RESEARCH ARTICLE

Dietary diversity of 6- to 59-month-old children in rural areas of Moramanga and Morondava districts, Madagascar

Nivo Heritiana Rakotonirainy¹, Valérie Razafindratovo², Chitale Rabaoarisoa Remonja¹, Randza Rasoloarjaona², Patrice Piola³, Charlotte Raharintsoa², Rindra Vatosoa Randremanana¹*¹

¹ Epidemiology unit, Institut Pasteur de Madagascar, Antananarivo, Madagascar, ² Laboratoire de Biochimie Appliquée aux Sciences de l’Alimentation et à la Nutrition, Faculté des Sciences, Université d’Antananarivo, Antananarivo, Madagascar, ³ Epidemiology and Public Health Unit, Institut Pasteur du Cambodge, Phnom Penh, Royaume du Cambodge

* rrandrem@pasteur.mg

Abstract

Background

A dietary imbalance or a disregard for the nutritional needs of children during early childhood can affect their growth. From the age of six months, breast milk is no longer able to meet the energy and micronutrient needs of children; the consumption of adequate complementary foods is therefore essential. Various indicators have been used to assess the quality of children’s diets, and the dietary diversity score is a good indicator of children’s diets. The objective of this study was to describe the dietary practices of children in rural areas of Moramanga and Morondava, Madagascar, and to identify the determinants of low dietary diversity to prioritize nutritional interventions.

Methods

We collected dietary data in 2014 on children aged 6–59 months in a study on the determinants of chronic malnutrition using the 24-hour recall method. Data on the characteristics of households and mothers were also collected. We carried out bivariate and multivariate analyses to identify the determinants of low dietary diversity scores for children.

Results

We included 1824 children: 893 from Moramanga and 931 from Morondava. Approximately 42.1% [95% CI: 39.0–45.4] of the children from Moramanga and 47.6% [95% CI: 44.4–50.8] of those from Morondava had a poorly diversified diet, consisting mainly of foods rich in carbohydrates and poor in meat products. Poor maternal education was associated with a high likelihood of having a non-varied diet in both study areas; the adjusted odds ratios were 2.2 [95% CI: 1.3–3.8] and 4.0 [95% CI: 2.5–6.4] for children from mothers with lower education levels for Moramanga and Morondava, respectively. For children recruited in Morondava, having low household socioeconomic status (adjusted OR: 1.8, 95% CI: 1.2–2.8) and
belonging to a household without livestock was associated with a low dietary diversity score (adjusted OR: 1.8, 95% CI 1.2–2.7).

Conclusion

Our results show the need to improve girls’ education, adapt nutrition education programs for mothers based on their level of education, and strengthen poverty reduction programs.

Introduction

Malnutrition remains a serious problem in most developing countries, affecting particularly vulnerable groups, especially children under the age of five. It is directly or indirectly responsible for 45% of all child deaths worldwide [1]. Moreover, malnutrition affects the psychomotor development and learning capacities of children, with a long-term impact on the socioeconomic development of the country. Malnutrition occurs due to the interaction of several determinants at different levels: the community, the household, and the individual. At the individual level, malnutrition results from inadequate diets that do not provide sufficient calories and micronutrients, from clinical or sub-clinical infections, or from a combination of both [2]. From the age of six months, breast milk is no longer able to meet the energy and micronutrient needs of children; the consumption of adequate complementary foods, in quality and quantity, is therefore essential [3]. Various indicators have been used to assess the quality of children’s diets. The dietary diversity score is a good indicator of children’s diets [4–6] and can be used to assess macro- and micronutrient consumption [7,8].

Appropriate feeding practices are insufficiently widespread in Madagascar: 41.9% of children aged 6–23 months are exclusively breastfed, and only 30.9% receive dietary supplementation [9]. Malnutrition is one of the main causes of the high rate of infant and child mortality (62‰ in 2012) [9]. The prevalence of chronic malnutrition is 47.4% and that of acute malnutrition is 8% [9].

The objective of this study was to describe the diet of 6- to 59-month-old children in two districts of Madagascar (Moramanga and Morondava) and to identify the determinants of low dietary diversity scores. These findings are essential for improving or adapting interventions concerning children’s diets to improve their nutritional status.

Materials and methods

Study sites and population

The children included in this study on feeding practices were those participating in a study on the determinants of chronic malnutrition [10], for which data collection took place from February to November 2014. The study was carried out in two rural areas, the Health and Demographic Surveillance Site (HDSS) of Moramanga and the Bemanonga Commune of the Morondava district. These two areas were selected, as they belong to 2 regions with different nutritional profiles: the Alaotra-Mangoro region is an area of high stunting prevalence (50–60%), whereas the Menabe region is located in an area with average stunting prevalence.

