Seasonality of Consumption of Nonstaple Nutritious Foods among Young Children from Nepal's 3 Agroecological Zones

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Abstract

Background: Children's dietary patterns vary seasonally, particularly in subsistence agriculture settings like Nepal, but the seasonality of nutritious nonstaple food consumption is not well explored in the literature.

Objective: This study aimed to examine seasonal differences in children's consumption of provitamin A–rich fruit and vegetables, dairy, eggs, meat, and fish in Nepal's 3 agroecological zones, and to assess whether seasonal patterns vary by wealth and caste/ethnicity.

Methods: Multivariable negative binomial regression models were used to analyze dietary data from 7-d food-frequency questionnaires, producing coefficient estimates in the form of incidence rate ratios (IRRs). Data were collected 3 times per year for 2 y from children aged 6–72 mo in Nepal's mountains ($n = 226$), hills ($n = 168$), and plains ($n = 225$).

Results: There were significant seasonal differences in children's consumption of provitamin A–rich fruit and vegetables, dairy, meat, and fish that varied by agroecological zone. Adopting monsoon season as the referent for all comparisons, children in the mountains ate provitamin A–rich fruit and vegetables less frequently during the postmonsoon and winter seasons (IRRs: 0.5 and 0.7, respectively; both $P < 0.004$), whereas in the plains, children's consumption of these foods was lower only during the postmonsoon season (IRR: 0.2; $P < 0.001$). Children's dairy intake frequency increased during the winter in the mountains (IRR: 0.7; $P < 0.004$) and decreased during the winter in the hills (IRR: 1.5; $P < 0.001$). Only in the plains did children's meat and fish intakes vary seasonally, increasing during the postmonsoon season (IRR: 1.6; $P < 0.004$). Wealth and caste/ethnicity variability influenced children's consumption of each of these nutritious groups of foods, and moderated seasonal effects in some instances.

Conclusions: Children's diets varied differently by season within each agroecological zone of Nepal and in some cases across socioeconomic groups, revealing the importance of taking a season- and location-specific approach to assessing diets and tailoring dietary strategies. *Curr Dev Nutr* 2018;2:nzy058.

Keywords: dietary diversity, infant and young child feeding, nutrition-sensitive agriculture, seasonality, micronutrient-rich foods

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Abbreviations used: IRR, incidence rate ratio; PCA, principal components analysis; PoSHAN, Policy and Science for Health, Agriculture, and Nutrition; VDC, Village Development Committee.

Introduction

In subsistence agricultural settings, diets may change substantially throughout the year owing to seasonal variability in crop production, feed for livestock, and costs of food in local markets, among other factors (1, 2). A large body of research documents the presence and negative nutritional impacts of "lean seasons" faced by the rural poor in low-income countries during periods before each major harvest when staple foods, usually grains, run low (1, 3–5). However, there are fewer reports in the literature describing the rural seasonality of consumption of other essential dietaries. Of particular importance are dark green leafy and orange-fleshed fruits and vegetables, which are sources of provitamin A carotenoids, and animal-source foods, which provide protein, essential fats, and micronutrients (6–8). Often referred to as "nonstaples" because they comprise a low portion of dietary intake in low-income countries, these foods are generally produced in smaller quantities and are more difficult to store for long periods of time and to transport compared with staple foods (9–13). In addition, their production patterns vary depending on the food and local climate. Seasonal patterns of nonstaple food consumption are therefore likely to differ from those of staple grains and to vary substantially by geographic location and food type.

Nepal, a landlocked country of great geographic and climatological diversity, with a largely subsistence rural food economy, may be particularly susceptible to seasonal variations in food production, availability, and consumption. It therefore provides an apt context for examining the seasonality of nutritious nonstaple food consumption and how it varies across diverse settings. Although Nepal spans <150 miles from its northern border with Tibet to its southern border with India, its terrain consists of 3 distinct agroecological zones, each with different climatological and topographic features, known as the mountains, hills, and low-lying plains (referred to as the Terai). Over 80% of Nepal's annual rainfall occurs during the monsoon season between June and September; however, the amount of rainfall received differs substantially by zone, with the hills receiving the most and the mountains receiving the least (14). The driest and coldest time of year occurs during January and February, when temperatures reach below freezing in the mountains but remain temperate in the hills and plains (14). Owing to topography, the amount of arable land differs by zone as well, ranging from nearly 100% in the plains to only 2% in the mountains (14). Finally, the presence of wide river basins, swamps, and ponds in the plains enables fishing and aquaculture to a far greater degree than in the other 2 zones (15). Given this variability, food production trends differ substantially throughout the year and between regions. In addition, livelihoods, ability to purchase foods, and access to resources needed for food production, including land and water, differ substantially by region, wealth, and caste/ethnicity (16–18).

Nepal's population includes >100 different caste and ethnic groups with varied livelihoods and food traditions (19). Caste designations are rooted in Hinduism, the dominant religion in the country. Historically, caste defined both social hierarchy and occupation in Nepal and it is associated with dietary and other behavioral practices (16). For example, Hindus of high caste traditionally practice vegetarianism, whereas Hindus of low caste, referred to as Dalits (previously "untouchables"), do not. Groups that are not part of the Hindu caste system in Nepal include indigenous groups (referred to as "Janajati"), most of whom traditionally practice Buddhism or animist religions (although many have adopted Hinduism), and Muslim groups. Muslims make up a small portion of Nepal's overall population but comprise ≥10% of the population in many districts in the plains (19). Caste and ethnicity are intertwined with socioeconomic status in Nepal, with upper-caste groups being the most socially and economically advantaged, whereas Dalits, Terai castes, and certain indigenous groups are the most disadvantaged (16, 18). These differences in social status (which correspond to differences in access to key food production resources like land and water) in combination with differing dietary practices may lead to caste/ethnicity-based variation in seasonal dietary patterns.

Although childhood nutritional status has improved substantially over the past decade in Nepal, persistent undernutrition and widespread micronutrient deficiencies pose a continuing threat to children's health and development (20–22). As in many other low-income settings, Nepali children consume a primarily cereal-based diet that is low in micronutrients (23, 24). Studies indicate that intakes of fruits, vegetables, and animal-source foods are generally quite low (25–27). Only a few previous studies have examined the seasonality of consumption of nonstaple nutritious foods in Nepal (24, 28, 29). As a whole, these studies suggest that seasonal differences in Nepali children's consumption frequency of key micronutrient-rich foods occur and may vary depending on location, but do not indicate how they vary, how much they vary, or for which types of food.

