the HDDS for setting food security targets for development projects.

The HDDS was developed as a rapid assessment tool to allow measuring the impact of programmes aiming to increase food security. However, in the setting of this study it could not be relied upon to do so. There is a missing fit between included food groups and the underlying latent trait, such that the components of the indicator do not form a reliable way of measuring the variable of interest: food access. Furthermore, outcome values are hard to interpret and hence hard to compare across settings. Possible ways to improve the quality of the indicator might be to create food groups based on nutritional values and to increase indicator accuracy on a household or individual level by increasing the recall period. Another topic that deserves further research is including portion sizes, at least as the number of times a particular food group was consumed, to verify if this would increase the validity of the HDDS as a measure of food security.

Acknowledgements

The data used for this analysis was collected within the framework of the Borderland Project, implemented by Catholic Relief Services (CRS) (http://coffeelands.crs.org). We thank Catholic Relief Services (CRS) and the International Centre for Tropical Agriculture (CIAT) of the Consultative Group on International Agricultural Research (CGIAR) for their invaluable support.

Appendix 1: HDDS Ecuador

Ahora quisiera preguntarle sobre los tipos de alimentos que usted o cualquiera de los miembros de su familia comieron durante el día de ayer y en la noche.

PREGUNTAS	CATEGORIAS DE CLASIFICACIÓN
LEA LA LISTA DE ALIMENTOS. SELECCIONE LA OPCIÓN "SÍ" DE LA CASILLA SI ALGÚN MIEMBRO DEL HOGAR CONSUMIÓ EL ALIMENTO NOMBRADO; SELECCIONE LA OPCIÓN "NO" EN LA CASILLA SI NINGÚN MIEMBRO DEL HOGAR CONSUMIÓ EL ALIMENTO.	
A. CEREALES ¿Algún cereal como el arroz, el maíz o el trigo, o algún producto elaborado con estos granos, como el pan, la galleta, la humita, etc.?	1. Sí ☐ 0. No ☐
B. RAÍCES Y TUBÉRCULOS Y PLÁTANO ¿Papas, camote, yuca, mandioca o cualquier otro alimento proveniente de raíces o tubérculos?	1. Sí ☐ 0. No ☐
C. VERDURAS ¿Verduras?	1. Sí ☐ 0. No ☐
D. FRUTAS ¿Frutas?	1. Sí ☐ 0. No ☐
E. CARNE, POLLO, DESPOJOS ¿Carne de vaca, de cerdo, de cordero, de cabra, de conejo, de caza silvestre, pollo, pato u otras aves, hígado, riñón, corazón u otras carnes de órganos?	1. Sí ☐ 0. No ☐
F. HUEVOS ¿Huevos?	1. Sí ☐ 0. No ☐
G. PESCADO Y MARISCOS ¿Pescado o mariscos frescos o secos?	1. Sí ☐ 0. No ☐
H. LEGUMBRES/LEGUMINOSAS/FRUTOS SECOS ¿Alimentos a base de frijoles, arvejas, lentejas o frutos secos?	1. Sí ☐ 0. No ☐
I. LECHE Y PRODUCTOS LÁCTEOS ¿Queso, yogurt, leche u otros productos lácteos?	1. Sí ☐ 0. No ☐
J. ACEITES/GRASAS ¿Alimentos a base de aceite, grasa o mantequilla?	1. Sí ☐ 0. No ☐
K. ÁZUCAR/MIEL ¿Azúcar o miel?	1. Sí ☐ 0. No ☐
L. ALIMENTOS DIVERSOS ¿Otros alimentos, como condimentos, café, té?	1. Sí ☐ 0. No ☐

Appendix 2: HDDS Colombia

Ahora quisiera preguntarle sobre los tipos de alimentos que usted o cualquiera de los miembros de su familia comieron durante el día de ayer y en la noche.

LEA LA LISTA DE ALIMENTOS. SELECCIONE LA OPCIÓN "SÍ" DE LA CASILLA SI ALGÚN MIEMBRO DEL HOGAR CONSUMIÓ EL ALIMENTO NOMBRADO; SELECCIONE LA OPCIÓN "NO" EN LA CASILLA SI NINGÚN MIEMBRO DEL HOGAR CONSUMIÓ EL ALIMENTO.