The HDSS site of Moramanga is in the middle-eastern part of Madagascar in the Alaotra-Mangoro region and has 70,000 inhabitants. It is divided into three communes composed of 30 fokontany (villages). A survey conducted in 2010 showed that this area had a high prevalence of chronic malnutrition, estimated at 59.6% [9]. The district of Moramanga has a hot
and humid tropical climate, an annual average rainfall of 1500 to 2000 mm, and light and frequent rainfalls, even in the winter. Staple crops (tubers, cereals) and crops of fruits and vegetables are common, as is the raising of poultry, goats, and pigs. The region of Alaotra-Mangoro is rich in mineral resources. The Moramanga district has the most mines (47.6% of its municipalities have mining operations) and is home to one of the country’s largest mining operations (cobalt and nickel) in the Ambatovy zone [11].

The study involved 13 villages in the rural community of Bemanonga in the Morondava district of Menabe. These 13 villages have an estimated population of 13,700 inhabitants (9% of the total population of the district of Morondava). The district of Morondava is located in the southwestern region of Madagascar. It has very low and irregular rainfall (< 800 mm per year), with six to eight months per year of the dry season. Farmers in the district mainly grow rice but also other crops, such as cassava, maize, and peas. The raising of zebu is common in the district, and families practice poultry farming [12].

The children were chosen randomly from the two study areas. First, a screening phase was conducted by measuring weight, height/length of all children under 5 years of age. Thereafter, simple random sampling of non-malnourished and stunted children was performed until the number of children included was at least 810 in each study site. If mothers had more than one eligible child, only the first randomly selected child was considered. All children under 5 years with disabilities preventing anthropometric measurements were not included in the screening phase. Those with both stunting and wasting and those not accompanied by their own mothers or caregivers during the survey were not included in study [10].

The parents of the children included in the study gave their written consent after being given information on the purpose and practical issues of the study. The protocol for the study was approved by the Ethics Committee of the Ministry of Public Health of Madagascar (N° 042-MSANP/CE of 13/06/2014).

Data collection

The questionnaire was administered to the mother, or the person who usually takes care of the child at home, by trained interviewers. Information was collected on the following characteristics: (i) the child’s age and sex; (ii) feeding practices, including breastfeeding, age at introduction of supplementary food, consumption of food and beverages, and meal frequency using the 24-hour recall method; (iii) the mother’s age, education, and occupation; and iv) regarding the household, property owned, the characteristics of the house, ownership of livestock, and the number of food crops cultivated (rice, fruits, tubers, legumes, vegetables, and others).

Data analysis

Evaluation of the feeding practices of children 6 to 23 months of age. The information collected on diet was used to develop several indicators of dietary practices for children aged 6 to 23 months. We considered the standard indicators proposed by the WHO [13]: early breastfeeding, breastfeeding for up to 12 months, consumption of supplementary food, minimum meal frequency, minimum acceptable diet, and consumption of iron-rich foods. The proportion of children with minimum acceptable diets is defined as the proportion of breastfed and non-breastfed children aged 6–23 months who i) received solid, semisolid, or soft foods (including milk feeds for non-breastfed children) the minimum number of 2 and 3 times for breastfed infants and 4 times for non-breastfed infants and ii) have consumed foods from at least 4 of the following food groups: starchy staples (grains, roots and tubers), legumes and nuts, dairy products, flesh foods, eggs, vitamin A-rich fruits and vegetables, and other fruits and vegetables.
Iron-rich foods include flesh foods, such as meat, poultry, fish, and liver/organ meat.

**Estimation of the food diversity score.** Food consumed by children the day before the survey was classified into the following seven food groups according to WHO guidance: (1) cereals, roots and tubers; (2) legumes and nuts; (3) milk and its derivatives; (4) meat products (meat, poultry, offal, and fish); (5) eggs; (6) vitamin A-rich fruits and vegetables (leafy green vegetables, yellow fruits and vegetables); and (7) other fruits and vegetables [13]. The dietary diversity score (DDS) was defined as the number of food groups consumed by the child the previous day. A DDS of four is considered the minimum DDS. Accordingly, a child with a DDS < 4 was classified as having low dietary diversity; otherwise, he was considered to have adequate dietary diversity [13].

Data collected about the household, apart from the possession of livestock and the number of food crops cultivated, were used to determine the household’s socioeconomic level. The wealth index was constructed using principal component analysis (PCA) for continuous variables and multiple correspondence analysis (MCA) for categorical variables. The variables included in the generation of this score were those having a dominant modality with a frequency of less than 80% (household assets, including radio, cart, television, bicycle; number of inhabitants per room; materials used for the roof and walls; combustible used for light and cooking; type of toilet; ownership of locales for cooking and bathing; source of drinking water; and the distance from the house to the source). The coefficients of each linear combination were used as a weight for each variable.

We defined four wealth index levels by treating the distribution quartiles as the interval threshold, with the 1st quartile representing the poorest segment of the population and the 4th quartile representing the wealthiest. Statistical analysis of the data was performed using R software (R Development Core Team (2008). R Foundation for Statistical Computing, Vienna, Austria).