In order for program planners and policymakers to make informed decisions about strategies for improving child diet quality, a better understanding is needed of the extent to which diets vary across time points and locations. In addition, effective targeting of interventions requires understanding how seasonal patterns may differ depending on economic and cultural factors. The goals of this analysis were therefore to: *1)* examine seasonal differences in Nepali children's consumption frequency of nonstaple nutritious foods; and *2)* assess the extent to which seasonality varied across an agroecologically and culturally diverse country.

Methods

Data used in this analysis were collected as a substudy of the Policy and Science for Health, Agriculture, and Nutrition (PoSHAN) community studies in Nepal (22). Started in 2013, the PoSHAN data collection system conducted 4 annual surveys of household food security, dietary intake, and nutritional status among preschool-aged children and their mothers located in rural areas of Nepal. Data collection took place in 21 Village Development Committees (VDCs), the primary sampling unit. To select these VDCs, Nepal's 75 districts were stratified into mountain, hill, and plains zones and were listed in contiguous order from west to east. VDCs within each district were individually listed in alphabetical order. After a random start within each zone, VDCs were systematically selected at equal intervals to provide 7 VDCs per zone. This method of selecting VDCs at equal intervals after a random start ensured that no more than 1 VDC would be selected in a given district. Within each VDC, data were collected from all eligible households within 3 of 9 wards, Nepal's smallest administrative unit. The included wards were selected by ordering all wards in a VDC according to total population, and then selecting 3 at equal intervals after a random start.

Household eligibility was determined by having ≥1 child <5 y of age (after initial enrollment, households continued to be considered eligible until the child reached 6 y of age), or there being a recently married (within 2 y of data collection) couple, not yet with children. Participating households received a small gift (a bar of soap and toothpaste) as a token of thanks but did not receive any other compensation or services. Further details of the PoSHAN study design and survey contents are reported elsewhere (22, 26, 30, 31). Ethical approval was granted by the institutional review board at the Johns Hopkins Bloomberg School of Public Health and from the Nepal Health Research Council.

At 3 of the 21 PoSHAN sites, households were surveyed 3 times, instead of once, per year over a 2-y period: during the monsoon season

(June–July, 2013–2014), the postmonsoon season (September, 2013–2014), and the winter (January–February, 2014–2015). These 3 VDCs, referred to henceforth as sentinel sites, were selected by comparing publicly available demographic, economic, and agricultural statistics for all PoSHAN sites within each agroecological zone and then identifying the site with the most values closest to the average across all variables examined. Geographically, the 3 selected sites were located in the districts of Jumla in the mid-Western mountains, Arghakhanchi in the Western hills, and Banke in the mid-Western Terai.

Data from 1 index child per sentinel site household at each time point when surveys were administered (referred to from this point on as observations) were included in analyses if the child was ≥6 mo old at the time of data collection, and if the observation met analysis-specific date criteria (occurred within 10 d of the previous year's data collection period for a given season). In households with >1 child, the child with the most observations across the 6 time points was considered the index child. In cases where ≥2 children in a household had the same number of observations, the index child was selected randomly.

Outcome variables were children's weekly consumption frequencies of provitamin A carotenoid–rich fruits and vegetables, eggs, dairy, and meat and fish. These variables were constructed with the use of data from a 7-d FFQ that was included in the PoSHAN community studies survey. The FFQ, patterned from an instrument previously used in Nepal, asked mothers to report how many times their child consumed each of 31 commonly eaten foods in the week before the survey (28). If foods were eaten multiple times a day, each instance of consumption was counted, so there was no upper limit to the range of possible values. To create outcome variables, the reported consumption frequencies of individual foods that fell into each of the 4 food categories were added together. For provitamin A–rich fruits and vegetables this included dark green leafy vegetables, carrots, pumpkin, ripe mango, jackfruit, and papaya. Dairy included milk and yogurt. The category of meat and fish included chicken, goat, buffalo, pork, large fish, dried fish, and small fish.

The primary independent variable was season of data collection (monsoon, postmonsoon, or winter). Secondary predictor variables were wealth and caste/ethnicity. Wealth was characterized by conducting a principal components analysis (PCA) that used survey questions regarding house construction materials and household asset ownership, generating a score for each household based on PCA factor loadings, and then dividing the population into tertiles based on those scores (32). In contrast to the method by which a wealth index was constructed for the larger PoSHAN dataset (31), the PCAs for this analysis were conducted separately by agroecological zone, because house construction materials and types of assets owned vary by sentinel site. Caste/ethnicity was initially categorized with the use of the groupings defined by the Nepal government for use in the national Health Management Information System: Dalit, Disadvantaged Janajati, Disadvantaged Terai Castes, Religious Minorities (which in this case referred only to Muslims), Advantaged Janajati, and Upper Caste (33). Because some of these groups had very low representation, for multivariable analyses caste/ethnicity was recategorized as either "Dalit", "Upper Caste", or "Other" in the mountains and hills and as "Disadvantaged Terai Castes", "Muslims", or "Other" in the plains.

Statistical analyses were conducted separately for each of the 3 agroecological zones. First, summary statistics for each food group were calculated (mean, median, and range of consumption frequency). Next, because outcome distributions were heavily right-skewed with substantial overdispersion, negative binomial regression was used for multivariable analysis (34, 35). These models produce results in the form of incidence rate ratios (IRRs). Random intercepts for each child were included to account for the longitudinal nature of the data. Cluster (ward) and year of data collection were included as fixed effects in multivariable analyses to adjust for potential unobserved cluster-specific and time-related factors influencing consumption. Child age in months was also included to adjust for differences in age across data collection rounds. With the exception of child age, all variables were treated as categoric, including those for which interactions were explored. All analyses were conducted in Stata 14 (StataCorp LP, College Station, TX) (36).

Models with and without interaction terms between season and wealth and season and caste/ethnicity were run for each outcome. Decisions about whether or not to retain interaction terms were made by assessing 3 fit indexes—log-likelihood, Akaike's Information Criterion, and the Bayesian Information Criterion—and the likelihood ratio test. The model with the best fit indexes for each outcome was selected. We also conducted a sensitivity analysis for each model to determine whether the method of index child selection (described above) may have introduced selection bias.

