Original Article

Factors which may limit the value of dietary diversity and its association with nutritional outcomes in preschool children in high burden districts of India

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Background and Objectives: Dietary diversity plays a critical role in infants as they need energy and nutrient dense foods for both physical and mental development. This study examines whether three dietary diversity indices validate against Nutrient Adequacy Ratio (NAR) and Mean Adequacy Ratio (MAR) and studies the relationship of dietary diversity with nutritional status of preschool children, in two districts of India: Wardha district in Maharashtra state and Koraput district in Odisha state. **Methods and Study Design:** Dietary diversity was calculated using: individual food scores calculated using 24 hour diet recall (FS_{24hr}) data; household dietary diversity using Berry's index (DDI) and food scores calculated using food frequency data (FS_{FFQ}). Nutritional status was assessed by anthropometric indices. **Results:** It was observed that 42.7% of 1 to 5 years children were underweight, 38% stunted and 27.6% wasted across both locations. The dietary diversity was found to be relatively better in Wardha when compared with Koraput with mean diversity of FS_{24hr} 7, DDI 90 and FS_{FFQ} 63 in both locations. Preschool children in both locations consumed a cereal based diet. Apart from protein in both locations and energy in Koraput, the NAR of all nutrients consumed was <70% of requirement. MAR showed lower consumption of nutrients than the recommended levels (50% adequacy). NAR and MAR correlate with FS_{24hr} indicating that dietary diversity calculated using 24 hour diet recall ensures nutrient adequacy but showed association only with Height-for-Age scores. **Conclusion:** Dietary diversity calculated using three methods did not show any correlation with nutritional status of 1 to 5 years children.

Key Words: dietary diversity indices, adequacy ratio, anthropometric parameters, nutritional status, preschool children

INTRODUCTION

Children between the ages of 6 months to 5 years are at high risk because this is the critical age group where growth and development falters largely due to a combination of frequent illness and inadequate diet (during transition from breastfeeding to family diet). According to the latest round of the National Family Health Survey,[1] 41.2% children under five years in rural India are stunted, 21.5% are wasted and 38.3% are underweight. Undernutrition is directly linked with an inadequate intake of nutrients in the diet. Studies highlight low dietary diversity as the primary cause for under-nutrition.[2,3] Dietary diversity is a good indicator of diet quality and is often linked to household food security. PAHO/WHO[4] has advocated the use of dietary diversity as an indicator in their recently updated guide for complementary feeding of infants and young children. Dietary diversity is positively correlated with nutrient density and adequacy of diets of people or groups[5-8] and is a proxy indicator to which the diet provides sufficient energy, protein, and essential micronutrients.[9] Calculation of the nutrient adequacy ratio (NAR) and the mean nutrient adequacy ratio (MAR)[10] are widely used approaches for mea suring nutrient adequacy.

Understanding the interactions between nutritional intake and nutritional status of preschool children is complex as it involves various factors including birth weight, frequency of morbidity, feeding practices and sanitation.[11] The methods used to measure dietary diversity also differ widely[12] between studies, particularly the studies on relationship between dietary diversity and nutritional outcome. Many researchers use food scores which are calculated by a simple counting of food groups and relating these scores to health indicators. FAO[13] recommends the 24 hour diet recall method to calculate dietary diversity. Few studies use food frequency to calculate dietary diversity.[14,15] Berry's index (Simpson's index) is a dietary diversity index (DDI) that is used to evaluate dietary diversity in terms of number as well as distribution and quantity of consumption of different food items.[16,17]

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For tackling malnutrition, much can be gained by linking agriculture and ecology to human nutrition,[18] given that biodiversity and hunger almost overlap.[19] Agricultural production diversity is positively associated with dietary diversity which in turn is correlated with nutritional outcomes in children.[14,20-23] A one per cent increase in land productivity increases the percentage of well-nourished children below six years by about 0.08%.[24] About 58% of rural households in India are dependent on agriculture;[25] the level of undernutrition in the population is also high. A Farming System for Nutrition (FSN) study under the research programme on Leveraging Agriculture for Nutrition in South Asia (LANSA) is currently ongoing in Wardha district of Maharashtra state and Koraput district of Odisha state in India to examine the feasibility of crop and animal husbandry interventions in promoting dietary diversity and its impact on nutritional outcomes.[26]