Qualitative variables are presented as percentages rounded to one decimal and quantitative variables as medians with interquartile ranges. The proportions were compared using a \( \chi^2 \) test, a Yates-adjusted \( \chi^2 \) test, or Fisher’s exact test. Averages and medians were compared using a means or median comparison test.

Bivariate analysis was used to identify the explanatory variables to be included in the multivariate analysis. The variable dietary diversity score was classified into two categories: low and adequate. Explanatory variables with a p-value < 0.2 were included in the multivariate analysis. A backward logistic regression was performed to obtain the final model and the variables associated with a low dietary diversity score.

**Results**

**Characteristics of the children included in the study**

We included 1824 children in the study: 893 from Moramanga and 931 from Morondava. In Moramanga, 7436 children under 5 years of age participated in the anthropometric measurements, 7359 (99.0%) of whom had valid measurements. For the study, we randomly selected 7139 children without wasting. In Morondava, 2048 children were screened, 1971 (96.2%) of whom had valid measurements; 1888 children were randomly selected for the study. The characteristics of the children are summarized in Table 1. Most were aged 24 months and over: 67.0% and 63.3% in Moramanga and Morondava, respectively. Among the children enrolled in the study, 52.7% in Moramanga and 49.0% in Morondava were female. There was a significant difference between the two study areas for all characteristics studied, except the sex of the children and the socioeconomic level of the households (Table 1).
Quality of dietary practices of children of 6 to 24 months

In Moramanga, the prevalence of early initiation of breastfeeding (within 1 hour of birth) was 53.5%. In Morondava, approximately 24.0% of children were breastfed within 1 hour of birth. The practice of breastfeeding up to the age of 12 months was very frequent in the two study.

Table 1. Characteristics of the children included in the study.

| Characteristics                          | Moramanga N (%) | Morondava N (%) |
|------------------------------------------|-----------------|-----------------|
| Child                                    |                 |                 |
| Age                                      |                 |                 |
| 6–11 months                              | 69 (7.7)        | 107 (11.5)**   |
| 12–23 months                             | 226 (25.3)      | 234 (25.1)      |
| 24–35 months                             | 192 (21.5)      | 229 (24.6)      |
| ≥ 36 months                              | 406 (45.5)      | 361 (38.8)      |
| Sex                                      |                 |                 |
| Female                                   | 470 (52.7)      | 457 (49.1)      |
| Male                                     | 423 (47.3)      | 474 (50.9)      |
| Dietary diversity score (DDS)            |                 |                 |
| Low DDS                                  | 376 (42.2)      | 444 (47.7)**   |
| Adequate DDS                             | 517 (57.8)      | 487 (52.3)      |
| Breastfeeding                            |                 |                 |
| Yes                                      | 290 (32.4)      | 258 (27.7)*    |
| No                                       | 603 (67.6)      | 673 (62.3)      |
| Mother                                    |                 |                 |
| Age: median [interquartile range]        | 29 years [24–36] | 26 years [20–35]** |
| Education level                          |                 |                 |
| No school                                | 98 (11.0)       | 363 (39.0)**   |
| Elementary school                        | 534 (59.8)      | 435 (46.7)      |
| Middle school or higher                  | 261 (29.2)      | 133 (14.3)      |
| Activities outside the home              |                 |                 |
| Yes                                      | 789 (88.4)      | 716 (77.0)**   |
| No                                       | 104 (11.6)      | 215 (33.0)      |
| Household                                 |                 |                 |
| Wealth index                             |                 |                 |
| Quartile 1 (poorest)                     | 237 (26.5)      | 259 (27.8)      |
| Quartile 2                                | 210 (23.5)      | 230 (24.7)      |
| Quartile 3                                | 223 (25.0)      | 220 (23.6)      |
| Quartile 4 (wealthiest)                  | 223 (25.0)      | 222 (23.9)      |
| Types of food crops                      |                 |                 |
| None                                     | 29 (3.2%)       | 56 (6.0%)**    |
| 1 to 3                                   | 394 (44.1%)     | 637 (68.4%)     |
| 4 or more                                | 470 (52.7%)     | 238 (25.6%)     |
| Possession of livestock                  |                 |                 |
| Yes                                      | 715 (80.0)      | 804 (86.3)**   |
| No                                       | 178 (20.0)      | 127 (13.7)      |
| Total                                    | 893             | 931             |

*p < 0.05; **p < 0.001;

https://doi.org/10.1371/journal.pone.0200235.t001
sites: 98.5% of children from Moramanga and 87.6% from Morondava were still being breastfed on the day before the survey.

All children in the study aged 6 to 9 months had already begun to consume complementary foods. Almost all children under 18 months of age (95%) had adequate meals according to their age and breastfeeding status, although the proportion decreased starting from 18 months of age (90.8% in Moramanga and 75.2% in Morondava).