When interpreting model output, a Bonferroni correction was used to adjust the threshold for determining statistical significance: the standard P value of 0.05 was divided by 12 to account for the 12 different analyses conducted, yielding an adjusted P value of 0.004. To facilitate interpretation of findings, Stata's margins and marginsplot commands were used to translate raw model output (IRRs) into approximate differences in consumption counts between seasons or groups (37). Average adjusted predictions by season were then calculated and plotted. When models indicated interactions between wealth or caste/ethnicity and season based on interaction term coefficients with P values <0.004, disaggregated average adjusted predictions by season were also calculated and plotted.

Finally, to understand which specific foods may be driving seasonal variations, the contributions of individual foods to the total instances of consumption of each food group were examined. For example, the total number of times that mangoes were consumed by children during the monsoon season in the plains was divided by the total number of times that any provitamin A–rich fruit or vegetable was consumed during the monsoon season in the plains.

Results

Seasonal data collection between monsoon season 2013 and winter 2015 (6 rounds of data collection) yielded a total of 3790 observations from a total of 857 children in 621 households. About half of the 857 children were surveyed at all 6 time points and in total, nearly 90% of these 857 children were surveyed over ≥3 time points. The primary reason that children were not surveyed at all 6 time points was age, i.e., the child was born after the study began or became too old to be eligible for the study. As shown in **Figure 1**, of the 3790 total observations, 2700 observations from 619 children were included in this analysis: 897 observations from 226 children at the mountains site, 787 observations from 168 children

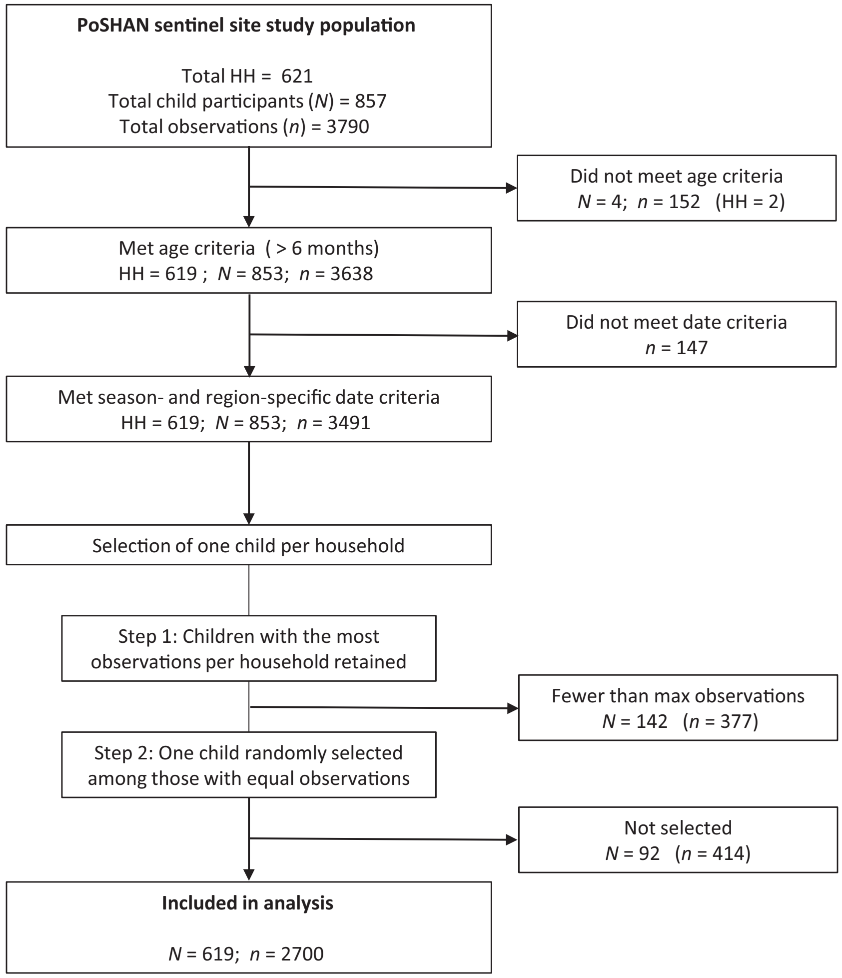

FIGURE 1 Flow diagram showing selection of the analysis sample from the PoSHAN study population, including total number of HH, total number of individual children (*N*), and total number of observations/interviews (*n*). HH, households; PoSHAN, Policy and Science for Health, Agriculture, and Nutrition.

at the hills site, and 1015 observations from 225 children at the plains site. Table 1 provides characteristics for all children included in the analysis sample at each of the 3 sites.

Descriptive statistics indicate that children's consumption frequencies of nonstaple nutritious foods were very low overall. Table 2 provides descriptive statistics for each of the 4 food groups at each study site. On average, children at all 3 sites consumed provitamin A–rich fruits and vegetables <5 times in the 7 d before the survey, and consumed eggs or meat and fish less than twice. In the hills, children consumed dairy slightly more than 10 times on average in the 7 d before the survey, whereas in the mountains and plains children's mean 7-d dairy consumption frequency was <5 and <4 times, respectively.

Multivariable regression model estimates indicated significant seasonal differences in consumption of provitamin A–rich fruits and vegetables in the mountains and plains, in consumption of dairy in the mountains and hills, and in consumption of meat and fish in the plains (see Table 3 for IRRs). Sensitivity analyses indicated that these findings were robust to any potential biases introduced by the index child selection method. As shown in Figure 2, the timing and magnitude of seasonal differences in consumption differed substantially by region and food group. In the mountains, children's consumption of provitamin A–rich fruits and vegetables (Figure 2A) peaked during the monsoon season and was lower in the postmonsoon season and winter. In the plains, average provitamin A–rich fruit and vegetable consumption was substantially lower during the postmonsoon season compared with the other 2 seasons, whereas in the hills it was fairly even across all 3 seasons. For eggs (Figure 2B), there was no significant seasonal variation in consumption frequency in any of the 3 regions and egg consumption was noted to be low across sites. Dairy consumption (Figure 2C) was lower during the winter in the mountains compared with the monsoon or postmonsoon seasons, whereas in the hills, consumption of dairy products decreased during the monsoon season (but was still much higher overall than in the mountains or plains). For meat and fish (Figure 2D), consumption frequency was very low across all regions and seasons. It only differed significantly by season in the plains, where consumption increased slightly during the postmonsoon season.