PREGUNTAS	CATEGORIAS DE CLASIFICACIÓN
A. CEREALES	
¿Algún cereal como el arroz, el maíz o el trigo, o algún producto elaborado con estos granos, como el pan, arepas, envueltos de choclo, fideos de trigo, hojaldres, tostadas, pasteles, o cualquier otro alimento hecho de mijo, sorgo, maíz, arroz, trigo, cebada, avena, etc.?	1. Sí ☐ 0. No ☐
B. RAÍCES, TUBÉRCULOS y PLÁTANOS	
¿Papas, batata, yuca, arracacha, plátano, o cualquier otro alimento proveniente de raíces, tubérculos o plátanos?	1. Sí ☐ 0. No ☐
C. VERDURAS	
¿Verduras?	1. Sí ☐ 0. No ☐
D. FRUTAS	
¿Frutas?	1. Sí ☐ 0. No ☐
E. CARNE, POLLO, DESPOJOS	
¿Carne de vaca, de cerdo, de cordero, de cabra, de conejo, de caza silvestre, cuy, pavo, pollo, pato u otras aves, hígado, riñón, corazón u otras carnes de órganos?	1. Sí ☐ 0. No ☐
F. HUEVOS	
¿Huevos?	1. Sí ☐ 0. No ☐
G. PESCADO Y MARISCOS	
¿Pescado o mariscos frescos o secos?	1. Sí ☐ 0. No ☐
H. LEGUMBRES/LEGUMINOSAS/FRUTOS SECOS	
¿Alimentos a base de frijoles, arvejas, lentejas o frutos secos?	1. Sí ☐ 0. No ☐
I. LECHE Y PRODUCTOS LÁCTEOS	
¿Queso, yogurt, leche u otros productos lácteos?	1. Sí ☐ 0. No ☐
J. ACEITES/GRASAS	
¿Alimentos a base de aceite, grasa o mantequilla?	1. Sí ☐ 0. No ☐
K. ÁZUCAR/MIEL	
¿Azúcar, miel o panela?	1. Sí ☐ 0. No ☐
L. ALIMENTOS DIVERSOS	
¿Otros alimentos, como condimentos, café, té?	1. Sí ☐ 0. No ☐

References

Adams, R., Wu, M., & Carstensen, C. (2007). Application of Multivariate Rasch Models in International Large-Scale Educational Assessments. In C. Carstensen (Ed.), *Multivariate and Mixture Distribution Rasch Models* (pp. 271-280): Springer New York.

Arimond, M., & Ruel, M. T. (2004). Dietary diversity is associated with child nutritional status: Evidence from 11 demographic and health surveys. *The Journal of Nutrition, 134*, 2579-2585.

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M. C., Deitchler, M., . . . Torheim, L. E. (2010). Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *The Journal of Nutrition, 140*, 2059-2069.

Atkin, D. (2013). Trade, Tastes, and Nutrition in India. *American Economic Review, 103*(5), 1629-1663. doi: doi: 10.1257/aer.103.5.1629

Barrett, C. B. (2010). Measuring Food Insecurity. *Science, 327*(5967), 825-828. doi: 10.1126/science.1182768

Bennett, M. (1941). Wheat in national diets. *Wheat Studies, 18*(2), 37-76.

Bond, T. G., & Fox, C. M. (2001). *Applying the Rasch model. Fundamental measurement in the human sciences*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Brown, K. H., Peerson, J. M., Kimmons, J. E., & Hotz, C. (2002). Options for achieving adequate intake from home-prepared complementary foods in low-income countries. In R. E. Black & K. Fleischer Michaelsen (Eds.), *Public health issues in infant and child nutrition* (Vol. 48). Philadelphia, PA: Nestlé Nutrition Institute.

Casillas, A., Schulz, E. M., Robbins, S. B., Santos, P. J., & Lee, R. M. (2006). Exploring the Meaning of Motivation Across Cultures: IRT Analyses of the Goal Instability Scale. *Journal of Career Assessment, 14*(4), 472-489. doi: 10.1177/1069072705283764

Coates, J., Wilde, P. E., Webb, P., Rogers, B. L., & Houser, R. F. (2006). Comparison of a Qualitative and a Quantitative Approach to Developing a Household Food Insecurity Scale for Bangladesh. *The Journal of Nutrition, 136*(5), 1420S-1430S.

Deaton, A. S. (1997). *The Analysis of Household Surveys: Microeconometric Analysis for Development Policy*. Baltimore: Md. John Hopkins University Press for the World Bank.