Overall, approximately 50% of children in both sites had an acceptable minimum diet. The proportion was highest for children aged 12 to 17 months: 65.1% in Moramanga and 47.8% in Morondava (Fig 1). It decreased from the age of 18 months. The decrease was most striking in Morondava, where only 24.8% of children aged 18–23 months had an acceptable minimum diet (Fig 1).

Iron-rich foods were eaten by 48.1% of children in Moramanga and 57.3% of those in Morondava. Children aged 12 to 17 months consumed the most iron-rich foods, 54.7% in Moramanga and 63.5% in Morondava. The proportion of children who consumed iron-rich foods was higher in Morondava than in Moramanga. The most highly consumed iron-rich foods were beef in Moramanga and fresh fish in Morondava.
Food consumption

A median of eight foods were consumed (solid and semi-liquid) the day before the survey (interquartile range: 6–10). In Moramanga, half of the children consumed at least nine foods (interquartile range: 7–11), whereas in Morondava, the median number of foods consumed the day before was seven (interquartile interval: 5–9).

The consumption frequencies of food groups in the two districts are summarized in Fig 2. The children's diet was composed mainly of "cereals, roots and tubers", "fruits and vegetables" (vitamin A-rich fruits and vegetables and other fruits and vegetables), and "meat products and fish".

These food groups were consumed by more than 45% of the children in the two districts. The consumption of eggs, and milk and its derivatives was rare, and less than 20% of children did so: 10.6% of children in Moramanga consumed eggs, and 16.8% consumed milk and dairy; in Morondava, 4.7% and 6.3% of children consumed eggs and milk and dairy, respectively.

The proportion of children who consumed food from groups other than staple foods (cereals, roots and tubers) and meat products was significantly higher in Moramanga compared to Morondava. Among those who ate meat products the day before, 53.1% came from Morondava and 46.8% from Moramanga (p < 0.05).

Rice was the staple food most frequently consumed by children at both study sites the day before the survey. Almost half (47%) of the children in Moramanga ate a cookie the day before and 41.4% of those from Morondava consumed sweet potato. In Morondava, children had

![Frequency of consumption of the food groups in the two study areas.](https://doi.org/10.1371/journal.pone.0200235.g002)
consumed more vitamin A-rich fruits the day before, such as mangoes (64.3%), whereas in Moramanga, the most highly consumed fruit the day before was bananas (45.6%), which belong to the category of other fruit. The most popular vitamin A-rich vegetables at the two study sites were green leafy vegetables (Chinese cabbage, sweet potato leaf, etc.): 25.3% for Moramanga and 42.2% for Morondava. Various meats were consumed by the children of Moramanga: 25.3% beef, 18.6% dried fish, and 14.9% poultry. In contrast, more than half of the children (56.4%) in Morondava consumed fresh fish the day before, and 11.2% consumed beef and 8.3% dried fish. Concerning legumes/nuts/seeds, children in Moramanga consumed beans (44.3%) and peanuts (31.7%). In Morondava, 52.1% of children consumed lima beans/butter beans and 32.8% peanuts the day before.

Dietary diversity and determinants

A low dietary diversity score was defined as the consumption of three or fewer food groups. The proportion of children with a low dietary diversity score was 42.1% [95% CI: 39.0%-45.4%] in Moramanga and 47.6% [95% CI: 44.4%-50.8%] in Morondava.

Children at the two study sites who had a low dietary diversity score rarely consumed eggs or foods belonging to the milk and its derivatives group. In Moramanga, less than 10% of children with a low dietary diversity score consumed dairy products and eggs, respectively at 7.0% and 9.5%. In Morondava, the proportion of children with a low dietary diversity score consuming dairy products the previous day was 8.5%, and the proportion of who consumed eggs was 4.5%.

Children in Morondava who had a low dietary diversity score mostly consumed foods belonging to the groups "legumes and nuts" and "meat products" (p < 0.001) (Fig 3).

We assessed the association between a low dietary diversity and many independent variables: household characteristics (wealth index, the ownership of livestock and the types of food crops), and mothers’ characteristics (age, occupation status and level of education). The final model showed that the main variables significantly associated with low dietary diversity were mothers’ education at both study sites and wealth index and non-possession of livestock in Morondava. In Moramanga, a low dietary diversity score was significantly associated with a low level of maternal education. Children whose mothers never attended school and those whose mothers completed at least one year in primary school were, respectively, 2.2-fold (95% CI: 1.3–3.8) and 1.8-fold (95% CI: 1.3–2.6) more likely to have a low dietary diversity score than those whose mothers spent at least one year in middle school or university (Table 2).

In Morondava, a low level of maternal education and low socioeconomic status of the household were risk factors for low dietary diversity. In addition, the probability of having a low dietary diversity score was 1.8-fold (95% CI: 1.2–2.7) higher for children living in households that do not raise livestock than for those living in households that do (Table 3).