A detailed baseline survey was undertaken in 2014 in selected villages in the two districts as part of the FSN study, to assess the nutritional status of the children and their consumption pattern. The objective of the present paper is to validate dietary diversity indices calculated using three different methods and to study its relationship with nutritional status of preschool children between 1 to 5 years of age. (This age group is chosen as the dietary diversity for children less than a year was very small given that complementary feeding is initiated only at 6 months).

METHODS

Study area

Eight villages from Wardha district in Maharashtra and eleven villages from Koraput district in Odisha were chosen for the study. These locations were purposively selected due to their characteristic contrast with regard to agro-climatic and socio-economic conditions, land holding status, agricultural practices and food consumption pattern. Though both sites are rain-fed farming areas, Koraput is characterised by subsistence farming, while Wardha is dominated by commercial crop cultivation. Both the sites are also characterized by high levels of under-nutrition[26] and are termed as high burden districts. There are 130 children in the preschool age group (1 to 5 years) in Wardha and 214 children in Koraput in our study.

Nutritional status

Anthropometric parameters

The height and weight of individual children aged 1 to 5 years were measured using standard equipment (Seco weight balance and stadiometer/ infantometer) by investigators trained in the methodology by a retired scientist from the National Institute of Nutrition (NIN), Hyderabad. Z scores were calculated using Anthro (version 3.2.2, 2011) software of the WHO. The prevalence of undernutrition among preschool children according to underweight (WAZ: weight for age median <-2 standard deviation), stunting (HAZ: height for age median <-2 standard deviation) and wasting (WHZ: weight for height median <-2 standard deviation) was computed using WHO Child Growth Standards. Ethical clearance was obtained from the institution's Ethics Committee. Oral consent was obtained from the head of the household before collecting household information.

Food intake pattern

Food intake pattern was assessed using a one-time 24 hour diet recall method. The calculated data was compared with Recommended Dietary Intake (RDI) given by Indian Council for Medical Research (ICMR).[27]

Dietary diversity

Three methods were used to calculate the dietary diversity: one using data from one-time 24 hour diet recall survey (which shows the individual dietary diversity) and the other two using average of 3 rounds of food frequency data (which shows household dietary diversity).

Food scores using 24 hour diet recall method (FS_{24hr})

The food intake collected once using 24 hour diet recall method was used for calculating the foods consumed per day as given by FAO.[28] The foods were categorized into 13 food groups as recommended by ICMR.[27] A simple counting of food groups was done to arrive at food scores with scores range from 1 to 13.

Berry's index (DDI)

Frequency of foods consumed was recorded at three points of time in a year. The value of monthly consumption was calculated for each of the three rounds using the frequency and quantity of food consumed. A uniform modal price (most frequently occurring price for a food item across households) was used for calculating the value of the food item consumed by each household. This amount was added up for the three rounds and the share of each food item in the total value of foods consumed was derived. DDI was calculated using the formula:

$$DDI = \frac{1}{\sum_i^n (s_i^2)} \; X\,100$$

Where, DDI: Dietary Diversity Index for a household, S_i: Share of value of i[th] individual food out of total value of food consumed calculated using the formula:

$$s_i = \frac{VF_i}{\sum_1^n VF_i}$$

Where, VF_i: Value of i[th] Food stuff

Food scores using food frequency (FS_{FFQ})

The frequency of consumption for the different food groups was recorded for a reference period of one month preceding the survey i.e. daily, twice or thrice a week, once a week, fortnightly, monthly and occasionally. The following scores were given: consumed daily: 7, twice or thrice a week: 3, once a week: 1, fortnightly: 0.5, monthly: 0.25 and occasionally: 0, following Hooshmand & Udipi.[14] The scores were added to get the food diversity score for the household. Food diversity scores range from 1 to 91, (i.e. if all 13 food groups are consumed daily, the maximum score will be 91).