Results also indicated significant differences in children's consumption frequencies by wealth and caste/ethnicity, and significant

TABLE 1 Characteristics of children included in analysis by geographic area

	Mountains	Hills	Plains
Total children, *n*	226	168	225
Observations per child, median (IQR)	4 (3–6)	6 (3–6)	5 (3–6)
Caste/ethnicity, *n* (%)[1]			
Dalit	64 (28.3)	53 (31.5)	15 (6.7)
Disadvantaged Janajatis	7 (3.1)	26 (15.5)	11 (4.9)
Disadvantaged Terai castes	1 (0.4)	0 (0.0)	100 (44.4)
Muslims	3 (1.3)	1 (0.6)	85 (37.8)
Advantaged Janajatis	9 (4.0)	18 (10.7)	2 (0.9)
Upper caste	142 (62.8)	70 (41.7)	12 (5.3)
Household wealth tertile,* *n* (%)			
High	76 (33.6)	57 (33.9)	68 (30.2)
Medium	81 (35.8)	54 (32.1)	72 (32.0)
Low	69 (30.5)	57 (33.9)	85 (37.8)
Gender, *n* (%)			
Male	121 (53.5)	100 (59.5)	136 (60.4)
Female	105 (46.5)	68 (40.5)	89 (39.6)
Average age in mo,[2] mean (SD)	29.2 (16.0)	28.6 (16.2)	29.4 (16.8)

[1]Owing to the low number of respondents within certain caste/ethnic groups, these were recombined for analyses: Upper Caste (Group 1), Dalit (Group 2), and "other" (Group 3) for the mountains and hills; and Disadvantaged Terai Castes (Group 1), Muslims (Group 2), and "other" (Group 3) for the plains.
[2]At child's first observation.

TABLE 2 Descriptive statistics for all observations (*n*) of children's 7-d consumption frequency of each food type by geographic area

	Children's 7-d consumption frequency		
	Mean ± SD	Median (IQR)	Range
Mountains (*n* = 898)			
Provitamin A–rich fruits and vegetables[1,2]	4.4 ± 5.9	2 (0–7)	0–41
Eggs	1.8 ± 2.9	0 (0–3)	0–21
Dairy[3]	4.5 ± 6.7	1 (0–7)	0–42
Meat and fish[1,4]	2.0 ± 2.5	1 (0–3)	0–21
Hills (*n* = 787)			
Provitamin A–rich fruits and vegetables[2]	3.7 ± 3.8	3 (1–5)	0–27
Eggs	1.0 ± 1.8	0 (0–2)	0–14
Dairy[3]	10.1 ± 9.5	7 (1–16)	0–45
Meat and fish[4]	2.0 ± 2.1	2 (1–3)	0–18
Plains (*n* = 1015)			
Provitamin A–rich fruits and vegetables[2]	2.4 ± 4.3	1 (0–3)	0–36
Eggs	1.0 ± 1.7	0 (0–2)	0–14
Dairy[1,3]	3.3 ± 5.6	0 (0–4)	0–35
Meat and fish[4]	1.7 ± 3.0	1 (0–2)	0–22

[1]One missing value.
[2]Includes dark green leafy vegetables, carrots, pumpkin, ripe mango, jackfruit, and papaya.
[3]Includes milk and yogurt.
[4]Includes chicken, goat, buffalo, pork, large fish, dried fish, small fish.

interactions between season and wealth or caste/ethnicity in some cases (see Table 3). Children from households in the lowest wealth quintile in the hills and plains consumed significantly less dairy (IRR: 0.6 [95% CI: 0.5, 0.7]; IRR: 0.5 [95% CI: 0.3, 0.7]), as did Dalit children and those from other nonupper-caste households in the hills (IRR: 0.5 [95% CI: 0.4, 0.7]; IRR: 0.6 [95% CI: 0.5, 0.8]). Also in the hills, Dalit children consumed more meat and fish than did upper-caste children (IRR: 1.6 [95% CI: 1.2, 2.0]). In the plains, children from Muslim and "other" households consumed significantly more eggs compared to children from Terai caste households (IRR: 2.3 [95% CI: 1.5, 3.5]; IRR: 2.1 [95% CI: 1.3, 3.3]), whereas Muslim children consumed significantly less dairy and more meat and fish (IRR: 0.4 [95% CI: 0.3, 0.6]; IRR: 1.9 [95% CI: 1.2, 2.9]). Models containing significant interaction terms indicated moderation of seasonal effects by wealth or caste/ethnicity, which can be seen by looking at disaggregated predicted consumption frequencies. As shown in **Figure 3**, children from poorer households had particularly low consumption of provitamin A–rich fruits and vegetables during the winter in the mountains compared with children from wealthier households (Figure 3A). In addition, the winter decrease in dairy consumption in the mountains was particularly severe among Dalit children, whose mean consumption dropped to near zero (Figure 3B). Consumption decreased among upper-caste children as well; however, the magnitude of the decrease relative to monsoon levels was greater among Dalit children. Variability in consumption also decreased among Dalit children in the winter (as indicated by the narrower CI around this time point shown in Figure 3B), suggesting that dairy consumption was uniformly very low among Dalit children at this time. Interestingly, as shown in Figure 3C, the slight overall increase in consumption of meat and fish among children in the plains during the postmonsoon season occurred primarily among Muslim children. Figure 3C also shows that the increase in meat and fish consumption was actually much larger than it initially appeared when looking at the aggregate data presented in Figure 2.

Finally, the specific types of provitamin A–rich fruits and vegetables and meat and fish that children consumed also differed by season and by region in some cases. Bar charts in **Figure 4** show the percentage that each individual food comprised of all instances of consumption of that food group for each season and region. Dark green leafy vegetables comprised the majority of provitamin A–rich fruits and vegetables consumed at all sites and time points, with 1 exception—during the monsoon season in the plains, mangoes comprised >80% of all consumption. This indicates that although consumption levels of provitamin A–rich fruits and vegetables in the plains were significantly higher in both the monsoon and winter seasons, mangoes were the source of greater consumption during the monsoon season and leafy greens were the source during the winter season. Types of meat and fish consumed varied substantially by region, with goat comprising the majority of consumption in the mountains and poultry comprising the majority in the hills. Poultry also made up the majority of consumption in the plains during the monsoon season and winter. However, fish consumption increased dramatically in the postmonsoon season, accounting for 75% of all meat and fish consumption. This indicates that fish were the source of the previously noted significant increase in consumption among Muslim children during the postmonsoon season.