Discussion

We performed a study at the HDSS of Moramanga and in the commune of Bemanonga in the Morondava district to describe the diet of children aged 6–59 months, including dietary diversity. Further statistical analysis allowed for the identification of determinants of a low dietary diversity score. Breastfeeding up to the age of 12 months was very common at both study sites, although almost half (46.5%) of the children in Moramanga and approximately three-quarters (76.0%) of those in Morondava did not benefit from early breastfeeding. The children’s diet consisted mainly of starchy foods (based on cereals, roots, and tubers), seasonal fruits and vegetables. The proportion of children with a low dietary diversity score was higher in Morondava (47.6%) than in Moramanga (42.1%). At both study sites, a low level of education of mothers...
Table 2. Results of the multivariate analysis between the dietary diversity score and the explanatory variables, Moramanga district: Final model.

| Age (in months) | Low N (%) | Adequate N (%) | Crude OR (95% CI) | Adjusted OR * (95% CI) |
|-----------------|-----------|----------------|-------------------|------------------------|
| ≥36             | 151 (37.3)| 255 (62.7)     | 1                 | 1                      |
| 24–35           | 78 (40.6) | 114 (59.4)     | 1.1 (0.8–1.6)     | 1.1 (0.8–1.6)          |
| 12–23           | 102 (45.1)| 124 (54.9)     | 1.3 (0.9–1.8)     | 1.3 (0.9–1.8)          |
| 6–11            | 45 (65.2) | 24 (34.8)      | 3.3 (1.9–5.8)     | 3.3 (1.9–5.9)          |

| Educational level of the mother | Low N (%) | Adequate N (%) | Crude OR (95% CI) | Adjusted OR * (95% CI) |
|---------------------------------|-----------|----------------|-------------------|------------------------|
| Middle school or higher         | 70 (26.8) | 191 (73.2)     | 1                 | 1                      |
| Elementary school               | 251 (47.1)| 283 (52.9)     | 2.4 (1.7–3.3)     | 1.8 (1.3–2.6)          |
| No school                       | 55 (56.1) | 43 (43.9)      | 3.5 (2.1–5.7)     | 2.2 (1.3–3.8)          |

95% CI: 95% confidence interval; OR: odds ratio; *: adjusted with household wealth index.

https://doi.org/10.1371/journal.pone.0200235.t002

Fig 3. Proportion of children with a low dietary diversity score who consumed each food group. Light gray bar: Moramanga. Dark gray bar: Morondava. First two bars: Cereals, roots and tubers. Second two bars: Eggs. Third two bars: Meat, poultry and fish. Fourth two bars: Other vegetables and fruits. Fifth two bars: Vitamin A-rich fruits and vegetables. Sixth two bars: Dairy. Seventh two bars: Legumes and nuts.

https://doi.org/10.1371/journal.pone.0200235.g003
was a risk factor for a low dietary diversity score. Children aged 6–11 months were more likely to have a relatively non-varying diet than older children. In Morondava, not having farm animals and belonging to the poorest household wealth index was also a risk factor.

Breastfeeding for up to 12 months was frequent. However, early breastfeeding was less frequent: only half the children of Moramanga and not even a quarter of the children of Morondava started breastfeeding early. The region of Menabe, which is part of the Morondava study site, is the region in Madagascar with the second-highest proportion of children who do not start to breastfeed early (40.7%) [9]. The WHO recommends breast-feeding within one hour of delivery, as colostrum is highly nutritious and contains antibodies to protect the child [14]. The poor perception of mothers of colostrum has been reported in the southern and southwestern regions of Madagascar, leading to calls for increased awareness and education of mothers (or influential individuals) on the benefits of colostrum [15,16]. Dietary diversity is an important element for appreciating the quality of the diet, although assessments are difficult in many developing countries. The methods used to estimate dietary intake require time and resources [17]. The diets of children in our two study sites were typical of those of developing countries: often poorly balanced; composed mainly of foods rich in carbohydrates, vegetables, and seasonal fruits; and poor in meat products [18]. Rice was the most highly consumed starchy food. Madagascar is among the countries with the highest rice consumption, which is estimated to be ≥ 300 g/d per inhabitant [19]. Consistent with findings from other studies [20,21], the dietary diversity score at our two study sites from the age of 12 months was higher than that of children aged 6 to 11 months. This may be because older children eat the foods prepared for the family as a whole and thus eat the same meals as other family members. In our two study sites, 56.0% of the children with data available on the type of dish consumed (n = 1003) consumed a family dish the day before. The proportion increased with child age: 43.1% for children aged 6–11 months, 49.8% for those aged 12–23 months, and approximately 60% for those aged 24 months.