Cut-off points

Associations between diversity and health outcomes are best understood by selecting cut-off points based on the internal distribution of the diversity indicator within the samples, usually by creating quintiles or tertiles.[11] In the analysis, the dietary diversity indices are divided into tertiles (low, moderate and high diversity), and used to study the association with anthropometric parameters.

Validation of dietary diversity indices

Validation of dietary diversity indices was done by Nutrient Adequacy Ratio (NAR) and Mean Adequacy Ratio (MAR). NAR was calculated for 11 nutrients including energy using 24 hour diet recall data. The NAR for a given nutrient is the ratio of a child's intake to the Recommended Dietary Allowances.[27] As an overall measure of the nutrient adequacy, MAR was calculated. NAR was truncated at 1 so that a nutrient with high NAR could not compensate for nutrient with a low NAR.[29]

$$MAR = \frac{\sum NAR\ (each\ truncated\ at\ 1)}{Number\ of\ nutrients}$$

Statistical method

The statistical packages of SPSS (IBM Version 20) and Stata (12.1) were used to study the associations. A 'bivariant Pearson's correlation' was applied to understand the relationship between NAR, MAR and dietary diversity; and dietary diversity tertiles and nutritional status.

RESULTS

It was observed that 42.7% of preschool children in both locations were underweight, 38.1% were stunted and 27.6% were wasted with Koraput having higher prevalence of underweight and stunted children than Wardha (Table 1). The overall mean scores of WHZ, HAZ and WAZ were skewed to the negative side indicating that the preschool children in both the locations were at a higher risk of becoming undernourished. Children in Wardha district were more vulnerable to becoming underweight and stunted than children in Koraput district.

The mean dietary diversity calculated using 24 hour diet recall (FS_{24hr}) was 7 in both the locations. Dietary diversity calculated using food frequency (DDI and FS_{FFQ}) showed that preschool children in Wardha have better diet diversity than preschool children in Koraput. It was observed that DDI showed dietary diversity score of 90 out of 100. Food scores calculated using food frequency showed that the children on an average consumed about 9 food groups (FS_{FFQ} 63) in both locations, with 10 food groups (FS_{FFQ} 69) in Wardha and 8 food groups (FS_{FFQ} 59) in Koraput.

Food intake of most of the children shows low dietary diversity when distributed according to food scores tertiles calculated using 24 hour diet recall (FS_{24hr}) and food frequency (FS_{FFQ}). Ekesa et al.[30] reported that preschool children consumed 3 or less than 3 food groups and Steyn et al.[6] reported consumption of 4 food groups by children in the ages of 1 to 8 years. In contrast, DDI showed high dietary diversity. Dietary diversity at household level does not necessarily translate into diversity of diet at individual level. Moreover, it can be considered as a measure of access to a diverse food basket for individuals. Berry's index has been used mainly to study economic food diversity[16] and uses food prices and income as economic factors influencing demand for diverse foods.[31]

Both the locations have cereal based diets. In fact the consumption of cereals is higher than the recommended levels (Wardha: 92% more than RDI; Koraput 227%

Table 1. Summary of children's anthropometric characteristics, mean dietary diversity scores and distribution of children according to dietary diversity tertiles