Deaton, A. S., & Muellbauer, J. (1986). On Measuring Child Costs: With Applications to Poor Countries. *Journal of Political Economy, 94*(4), 720-744.

Deitchler, M., Ballard, T., Swindale, A., & Coates, J. (2010). Validation of a measure of household hunger for cross-cultural use. Washington, D.C.: Food and Nutrition Technical Assistance II Project (FANTA-2).

Derrickson, J. P., Fisher, A. G., & Anderson, J. E. L. (2000). The Core Food Security Module Scale Measure Is Valid and Reliable When Used with Asians and Pacific Islanders. *The Journal of Nutrition, 130*(11), 2666-2674.

Drewnowski, A., Henderson, S. A., Driscoll, A., & Rolls, B. J. (1997). The dietary variety score: Assessing diet quality in healthy young and older adults. *Journal of the American Dietetic Association, 97*, 266-271.

Dufour, D. L., Staten, L. K., Reina, J. C., & Spurr, G. B. (1997). Living on the edge: Dietary strategies of economically impoverished women in Cali, Colombia. *American Journal of Physical Anthropology, 102*, 5-15.

Faber, M., Schwabe, C., & Drimie, S. (2009). Dietary diversity in relation to other household food security indicators. *International Journal of Food Safety, Nutrition and Public Health, 2*(1), 1-15. doi: 10.1504/ijfsnph.2009.026915

FAO. (1996). Rome declaration on world food security *World Food Summit*. Rome: Food and Agriculture Organization.

FAO. (2012). Guidelines for Measuring Household and Individual Dietary Diversity. In G. Kennedy, T. Ballard & M. Dop (Eds.). Rome: Food and Agriculture Organisation of the United Nations.

Hatloy, A., Hallund, J., Diarra, M. M., & Oshaug, A. (1999). Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutrition, 3*(1), 57-65.

Heady, D., & Ecker, O. (2013). Rethinking the measurement of food security: From first principles to best practice. *Food Security, 5*, 327-343.

Hoddinott, J., & Yohannes, Y. (2002). Dietary diversity as a food security indicator *FCND Discussion Paper* (Vol. 136). Washington, D.C.: International Food Policy Research Institute.

INEC. (2006). Las condiciones de vida de los Ecuatorianos. Quito, Ecuador: Instituto Nacional de Estadistica y Censos.

Jensen, R. T., & Miller, N. H. (2010). A revaled preference approach to measuring undernutrition and poverty using calorie shares *NBER Working Paper*.

Jones, A. D., Ngure, F. M., Pelto, G., & Young, S. L. (2013). What are we assessing when we measure food security? A compendium and review of current metrics. *Advances in Nutrition, 4*, 481-506.

Kennedy, G., Berardo, A., Papavero, C., Horjus, P., Ballard, T., Dop, M., . . . Brouwer, I. D. (2010). Proxy measures of household food consumption for food security assessment and surveillance: Comparison of the household dietary diversity and food consumption scores. *Public Health Nutrition, 13*(12), 2010-2018.

Kennedy, G. L., Pedro, M. R., Seghieri, C., Nantel, G., & Brouwer, I. D. (2007). Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. *The Journal of Nutrition, 137*, 472-477.

Linacre, J. M. (2002). Understanding Rasch measurement: Optimizing rating scale category effectiveness. *Journal of Applied Measurement, 3*(1), 85-106.

Lobao, L. M., & Brown, L. A. (1998). Development context, regional differences among young women, and fertility: The Ecuadorean Amazon. *Social Forces, 76*, 819-848.

Mair, P., & Hatzinger, R. (2007). CML based estimation of extended Rasch models with the eRm package in R. *Psychology Science, 49*(1), 26.

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370-396.

Moursi, M. M., Arimond, M., Dewey, K. G., Trèche, S., Ruel, M. T., & Delpeuch, F. (2008). Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar. *The Journal of Nutrition, 138*, 2448-2453.

Murphy, S. P., & Allen, L. H. (2003). Nutritional importance of animal source foods. *Journal of Nutrition, 133*, 3932-3935.

Opsomer, J. D., Jensen, H. H., & Pan, S. (2003). An Evaluation of the U.S. Department of Agriculture Food Security Measure with Generalized Linear Mixed Models. *The Journal of Nutrition, 133*(2), 421-427.

Osterlind, S. J., & Everson, H. T. (2009). *Differential item functioning* (Vol. 7): Sage.

