

Dietary habits and growth: an urban/rural comparison in the Andean region of Apurimac, Peru

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Abstract

Introduction. The efficacy of interventions against children malnutrition crucially depends on a myriad of factors other than the simple food intake, that must be carefully studied in order to plan a balanced policy. The relation between dietary patterns and growth is at the very heart of the problem, especially in consideration of the fact that dietary pattern involves dimension other than pure caloric intake in its definition. In this work we investigated the relations between dietary pattern and growth comparing children from a rural and a urban area in Andean Peru, in terms of food habits and anthropometric variables to develop a model usable in context interventions against malnutrition.

Material and methods. A sample of 159 children (80 from urban, 79 from rural area), aged from 4 to 120 months (72.7 ± 37.5 SD) was collected. The data were investigated by a multidimensional (principal component analysis followed by inferential approach) analysis to correlate the different hidden dimensions of both anthropometric and dietary observables. The correlation between these dimensions (in the form of principal components) were computed and contrasted with the effects of age and urban/rural environments.

Results. Caloric intake and growth were not linearly correlated in our data set. Moreover urban and rural environment were demonstrated to show very different patterns of both dietary and anthropometric variables pointing to the marked effect of dietary habits and demographic composition of the analyzed populations. The relation between malnutrition and overweight was at the same time demonstrated to follow a strict area-dependent distribution.

Discussion and conclusion. We gave a proof-of-concept of the non-linear character of the relation between malnutrition (in terms of caloric intake) and growth, pointing to the need to calibrate interventions on food pattern and not only quantity to contrast malnutrition effects on growth. The education toward a balanced diet must go hand-in-hand with the intervention on caloric intake in order to prevent effects on health.

Key words

- multilevel modeling
- social epidemiology
- malnutrition
- growth
- dietary habits

INTRODUCTION

Among developing countries, Peru is classified on track toward achieving MDG (millennium development goals), in 2015 thanks to the pursued policy in line with them in the field of children and maternal health [1]. The UNICEF data regarding children malnutrition in Peru, show 30% of stunting in children aged less than 5 (using as the referral standards the WHO growth curves) [2, 3]. In the same range, 6% of children are underweight and 1% show wasting. It should be also considered that 35% of the population ranges between 0-14 years, and 58.8% between 15-64 years and only 6.2% is older than 65 years [4].

Some programs of infant nutritional surveillance are on-going like MONIN [5] (*Monitoreo Nacional de Indicadores Nutricionales*) and The Wawa Wasi, a social program with the specific aim of fighting chronic malnutrition and to induce positive conditions for a fully integrated social development of children aged less than 3 years in extreme poverty. Apart from altitude, differences in socioeconomic factors, nutrition and quality of health care and genetic potential may be responsible for the differences in physical growth between urban and rural Andean children [6].

Some studies support the view that the slow physical growth observed in Amerindian children living in the

Andean ecosystem is a developmentally mediated response to an energy limited social environment [7-9]. Thus, conducting a simultaneous study of growth patterns in Quechua children from different residing areas at different altitude corresponds to the choice of a relatively "well-controlled" situation in which a largely shared genetic background is challenged by changes in life habits. In this work we investigate the association between dietary pattern and growth comparing children from a rural and urban area in Peru Andes in terms of food habits and anthropometric variables [2, 3]. We aim to demonstrate the complex and intermingled nature of the relations between dietary intake and anthropometric data.

METHODS

Study design and location

The study was conducted in the Apurimac region, an 895.79 km² wide area in the highlands of the Sierra, with a population density of 19.3 inhabitants/km². Apurimac region is divided into 7 provinces, each of which has its own capital [9]. The data were collected primarily in the province of Abancay, located in the Centre-North Apurimac and coincident with the capital of this region. In this territory, the population is distributed for 63.3% in urban area and for 36.7% in rural area with a total density of 27.9 inhabitants/km² [10].

Abancay covers an area of 3447.13 km² while and altitude ranges from 1.900 m (Pachachaca Valley) to 5220 m above sea level (Mount Ampay). In this study, we recruited a sample of 159 Peruan children of the Apurimac region in the range from 3.5 to 159 months (13 years) with an average of 72.75 months (approximately 6 years).

The rural children living in the higher lands of the Apurimac region, come from two communities located between 3000 and 4000 m of altitude, while the urban group was enrolled in Abancay, the capital city of Abancay Province located at 2350 m of altitude.

Anthropometric assessments and classification of malnutrition

In accordance with international standards, anthropometric parameters assessed included weight and height, but not arm circumference (due to the wide age range considered) and the presence of bilateral pre-tibiae oedema (not present in our sample). Children were measured without clothing or footwear; weight (in kilograms) is determined using a mechanical scale and the baby scale by UNICEF (United Nation International Children's Fund), while height (in centimetres) is assessed by laying children on their back and using a stadiometer for new-born babies and infants (SECA 210, <http://www.seca.com>). Weight and height data were managed using the WHO/Anthro package [11] and WHO/Anthro package plus [12] for subjects aged between 5 and 19 years. Children with weight for height z-scores (WHZ) < -2 and/or weight for age z-score (WAZ) < -3 z-score and/or two consecutive static or declining weights are identified as children with Moderate Malnutrition. Severe Malnutrition is characterized by a WHZ < -3 in accordance with WHO/UNICEF criteria [13-15].