Particulars	Wardha (n=130)	Koraput (n=214)	Total (n=344)
Nutritional status (%)			
Underweight	40.8	43.9	42.7
Stunting	36.2	39.3	38.1
Wasting	27.7	27.6	27.6
WHZ scores (Mean±SD)	-1.36±1.19	-1.46±0.98	-1.42±1.06
HAZ scores (Mean±SD)	-1.60±1.55	-1.26±2.05	-1.39±1.88
WAZ scores (Mean±SD)	-1.83±1.15	-1.71±1.41	-1.76±1.32
Dietary diversity (Mean±SD)			
FS_{24hr}	7.10±2.11	6.93±1.65	6.99±1.84
DDI	94.0±2.00	88.0±5.00	90.0±5.00
FS_{FFQ}	69.41±3.86	59.20±4.22	63.06±6.42
% children according the FS_{24hr} tertiles			
Low diet diversity (<7)	75.4	61.7	66.9
Moderate diet diversity (8)	13.8	25.2	20.9
High diet diversity (>12)	10.8	13.1	12.2
% children according the DDI tertiles			
Low diet diversity (<88.4)	28.5	24.3	25.9
Moderate diet diversity (88.5 to 92.7)	32.3	33.6	33.1
High diet diversity (>92.7)	39.2	42.1	41.0
% children according the FS_{FFQ} tertiles			
Low diet diversity (<60)	39.2	40.7	40.1
Moderate diet diversity (60 to 69.5)	36.9	27.1	30.8
High diet diversity (>69.5)	23.8	32.2	29.1

SD: standard deviation; WHZ: weight of height Z scores; HAZ: height for age Z scores; WAZ: weight for age Z scores; DDI: dietary diversity index calculated using Berry's index; FS_{24hr}: food scores calculated using 24 hour diet recall data; FS_{FFQ}: food scores calculated using food frequency data.

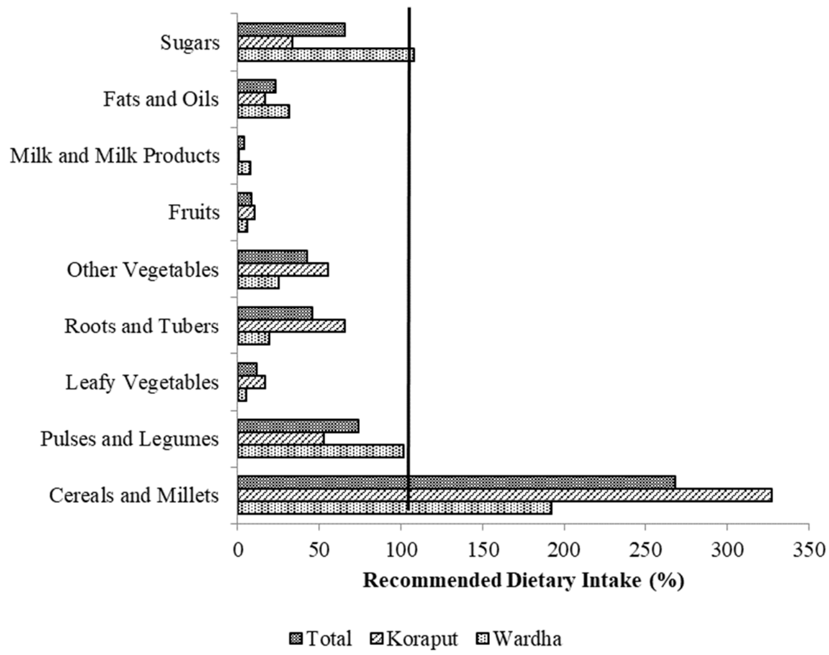

Figure 1. Food consumption pattern against recommended levels in Wardha and Koraput

more than RDI). Figure 1 shows the consumption of different food groups against recommended levels. Ragi or finger millet was consumed daily in Koraput but in very limited quantities. Consumption of protein and calorie rich foods like pulses and sugars was higher or equal to recommended levels in Wardha. Vegetables were consumed in better quantities in Koraput than in Wardha, however their consumption was less than the recommended levels. Roots and tubers, mainly potato and onions, were consumed frequently in both the locations. Green leafy vegetables were consumed in less quantity and fruits, milk and milk products were consumed in negligible amounts in both the locations. Meat, poultry and fish were consumed occasionally in small quantities in both locations (not shown in figure as ICMR has not given recommended levels).