The proportion of children with a low dietary diversity score was significantly higher in Morondava than in Moramanga. More than two in five children (47.6%) in Morondava had a

| Table 3. Results of the multivariate analysis between the dietary diversity score and the explanatory variables, Morondava district: Final model. |
|---------------------------------------------------------------|
| Dietary diversity score | Crude OR (95% CI) | Adjusted OR* (95% CI) |
| Low N (%) | Adequate N (%) |  |
| Educational level of the mother |  |  |
| Middle school or higher | 31 (23.3) | 102 (76.7) | 1 | 1 |
| Elementary school | 194 (44.6) | 241 (55.4) | 2.6 (1.7–4.1) | 2.4 (1.5–6.4) |
| No school | 219 (60.3) | 144 (29.7) | 5.0 (3.2–7.9) | 4.0 (2.5–6.4) |
| Household socioeconomic level |  |  |
| 4th Quartile (wealthiest) | 73 (32.9) | 149 (67.1) | 1 | 1 |
| 3rd Quartile | 103 (46.8) | 117 (53.2) | 1.8 (1.2–2.6) | 1.4 (1.0–2.1) |
| 2nd Quartile | 119 (51.7) | 111 (48.3) | 2.2 (1.5–3.2) | 1.5 (1.0–2.2) |
| 1st Quartile (poorest) | 149 (57.5) | 110 (42.5) | 2.7 (2.0–4.0) | 1.8 (1.2–2.8) |
| Possession of livestock |  |  |
| Yes | 365 (45.4) | 439 (54.6) | 1 | 1 |
| No | 79 (62.2) | 48 (37.8) | 2.0 (1.3–3.0) | 1.8 (1.2–2.7) |

95% CI: 95% confidence interval; OR: odds ratio; *: adjusted with age

https://doi.org/10.1371/journal.pone.0200235.t003
low dietary diversity score, whereas in Moramanga, the proportion was approximately 42.1%. The difference may be because Morondava is in a region where the proportion of households with food insecurity is higher. A survey conducted in 2010 suggested that 41.1% of households in the Menabe region were food insecure, whereas the proportion was only 9.6% in the more highly developed Alaotra-Mangoro region [22].

We show that a low education level of mothers and low socioeconomic status of the child’s household increased the likelihood of having a low dietary diversity score. The importance of the level of education of the parents, particularly the mother, on children’s food practices has already been demonstrated in developing countries [21,23]. The quality of the diet of children during their early years depends mainly on the behavior and decisions of the mothers or those who usually care for the child [24]. Efforts should be made to improve the education of women and girls, as this could improve children’s dietary practices, and particularly dietary diversity. In addition, nutrition education and awareness programs should be adapted to women and mothers with poor education. In Madagascar, the ratio of girls to boys in education decreases as the level of education increases: 1.05 for primary education, 0.8 for secondary education, and 0.7 for higher education [25]. One of the many reasons for extending the education of girls is that it later becomes a major determinant of their children’s diets. Universal education, a complete cycle of free primary and secondary education by 2030 for girls and boys, constitutes Objective 4 of the Sustainable Development Objective (SDO) [26].

A low household socioeconomic status was a risk factor for child dietary diversity for children at the Morondava study site: the proportion of children with a low dietary diversity score increased with decreasing household socioeconomic score. Our results are consistent with those of other groups [20,23,27–29] and may reflect food insecurity in these households. Indeed, a lack of resources undoubtedly reduces the purchasing power, and thus, access to food, of households.

In Morondava, the risk of low dietary diversity scores was higher in households with no livestock than those with at least one animal (Adjusted OR: 1.8, 95% CI: 1.2–2.7). Ownership of livestock can directly improve the quality of children’s diets if livestock products are used for home consumption (milk and milk products, eggs, meat)[30]. The income from livestock products can also indirectly contribute to the improvement of the children’s diet, if appropriately managed [31,32]. Data on the use of livestock products or the origin of foods consumed by the households were not available in this study, and we found no statistically significant association between meat consumption by the child the day before the survey and the possession of livestock by the household. Indeed, one limitation of this study is that data on the children’s diet were collected by single 24-hour recall; evidence suggests that the use of repeated, nonconsecutive 24-hour recall might improve data reliability and the estimation of diet [33]. However, we found some common determinants that were reported elsewhere, and the appropriate modeling for confounding effects adds strength to the validity of our findings. The lack of seasonality information could also be a limitation; a study conducted in Ethiopia with representative data suggested a seasonal variation in dietary diversity likely related to many factors (fasting period, lower availability of production) [34]. Studies including follow-up visits could examine seasonality more explicitly.

Our study shows that the diet of more than two-fifths of the children at our study sites in Bemanonga Commune, Morondava and the HDSS of Moramanga, were not diversified; this finding applied particularly to the youngest children (6–11 months). The low level of education of the mothers was the main risk factor for the low dietary diversity score in Moramanga. In Morondava, the low socioeconomic level of households and the lack of ownership of farm animals increased the likelihood of having a low dietary diversity score. One strength of this study is the random selection of the participants, such that they are representative of the
children aged 6 to 59.9 months in the two zones. Few studies about infant and young child feeding practices have been conducted in Madagascar [6,29], and our results were complementary. Our study contributes to the understanding of the association between dietary diversity and its determinants. Our findings indicate that improving the level of education of women would be beneficial in the long term and that in the short term, nutrition education programs (messages transmitted, type of educational materials) should be adapted for women with a low educational level to improve children’s food practices.