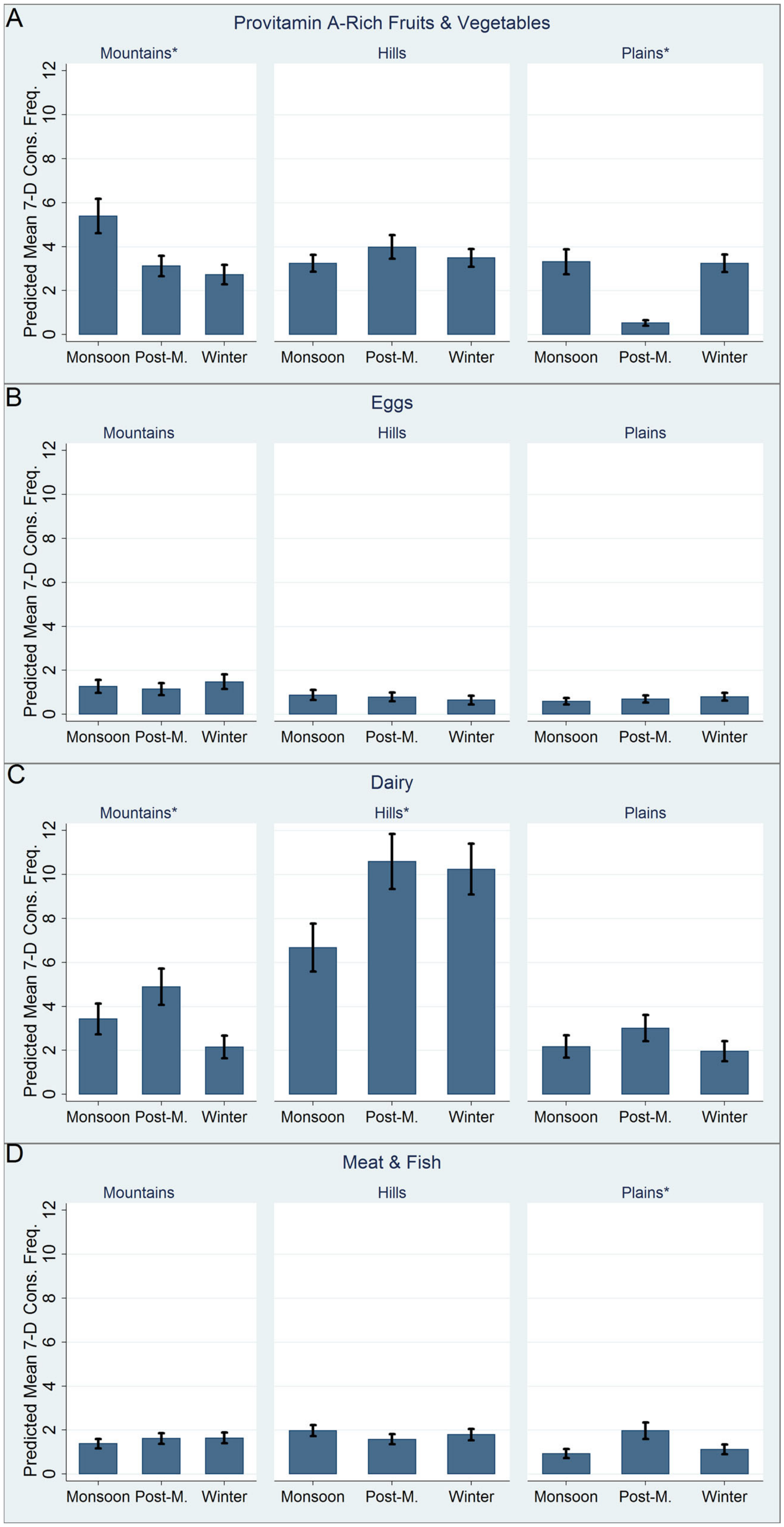

FIGURE 2 Marginal plots showing average adjusted predictions and 95% CIs for children's mean 7-d consumption frequency by season for provitamin A–rich fruits and vegetables (A), eggs (B), dairy (C), and meat and fish (D). *Evidence for significant average marginal effect of season. Predictions were generated based on multivariable model estimates and adjusted for wealth, caste/ethnicity, cluster, year of data collection, and child age. Cons. Freq., consumption frequency; Post-M., postmonsoon.

TABLE 3 Multivariable negative binomial regression results expressed as estimated IRRs for children's 7-d consumption of each food group by region[1]