The food consumption pattern is reflected in the nutrient adequacy. In Wardha, only the consumption of protein was >70% of requirement as the consumption of cereals and pulses was higher than the recommended levels. Figure 2 shows the nutrient adequacy ratio and mean adequacy ratio of different nutrients. In Koraput, protein and energy were consumed in adequate amounts (>70% of requirement) as cereals are consumed 200% higher than the recommended level. Apart from iron, thiamine and niacin which were consumed at more than 50% of recommended level, the consumption of remaining nutrients was not adequate in 51% of the recommended levels, with 48% in Wardha and 52% in Koraput. Steyn et al[6] reported 50% MAR in 1 to 8 year old children.

Table 2 shows the correlation between nutrient adequacy and the three diet diversity scores. Food score calculated using 24 hour diet recall data (FS_{24hr}) showed an association with adequacy of all the nutrients in both the locations. A study in Mali reported a significant association between both the locations. The mean adequacy ratio was about nutrient adequacy with individual dietary

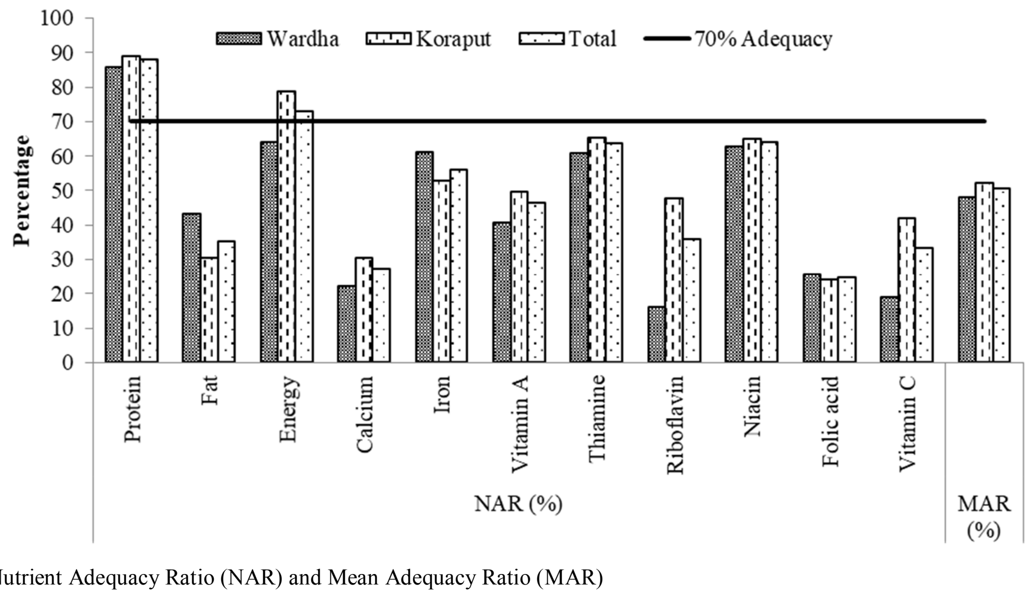

Figure 2. Nutrient Adequacy Ratio (NAR) and Mean Adequacy Ratio (MAR)