Interventions favoring food accessibility for disadvantaged households should be strengthened, including the promotion of husbandry practices and the use of the resulting food products [35]. Programs to reduce poverty and improve food availability through conditional transfer programs could be helpful [36]. We recommend programs that integrate several types of intervention (maternal education, food accessibility, poverty reduction), as they will improve children’s dietary diversity and possibly their nutritional status.

Supporting information
S1 Data. Data used for the analysis.
(XLSX)

Acknowledgments
We thank the study participants, investigators, team leaders, community health workers, and administrative and health authorities in the districts of Moramanga and Morondava. We also thank the group of Louvain Coopération-Morondava, which participated in the data collection in Morondava, and the National Office of Nutrition, which helped us with the logistics. We are grateful to Professor Christophe Rogier and Dr Laurence Baril for their invaluable help.

Author Contributions
Conceptualization: Patrice Piola, Rindra Vatosoa Randremanana.
Formal analysis: Nivo Heritiana Rakotonirainy, Rindra Vatosoa Randremanana.
Funding acquisition: Patrice Piola, Rindra Vatosoa Randremanana.
Investigation: Randza Rasoloarijaona.
Methodology: Nivo Heritiana Rakotonirainy, Valérie Razafindratovo, Chitale Rabaoarisoa Remonja, Charlotte Raharintsoa, Rindra Vatosoa Randremanana.
Supervision: Nivo Heritiana Rakotonirainy, Chitale Rabaoarisoa Remonja, Randza Rasoloarijaona, Charlotte Raharintsoa, Rindra Vatosoa Randremanana.
Validation: Valérie Razafindratovo, Charlotte Raharintsoa, Rindra Vatosoa Randremanana.
Writing – original draft: Nivo Heritiana Rakotonirainy, Rindra Vatosoa Randremanana.
Writing – review & editing: Valérie Razafindratovo, Chitale Rabaoarisoa Remonja, Randza Rasoloarijaona, Patrice Piola, Charlotte Raharintsoa, Rindra Vatosoa Randremanana.

References
1. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013; 382: 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X PMID: 23746772
2. UNICEF, WHO. The World Bank Group 2013 Joint child malnutrition estimates—Levels and trends. 2014.
3. INSTAT, ORC Macro. Enquête Démographique et de Santé de Madagascar 2003–2004. Calverton, Maryland: 2005.
4. Hatloy A, Torheim LE, Oshaug A. Food variety—a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr. 1998; 52: 891–898. PMID: 9881884
5. Steyn N, Nel J, Nantel, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy. Public Health Nutr. 2005; 9: 644–650
6. Mourni MM, Arimond M, Dewey KG, Treche S, Ruel MT, Delpeuch F. Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar. J Nutr. 2008; 138: 2448–2453. https://doi.org/10.3945/jn.108.093971 PMID: 19022971
7. Steyn N, Nel J, Labadarios D, Maunder E, Kruger H. Which dietary diversity indicator is best to assess micronutrient adequacy in children 1 to 9 y. Nutrition. 2014; 30: 55–60 https://doi.org/10.1016/j.nut.2013.06.002 PMID: 24290599
8. Kennedy G, Ballard T, Doph MC. Guidelines for measuring household and individual dietary diversity. Rome: Food and Agriculture Organization of the United Nations, 2013.
9. INSTAT. Enquête Nationale sur le Suivi des indicateurs des Objectifs du Millénaire pour le Développement 2012–2013. Madagascar. 2014.
10. Rabaoarisoa CR, Rakotoarison R, Rakotonirainy NH, Mangahasimbola RT, Randrianarisoa AB, Jambou R, et al. The importance of public health, poverty reduction programs and women’s empowerment in the reduction of child stunting in rural areas of Moramanga and Morondava, Madagascar. PLoS One. 2017; 12: e0186493. https://doi.org/10.1371/journal.pone.0186493 PMID: 29045444
11. Ministère de l’Économie et du plan Madagascar, Les activités économiques de la Région Alaotra Mangoro 2015 [02/11/2016]. http://www.economie.gov.mg/les-activites-economiques-3/
12. SAHA, Association Famplita. Rapport d’enquête communautaire de l’observatoire rural de Morondava, campagne 2007. 2007.
13. WHO. Indicators for assessing infant and young child feeding practices: conclusions of a consensus meeting held. Washington DC: World Health Organization, 2007.
14. WHO. Guiding principles for feeding infants and young children during emergencies. Geneva: World Health Organization; 2004 [12/02/2016]. http://www.unhcr.org.45f6c8d62. pdf.
15. Steyn N, Nel J, Labadarios D, Maunder E, Kruger H. Which dietary diversity indicator is best to assess micronutrient adequacy in children 1 to 9 y. Nutrition. 2014; 30: 55–60 https://doi.org/10.1016/j.nut.2013.06.002 PMID: 24290599
16. Kennedy G, Ballard T, Doph MC. Guidelines for measuring household and individual dietary diversity. Rome: Food and Agriculture Organization of the United Nations, 2013.
17. WHO. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr 2004; 134: 2579–2585. https://doi.org/10.1093/jn/134.10.2579 PMID: 1546751
18. Arimond M, R MT. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr Metab. 2013; 2013:782931. https://doi.org/10.1155/2013/782931 PMID: 24455218
19. FAO. FAOSTAT Database Rome: FAO; 2013 [2017/01/25]. www.fao.org/faostat/en/
20. Issaka A, Agho K, Page A, Burns P, Stevens G, Dibley M. Determinants of suboptimal complementary feeding practices among children aged 6–23 months in four anglophone West African countries. Matern Child Nutr. 2015; 11: 14–30. https://doi.org/10.1111/mcn.12194 PMID: 26364789
21. Aemro M, Mesele M, Birhanu Z, A A. Dietary Diversity and Meal Frequency Practices among Infant and Young Children Aged 6–23 Months in Ethiopia: A Secondary Analysis of Ethiopian Demographic and Health Survey 2011. J Nutr Metab. 2013; 2013:782931. https://doi.org/10.1155/2013/782931 PMID: 24455218
22. UNICEF, PAM, ONN, MSP. Analyse globale de la sécurité alimentaire et nutritionnelle et de la vulnérabilité en milieu rural à Madagascar 2010. 2011.
23. Senarath U, Agho K, Akram D, Godakandage S, Hazir T, Jayawickrama H, et al. Comparisons of complementary feeding indicators and associated factors in children aged 6–23 months across five South Asian countries. Matern Child Nutr. 2012; 8 89–106. https://doi.org/10.1111/j.1740-8709.2011.00370.x PMID: 22168521
24. Jones A. The production diversity of subsistence farms in the Bolivian Andes is associated with the quality of child feeding practices as measured by a validated summary feeding index. Public Health Nutr 2014; 18: 329–342. https://doi.org/10.1017/S1368980014000123 PMID: 24552695
25. INSTAT. Enquête Démographique et de Santé (EDS) Madagascar 2008–2009. 2010.
26. ONU. Objectifs du développement durable 2015 [12/02/2016]. http://www.un.org/sustainabledevelopment/fr/summit/.