	Mountains				Hills				Plains			
	Provitamin A fruit and vegetables	Egg	Dairy	Meat and fish	Provitamin A fruit and vegetables	Egg	Dairy	Meat and fish	Provitamin A fruit and vegetables	Egg	Dairy	Meat and fish
Season												
Monsoon season	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Postmonsoon season	0.5 (0.4, 0.7)**	0.9 (0.8, 1.1)	1.3 (1.0, 1.7)	1.0 (0.8, 1.2)	1.2 (1.0, 1.4)	0.9 (0.7, 1.1)	1.6 (1.4, 1.9)**	0.8 (0.7, 0.9)	0.2 (0.1, 0.2)**	1.2 (1.0, 1.5)	1.4 (1.1, 1.7)	1.6 (1.2, 2.2)*
Winter season	0.7 (0.6, 0.9)*	1.2 (1.0, 1.4)	0.7 (0.5, 0.9)*	1.0 (0.9, 1.2)	1.1 (0.9, 1.3)	0.7 (0.5, 1.0)	1.5 (1.3, 1.8)**	0.9 (0.8, 1.1)	1.0 (0.8, 1.2)	1.3 (1.1, 1.7)	0.9 (0.7, 1.2)	1.0 (0.7, 1.3)
Wealth												
High	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Medium	0.9 (0.6, 1.1)	0.9 (0.7, 1.2)	1.0 (0.7, 1.5)	1.1 (0.8, 1.4)	0.8 (0.7, 1.0)	0.6 (0.4, 0.9)	0.8 (0.7, 1.0)	0.9 (0.7, 1.1)	0.9 (0.8, 1.2)	0.9 (0.6, 1.1)	0.8 (0.5, 1.0)	1.1 (0.8, 1.5)
Low	0.8 (0.6, 1.1)	0.9 (0.6, 1.3)	0.6 (0.4, 0.9)	1.1 (0.8, 1.5)	0.8 (0.7, 1.0)	0.6 (0.4, 0.9)	0.6 (0.5, 0.7)**	0.8 (0.7, 1.1)	0.9 (0.7, 1.2)	0.7 (0.5, 1.0)	0.5 (0.3, 0.7)**	0.7 (0.5, 0.9)
Caste/ethnicity[2]												
Group 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Group 2	0.7 (0.5, 1.1)	0.6 (0.3, 0.9)	0.5 (0.3, 0.9)	1.1 (0.8, 1.5)	1.0 (0.8, 1.2)	0.8 (0.5, 1.3)	0.5 (0.4, 0.7)**	1.6 (1.2, 2.0)**	0.8 (0.7, 1.0)	2.3 (1.5, 3.5)**	0.4 (0.3, 0.6)**	1.9 (1.2, 2.9)*
Group 3	0.4 (0.3, 0.7)**	1.2 (0.8, 1.9)	0.6 (0.3, 1.2)	0.4 (0.2, 0.8)	0.8 (0.7, 1.0)	1.0 (0.6, 1.4)	0.6 (0.5, 0.8)**	1.2 (1.0, 1.5)	1.1 (0.9, 1.4)	2.1 (1.3, 3.3)*	0.9 (0.6, 1.4)	1.8 (1.0, 3.1)
Season*wealth interaction												
Postmonsoon season*medium	1.0 (0.7, 1.5)	—	0.9 (0.6, 1.4)	—	—	—	—	—	—	—	—	—
Postmonsoon season*low	1.3 (0.9, 1.9)	—	1.6 (1.0, 2.7)	—	—	—	—	—	—	—	—	—
Winter*medium	0.5 (0.3, 0.7)**	—	1.0 (0.6, 1.8)	—	—	—	—	—	—	—	—	—
Winter*low	0.7 (0.4, 1.1)	—	1.0 (0.5, 2.2)	—	—	—	—	—	—	—	—	—
Season*caste/ethnicity interaction												
Postmonsoon season*Group 2	0.6 (0.4, 0.9)	—	1.0 (0.6, 1.7)	1.4 (1.0, 1.9)	—	—	—	—	—	—	—	1.7 (1.1, 2.5)*
Postmonsoon season*Group 3	2.6 (1.5, 4.7)[3]**	—	1.2 (0.5, 2.7)	3.8 (2.0, 7.5)**	—	—	—	—	—	—	—	0.8 (0.5, 1.4)
Winter*Group 2	0.5 (0.3, 0.9)	—	0.3 (0.1, 0.8)*	1.4 (1.1, 1.9)	—	—	—	—	—	—	—	1.3 (0.8, 1.9)
Winter*Group 3	1.1 (0.6, 2.0)	—	1.6 (0.7, 3.8)	2.2 (1.0, 5.0)	—	—	—	—	—	—	—	1.6 (1.0, 2.5)

[1]Values are IRRs (95% CIs) unless otherwise indicated. IRRs should be interpreted as the ratio of times a child in a given category consumed a food in a 7-d period compared with children in the baseline category. Adjusted for geographic cluster, year of data collection, and child age. $^*P < 0.004$, $^{**}P < 0.001$. IRR, incidence rate ratio.

[2]Group 1 identifies Upper Caste households in the mountains and hills and Disadvantaged Terai Castes in the plains; Group 2 identifies Dalit households in the mountains and hills and Muslims in the plains; Group 3 identifies all "other" households for all 3 districts.

[3]Given the small number of children from this group within each time point ($n < 20$), these findings should be interpreted with caution (and for this reason no average adjusted predictions were calculated or plotted for this group).