Table 2. Correlation between adequacy ratio and diet diversity scores

		Wardha (n=130)			Koraput (n=214)			Total (n=344)		
		FS_{24hr}	DDI	FS_{FFQ}	FS_{24hr}	DDI	FS_{FFQ}	FS_{24hr}	DDI	FS_{FFQ}
NAR (%)	Protein	0.480**	0.120	-0.284**	0.450**	-0.083	-0.105	0.457**	-0.070	-0.161**
	Fat	0.529**	0.118	-0.036	0.419**	0.049	-0.026	0.469**	0.186**	0.159**
	Energy	0.455**	0.277**	-0.160	0.423**	-0.075	-0.162*	0.411**	-0.145**	-0.287**
	Calcium	0.340**	-0.110	0.108	0.321**	-0.057	-0.068	0.310**	-0.164**	-0.150**
	Iron	0.387**	0.091	-0.121	0.376**	-0.029	0.033	0.384**	0.088	0.092
	Vitamin A	0.580**	-0.077	0.104	0.305**	-0.004	-0.060	0.395**	-0.087	-0.098
	Thiamine	0.383**	0.042	-0.064	0.343**	0.066	0.043	0.358**	0.002	-0.051
	Riboflavin	0.247**	0.053	0.044	0.372**	0.022	0.007	0.255**	-0.251**	-0.330**
	Niacin	0.397**	0.166	-0.155	0.399**	-0.032	-0.118	0.394**	-0.013	-0.113*
	Folic acid	0.292**	-0.331**	0.152	0.371**	0.034	-0.017	0.335**	-0.005	0.054
	Vitamin C	0.488**	-0.051	0.059	0.285**	0.040	0.089	0.303**	-0.212**	-0.245**
MAR (%)		0.459**	0.336**	-0.196*	0.504**	-0.013	-0.048	0.474**	0.000	-0.141**

NAR: nutrient adequacy ratio; MAR: mean adequacy ratio; n: number of children; DDI: dietary diversity index calculated using Berry's index; FS_{24hr}: food scores calculated using 24 hour diet recall data; FS_{FFQ}: food scores calculated using food frequency data.
$^{**}p<0.01$, $^{*}p<0.05$.