Partchev, I., Partchev, M. I., & Suggests, M. (2009). Package 'irtoys'.

Pinstrup-Andersen, P. (2009). Food security: definition and measurement. *Food Security, 1*(1), 5-7. doi: 10.1007/s12571-008-0002-y

Rasch, G. (1960). *Probabilistic models for some intelligence and attainment tests*. Chicago: University of Chicago Press.

Rashid, D. A., Smith, L. C., & Rahman, T. (2011). Determinants of Dietary Quality: Evidence from Bangladesh. *World Development, 39*(12), 2221-2231. doi: http://dx.doi.org/10.1016/j.worlddev.2011.05.022

Rose, D., & Charlton, K. E. (2002). Quantitative Indicators from a Food Expenditure Survey Can Be Used to Target the Food Insecure in South Africa. *The Journal of Nutrition, 132*(11), 3235-3242.

Ruel, M. T. (2002). Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs *Food Consumption and Nutrition Division Discussion Paper* (Vol. 140). Washington, D.C.: International Food Policy Research Institute.

Ruel, M. T. (2003). Operationalizing dietary diversity: A review of measurement issues and research priorities. *The Journal of Nutrition, 133*, 3911-3926.

Sahyoun, N. R., Nord, M., Sassine, A. J., Seyfert, K., Hwalla, N., & Ghattas, H. (2014). Development and Validation of an Arab Family Food Security Scale. *The Journal of Nutrition*. doi: 10.3945/jn.113.187112

Salzberger, T., Sinkovics, R. R., & Schlegelmilch, B. B. (1999). Data Equivalence in Cross-Cultural Research: A Comparison of Classical Test Theory and Latent Trait Theory Based Approaches. *Australasian Marketing Journal (AMJ), 7*(2), 23-38. doi: http://dx.doi.org/10.1016/S1441-3582(99)70213-2

Smith, A., Rush, R., Fallowfield, L., Velikova, G., & Sharpe, M. (2008). Rasch fit statistics and sample size considerations for polytomous data. *BMC Medical Research Methodology, 8*(1), 33.

Smith, L. C., El Obeid, A. E., & Jensen, H. H. (2000). The geography and causes of food insecurity in developing countries. *Agricultural Economics, 22*(2), 199-215. doi: http://dx.doi.org/10.1016/S0169-5150(99)00051-1

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., & Labadorios, D. (2006). Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy? *Public Health Nutrition, 9*(5), 644-650.

Swindale, A., & Bilinsky, P. (2006). Household dietary diversity score (HDDS) for measurement of household food access: Indicator guide (v.2) *Food and Nutrition Technical Assistance Project*. Washington D.C.: Academy for Educational Development.

Swindale, A., & Ohri-Vachaspati, P. (2005). Measuring household food consumption: A technical guide. Washington, D.C.: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED).

Thiele, S., & Weiss, C. (2003). Consumer demand for food diversity: evidence for Germany. *Food Policy, 28*(2), 99-115. doi: http://dx.doi.org/10.1016/S0306-9192(02)00068-4

Toledo Vianna, R., Hromi-Fiedler, A., Segall-Correa, A., & Pérez-Escamilla, R. (2012). Household food insecurity in small municipalities in Northeastern Brazil: a validation study. *Food Security, 4*(2), 295-303. doi: 10.1007/s12571-012-0181-4

Walker, C. M., & Beretvas, S. N. (2003). Comparing Multidimensional and Unidimensional Proficiency Classifications: Multidimensional IRT as a Diagnostic Aid. *Journal of Educational Measurement, 40*(3), 255-275. doi: 10.1111/j.1745-3984.2003.tb01107.x

Webb, J., Mainville, N., Mergler, D., Lucotte, M., Betancourt, O., Davidson, R., . . . Quizhpe, E. (2004). Mercury in fish-eating communities of the Andean Amazon, Napo River Valley, Ecuador. *EcoHealth, 1*(2), 59-71.

Webb, P., Coates, J., Frongillo, E. A., Rogers, B. L., Swindale, A., & Bilinsky, P. (2006). Measuring Household Food Insecurity: Why It's So Important and Yet So Difficult to Do. *The Journal of Nutrition, 136*(5), 1404S-1408S.

Witt, J. M., Kakabadse, Y., Ortiz, R., & Maldonado, L. (1999). Zonas intangibles de la Amazonia Ecuatoriana. Quito, Ecuador: Ministerio de Medio Ambiente.