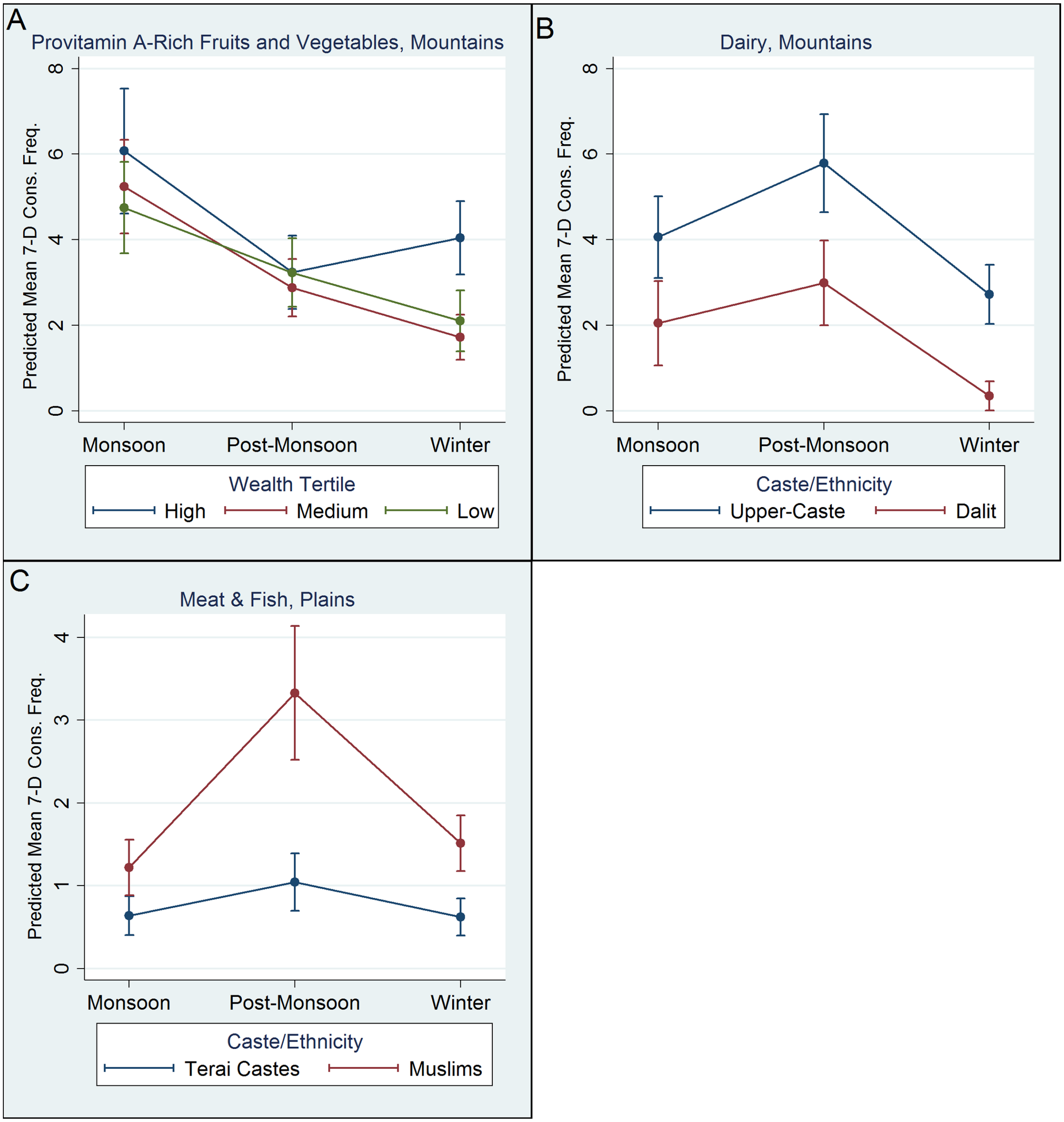

FIGURE 3 Marginal plot showing average adjusted predictions and 95% CIs for children's consumption frequencies of provitamin A–rich fruits and vegetables in the mountains (A), dairy in the mountains (B), and meat and fish in the plains (C), disaggregated by wealth or caste/ethnicity, in cases where model estimates indicated significant interaction terms. Predictions were generated based on multivariable model estimates and are adjusted for all variables in the model. Cons. Freq., consumption frequency.

Discussion

Patterns in Nepali children's consumption of vegetables, fruit, dairy, meat, and fish vary over the course of the year by agroecological zone, in some cases quite substantially. These findings demonstrate the value of longitudinal data for revealing seasonal differences in diet and suggest that in countries with substantial geographic and climatic variation like Nepal, seasonal patterns identified in 1 zone of the country cannot be assumed to apply nationwide. Findings also demonstrate the value of individual food frequency data, as opposed to aggregate measures like dietary diversity scores, for identifying foods driving seasonal differences in diet quality. Such information is important for tailoring

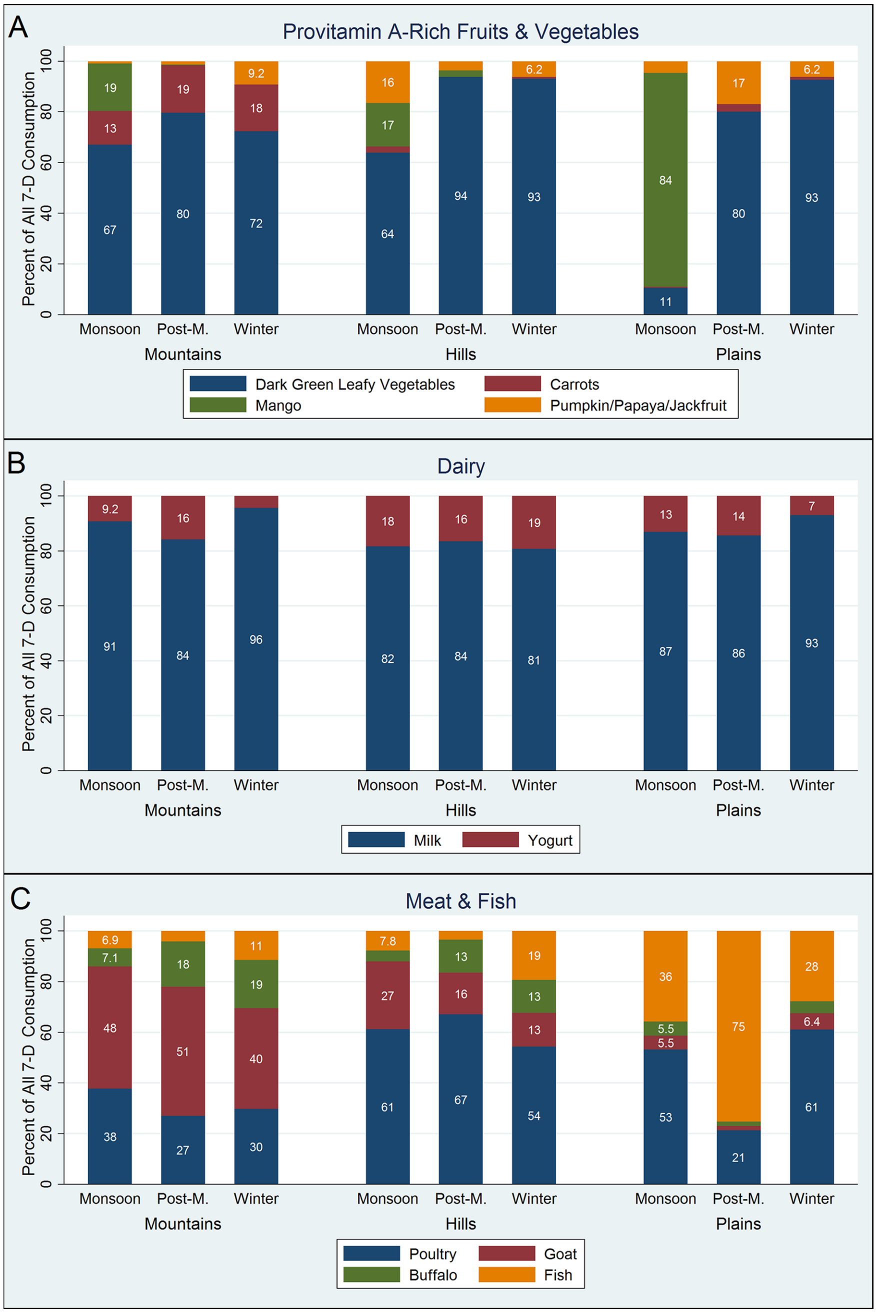

FIGURE 4 Percentage of children's total 7-d consumption frequency of each food group contributed by individual foods, by region and by season. (A) Provitamin A–rich fruits and vegetables, (B) dairy, and (C) meat and fish. Post-M., postmonsoon.

diet quality improvement efforts to be responsive to the needs in a given setting and to the needs of specific populations. Indeed, evaluations of nutrition-sensitive agriculture programs in Nepal have noted that program effectiveness differs by season and agroecological zone, and emphasize the importance of taking context-specific approaches (38, 39).