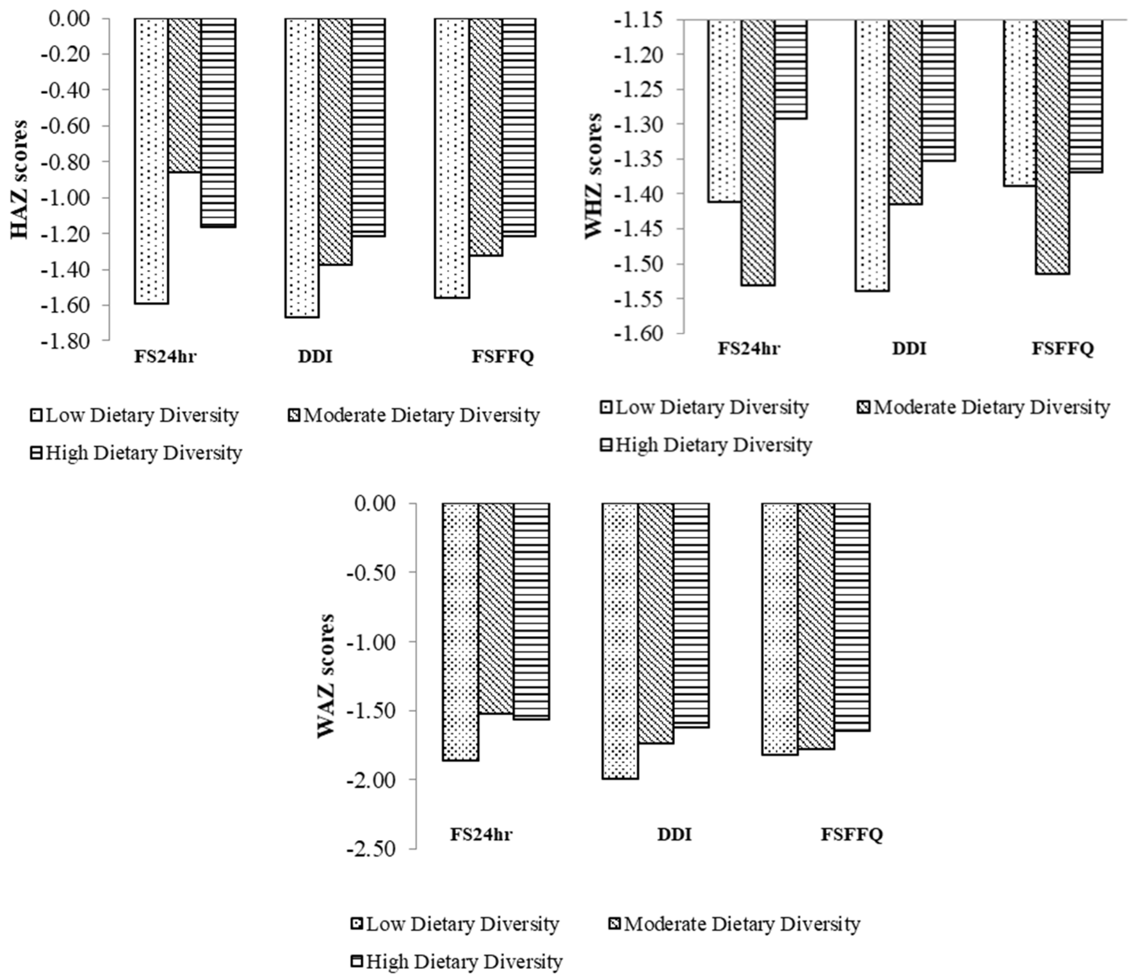

Figure 3. Change in mean Z scores according to dietary diversity indices.

diversity scores.[32]

DDI did not show any correlation with NAR (%) except energy in Wardha, while it showed positive association only with fat in both locations taken together. It showed a negative association with energy, calcium, riboflavin and vitamin C which is not practical. FS_{FFQ} showed association with protein, fat, energy, calcium, riboflavin, niacin and vitamin C when both the locations are taken together, while it showed association only with protein in Wardha and only with energy in Koraput.

MAR showed positive association with FS_{24hr} in both locations. It showed association with DDI only in Wardha. Even though both DDI and FS_{FFQ} were calculated using food frequency data, a negative association of MAR with FS_{FFQ} was observed in Wardha and in both locations taken together. This shows that quantity of food consumed is a crucial factor. While Berry's index (DDI) takes into account the quantity of food consumed, food scores cal-

Table 3. Correlation dietary diversity tertiles with the nutritional outcomes of 1 to 5 years children

		WHZ	HAZ	WAZ
Wardha	FS_{24hr}	0.06	0.126	0.130
	DDI	0.039	0.198*	0.180*
	FS_{FFQ}	-0.027	0.150	0.103
Koraput	FS_{24hr}	-0.013	0.114	0.087
	DDI	0.096	0.042	0.074
	FS_{FFQ}	0.025	0.043	0.031
Total	FS_{24hr}	0.012	0.126*	0.105
	DDI	0.069	0.094	0.111*
	FS_{FFQ}	0.002	0.078	0.055

WHZ: weight of height Z scores; HAZ: height for age Z scores; WAZ: weight for age Z scores; DDI: dietary diversity index calculated using Berry's index; FS_{24hr}: food scores calculated using 24 hour diet recall data; FS_{FFQ}: food scores calculated using food frequency data.
$^{*}p<0.05$.

culated using food frequency do not.

Figure 3 shows the mean z scores under the three dietary diversity indices. A positive and generally linear trend in mean HAZ is observed as dietary diversity (DDI and FS_{FFQ} tertiles) increases indicating that low dietary diversity increases the risk of under-nutrition. The mean difference in z scores of children having low dietary diversity and high dietary diversity calculated using DDI was HAZ -0.45 and FS_{FFQ} was HAZ -0.35. All three dietary diversity indices showed linear association WAZ scores with mean difference in z scores between children having low dietary diversity and high dietary diversity calculated using FS_{24hr}: WAZ -0.30, DDI: WAZ -0.37 and FS_{FFQ}: WAZ -0.18. A positive Only DDI tertiles showed linear association with WHZ with mean difference of WHZ -0.19. Onyango et al[33] reported that diversity >5 was important for the growth of children and HAZ of children with >5 was 0.9 z scores higher than the HAZ of children having low dietary diversity. Arimond and Ruel[34] reported mean difference of 0.65 in adjusted HAZ scores between children (12 to 36 months) having high dietary diversity and low dietary diversity.