27. Mayen A, Marques-Vidal P, Paccaud F, Bovet P, Stringhini S. Socio-economic determinants of dietary patterns in low and middle-income countries: a systematic review. Am J Clin Nutr 2014; 100:1520–1531. https://doi.org/10.3945/ajcn.114.089029 PMID: 25411287

28. Joshi N, Agho K, Dibley M, Senarath U, Tiwari K. Determinants of inappropriate complementary feeding practices in young children in Nepal: secondary data analysis of Demographic and Health Survey 2006. Matern Child Nutr. 2012; 8:45–59. https://doi.org/10.1111/j.1740-8709.2011.00384.x PMID: 22168518

29. Rakotomanana H, Gates GE, Hildebrand D, Stoecker BJ. Situation and determinants of the infant and young child feeding (IYCF) indicators in Madagascar: analysis of the 2009 Demographic and Health Survey. BMC Public Health. 2017; 17:812. https://doi.org/10.1186/s12889-017-4835-1 PMID: 29037229

30. Gillespie S, Harris J, Kadiyala S. The agriculture-nutrition disconnect in India: What do we know? Washington, DC: IFPRI, 2012.

31. Kennedy G, Ballard T, Dop M. Guidelines for measuring household and individual dietary diversity. Rome: Food and Agriculture Organization of the United Nations, 2011.

32. Hoddinott J, Haddad L. Women’s income and boy–girl anthropometric status in the Coôte d’Ivoire. World Dev 1994; 22:543–553.

33. Biró G, Hulshof K, Ovesen L, Amorim Cruz J, Group E. Selection of methodology to assess food intake. Eur J Clin Nutr. 2002; 56: S25–S32.

34. Sibhatu K, Qaim M. Rural food security, subsistence agriculture and seasonality. PLoS One. 2017; 12: e0186406. https://doi.org/10.1371/journal.pone.0186406 PMID: 29049329

35. Miller L, Joshi N, Lohani M, Rogers B, Loraditch M, Houser R, et al. Community development and livestock promotion in rural Nepal: effects on child growth and health. Food Nutr Bull. 2014; 35:312–326. https://doi.org/10.1177/156482651403500304 PMID: 25902591

36. Ramirez-Luzuriaga M, Unar-Munguia M, Rodriguez-Ramirez S, Rivera J, Gonzalez de Cosio T. A food transfer program without a formal education component modifies complementary feeding practices in poor rural Mexican communities. J Nutr 2016; 146:107–113. https://doi.org/10.3945/jn.115.215962 PMID: 26561408