Differences in seasonal patterns observed across agroecological zones for certain foods, specifically dairy and provitamin A–rich fruits and vegetables, are likely attributable to location-specific variation in production of these foods. Although identification of the specific causes of such variation is beyond the scope of this analysis, they are unsurprising given the substantial climatic and agricultural variation across zones. For example, the trend of greater overall dairy consumption in the hills is consistent with this area having Nepal's highest levels of dairy cattle husbandry, and the decrease in consumption observed during the monsoon season aligns with the "lean season" in milk collection previously noted within Nepal's dairy industry (40). The contrasting trend of decreased dairy consumption during the winter in the mountains may be due to differences in types of cattle (i.e., raising cows or yak compared with buffalo, which have different calving seasons) or timing and amount of fodder availability (40, 41). Differing seasonal patterns in provitamin A–rich fruit and vegetable consumption across zones may be attributable to variations in amounts of precipitation received, and types of fruits and vegetables produced. For example, the substantial increase in mango consumption during the monsoon season in the plains reflects the seasonality of mango production and the higher number of mango trees in this area, in contrast to the mountains and hills where mangos are often only available in the market (42).

Findings also reveal wealth- and caste/ethnicity-based differences in children's consumption of certain foods that differ by agroecological zone, and that in a few cases interact with seasonal effects. The fact that these differences and interactions were observed in some zones but not others suggests a complex interplay between contextual factors and socioeconomic factors that deserves greater attention. It is likely both agroecological variation and variation in the distributions of caste and ethnic groups which drive the differences in dietary patterns and seasonal trends observed across zones. The observed increase in fish consumption among Muslim children during the postmonsoon season in the plains provides one example of a zone-specific trend that probably resulted from a combination of agroecological and caste/ethnicity-related factors. The mountains and hills contain few Muslim households; however, it is unlikely that the seasonal increase in fish consumption seen in the plains would occur in these zones even if their Muslim populations grew because there is much lower fish production in these areas (15). In the plains, access to fisheries and seasonal fluctuations in fish populations (agroecological factors), in combination with food traditions and/or livelihoods specific to Muslim communities, likely led to the observed difference in consumption patterns. In addition, evidence of interactions between season and caste/ethnicity and season and wealth was seen in the mountains but not in the hills or plains. This suggests that context-specific factors within the mountains (which are discussed further below) may increase the susceptibility of socioeconomically vulnerable households to seasonal dietary deficits in comparison with similarly vulnerable Dalit and low-income households in other zones. Overall, these findings indicate the need for further analyses that use both quantitative and qualitative methods to explore the reasons underlying observed differences in seasonal patterns across zones.

Exploring the reasons why there are differences in consumption of certain foods in some areas but not in others, and why some differences become more pronounced during certain seasons, could help to inform strategies to support vulnerable groups by shedding light on the factors that make them vulnerable. For example, the finding that consumption of dairy in the mountains decreased more during the winter among Dalit children than among upper-caste children could have several explanations. One possibility is that it reflects a winter shortage of cattle fodder among lower-caste households, which may be due to their having less access to land than upper-caste households (43, 44). The finding that consumption of provitamin A–rich fruit and vegetables in the mountains decreased more during the winter among children from poorer households may reflect the difficulty of garden production due to water scarcity during the dry winter season, and the greater water-insecurity faced by the socioeconomically disadvantaged (45).

In other cases, the caste/ethnicity-based differences noted in the findings are likely related to religious restrictions and cultural traditions. In the plains, children from Muslim households consumed more eggs and fish than did children from other Terai caste households and in the hills, Dalit children consumed more meat and fish compared with upper-caste children. Both of these findings are consistent with religious restrictions on consumption of certain animal source foods among high-caste and Terai caste Hindus (46, 47). Again, there is a need for further research, particularly qualitative studies, exploring how group-specific food restrictions and preparation practices vary and may influence experiences of seasonality.

This research had several important strengths. The analysis utilized the PoSHAN study's rigorous, sentinel site longitudinal data which covered 6 different time points across 2 full years and represented Nepal's 3 different agroecological zones. In addition, the analysis utilized consumption frequency data, rather than dichotomous consumption indicators, which are often used in studies of diet quality. Although useful for making comparisons across large populations, dichotomous indicators such as minimum dietary diversity have poor specificity and are subject to substantial random within-person variation which result in misclassification and reduced statistical power in regression analyses (48, 49). Finally, the analyses described in this paper were conducted separately by agroecological zone and by food type, which generated important insights and demonstrated the value of data disaggregation.

The foremost limitation of this research is that although the seasonal sentinel sites were selected to represent the centroid of randomly selected study VDCs in each agroecological zone, these specific findings may not be generalizable throughout a zone due to climatic, production, market, cultural, and sampling variability. In addition, data collection did not include information on quantities of consumption for each food, so no conclusions can be drawn regarding nutrient intakes, and children's consumption frequency data were based on maternal report so are subject to potential measurement error due to inaccurate recall and social desirability bias. Finally, like most observational studies examining factors associated with diet, this analysis is subject to possible unmeasured confounders. It does not allow inferences about causality based on the associations observed or about the pathways and intervening factors that may be driving associations. Although possible agroecological and sociocultural explanations for key findings have been discussed, verifying these proposed explanations will require further research.

Despite these limitations, results from this analysis demonstrate the importance of examining seasonality to understand dietary patterns in rural agrarian societies like Nepal, and the value of disaggregating seasonal data geographically, socioeconomically, and by food type. They indicate the need for caution when estimating usual long-term dietary intakes from cross-sectional, national-level surveys. Future studies should examine whether and to what extent single time point surveys obscure seasonal and regional differences in diet by comparing findings from single time point and multiseason surveys conducted with the same population. Researchers should quantify the extent to which indicators of child diet quality generated from the 2 survey types correlate, and the number of children whose diet quality is classified differently based on the 2 surveys. Future research should also explore the intertwined environmental, social, and economic drivers of seasonal differences in order to design and target appropriate interventions.

Our findings of strong, local patterns of seasonal variation in children's consumption of nutrient-rich foods have important implications for programs to enhance dietary diversity, including homestead food production programs. Most existing data sources only give a one-time cross-sectional view of diet. Our findings suggest that the concept of year-round dietary quality should be given more prominence, which may require different measurement strategies and possibly geographically tailored strategies aimed at filling seasonal nutrient deficits. Approaches to measuring the impact of such programs should incorporate multiseason data collection, also ensuring that the timings of baseline and endline assessments occur in the same season, ideally in the seasons in which the intervention has the greatest potential to improve diets.

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