Examining the correlation of dietary diversity tertiles with nutritional outcomes in Table 3, we find that in Wardha, DDI tertiles were associated with stunting and underweight ($p<0.05$) showing that when the dietary diversity increases, WAZ and HAZ moves positively. When both locations were taken together, FS_{24hr} tertiles showed association ($p<0.05$) with height for age and DDI tertiles with weight for age ($p<0.05$). FS_{FFQ} did not show any association with the nutritional status. Brown et al[35] demonstrated that there was no association between dietary diversity and nutritional status of 9 to 11 month old children (HAZ and WHZ); Tarini et al[36] showed similar finding in the case of 24 to 48 month old children. In a study in Congo, Ekesa et al[30] demonstrated a poor relationship between dietary diversity and stunting/ underweight/wasting which indicated that there was more to malnutrition than just diet. However Onyango et al[33] reported a strong relationship between dietary diversity and nutritional status of 12 to 36 month old children.

DISCUSSION

The dietary guidelines for recommended food intake of most countries across the globe have been formulated keeping dietary diversity as the basis to ensure adequate intake of essential nutrients. Consuming different food groups in a day significantly contributes to the mean probability of nutrient adequacy, independent of the energy intake.[8] In developing countries, lack of low food diversity is a major problem among poor populations as their habitual diet is predominately cereal-based and dominated by starchy staples.[11] Previous studies have highlighted that dietary diversity is positively associated with higher intake of energy and other nutrients among young children in developing countries.[11] Positive association between dietary diversity and improved nutritional status has also been reported.[37] Even though the importance of dietary diversity is recognized nowadays, there is still a lack of uniformity in methods to measure dietary diversity.[11] Individual dietary diversity scores (counting of food groups) are efficient means to estimate nutrient adequacy of the diet[6,32] which is in line with the findings of the present study.

An association of dietary diversity and nutritional status of preschool children[21,34] has been established by different studies. From the present study it is observed that preschool children in both locations consume cereal based diets and have less dietary diversity. It is also clear that most nutrient adequacy ratios were correlated with the dietary diversity calculated using 24 hour diet recall (FS_{24hr}). Even though it was perceived that this is due to calculating the NAR and MAR using 24 hour diet recall data, previous studies have also reported similar results. Tavakoli et al[38] have reported that dietary diversity score developed using 24 hour diet recall can be used as a proxy for nutrient adequacy. Sealey-Potts and Potts[22] have reported positive correlation between NAR and dietary diversity scores in preschool children. In our study, FS_{24hr} showed a weak association only with weight for age of preschool children when both locations are taken together. The limitation of using a single 24 hour diet recall round with sub sample data to calculate dietary diversity is that it gives the snapshot of the village or community at one time point which has the potential bias of under and over reporting thereby clouding the true dietary diversity.[39] In Wardha, dietary diversity calculated using Berry's index showed a weak association with both height for age and weight for age of preschool children. However, when both the locations were taken together, DDI showed an association only with weight for age. Some other studies[22,30,33] have shown that there is no association between dietary diversity and nutritional indicators in preschool children.

Our findings suggest that food scores calculated using 24 hour diet recall ensure essential nutrient adequacy but do not show association with nutritional status of children except for WAZ scores when both the locations are taken together. Dietary diversity calculated using Berry's Index shows association with HAZ scores and WAZ in Wardha but shows association only with energy adequacy. However DDI has the limitation of being a household indicator. Although FS_{24hr} showed nutrient adequacy, it does not show correlation with nutrition status of children. From the present study, it can be concluded that dietary diversity indices are not effective as an indicator to reflect the nutritional status of 1 to 5 year preschool children particularly in areas with a high burden of undernutrition.

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AUTHOR DISCLOSURES
The authors declare no conflict of interest.

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