Food survey and calculation of nutritional intake

In order to assess eating habits of study subjects, trained staff utilized a 24-hour food recall diary, a food diversity index (the dietary diversity score, DDS) [16], and a food atlas [17]. This allowed a qualitative and semi-quantitative assessment of the infants' diet (esteem of the quantity of foods consumed). Dietary diversity was assessed using the DDS. The index evaluates dietary diversity with reference to the 12 food groups used by FAO for developing countries. Food diary data for the infants was entered and processed using the Nutrisurvey (WHO) software (<http://www.nutrisurvey.de>), a package for Windows XP/Vista/2007 previously used in similar studies. A value of less than 75% of the FAO recommended nutritional intake was considered inadequate [18].

Statistical analysis

Principal component analysis (PCA) was applied to the two sets of dietary consumption and anthropometric measures to single out the independent factors corresponding to the hidden variables shaping the system at hand. Analysis of variance (ANOVA) and Student's t-test were then applied to such components in order to check the effect of demographic variables (sex, location, malnutrition) while Pearson correlations were used to motivate the observed results. Statistical analysis was conducted with SAS, statistical application system, Version 8.1 (www.sas.com/technologies/analytics/statistics/stat/index.html). In order to assess the mutual correlations between the different aspects of the investigated phenomenon variables were split into three groups:

- 1) diet (FOOD) (kcal (estimated global caloric intake), carbohydrates, fats, proteins and vitamin A intake);
- 2) anthropometric (ANTHRO), WHZ (weight z-score), HAZ (height z-score), WAZ (weight for age z-score); BMI Z(body mass index, z-score);
- 3) demographic (sex, rural/urban area, age).

The discrete (yes/no) variable malnutrition is obviously linked with the groups one and two as observable, while playing the role of end-point as for the group three. PCA gave rise to a three component solution for both FOOD and ANTHRO subsets, globally explaining the 97% (food set) and 98% (ANTHRO set) of total variability. We then analyzed the resulting component scores by a two-way analysis of variance having as sources of variation area of origin (R/U), malnutrition (Y/N) and the interaction between them.

RESULTS

The sample (159 children) was split in two groups depending on the residing area, 80 from urban (36 females and 44 males, aged 76.12 ± 36.5 SD months), and 79 from rural area (36 females and 43 males, aged 69.37 ± 38.5 SD). The asterisk (*Table 1*) shows a statistically significant difference between rural and urban locations. Apart from the marked difference in food intake variables, it is worth noting that 25% and 45% of urban and rural children respectively show medium to severe malnutrition and that, not surprisingly 11% and 10% show overweight. Indeed, as we noted before, in villages and city, eating less is not linearly linked with

Table 1
Descriptive analysis: mean values of demographic and nutritional variables

	Urban area			Rural area		
	Male	Female	Total	Male	Female	Total
Number of subjects	36	44	80	36	43	79
Age (months)	78.5	74.2	76.12 ± 36.5	68.24	70.3	69.36 ± 38.5
Weight (kg)	21.58	18.49	19.88	19.31	18.64	18.95
Height (cm)	111.87	108.58	110.06	100.14	103.88	102.18
kcal	1904.0	2143.6	2035.8*	1442.3	1275.4	1351.5
Δ kcal^Δ	+ 71.84	+ 497.67	+ 306.05*	-274.775	- 335.32	- 307.73*
Protein intake (g)	67.73	85.6	77.56	52.96	47.23	49.85
Δ Protein^Δ (g)	+ 71.84	+ 85.60	+ 176.97	+ 31.16	+ 24.88	+ 22.15
Vitamin A intake (μg)	820.05	846.5	834.56*	537.25	556.1	547.51*
Δ Vitamina^Δ A (μg)	+ 324.68	+ 366.50	+ 347.69	+ 60.17	+ 75.86	+ 68.72
DDS	9.4	7.8	8.5*	6.6	6.2	6.4*
Medium to severe malnutrition	7	10		12	16	
	5	6	25%*	8	11	42%*
	2	4		4	5	
Overweight	4	0	11%	2	2	10%

*Statistically significant difference between rural and urban area. The Δ^{Δ} variables refer to the difference between recommended and registered nutrients intake, Δ° dietary diversity score. Statistical significance was computed by t/test for continuous variables and by chi/square for malnutrition and overweight distribution.

malnutrition, it means that malnourishing condition does not depend solely upon dietary intake but needs other concurring causes. In *Table 1* we can appreciate the gap in height between urban and rural is 8 cm more for urban but the gap in energy intake is + 614 kcal more, daily for urban children always higher than WHO recommended calories intake (*Figure 1*).

Moreover, the DDS score shows that dietary diversity (with reference to the 12 food groups used by FAO for developing countries), is 8.5 in urban and 6.4 in rural children, because the diet in the city is more diverse than in rural environment thanks to “fish” and “junk food” categories while the availability and accessibility to fruit and vegetables is the same in both areas. It's important to remember that several studies demonstrate a positive association between dietary diversity and nutritional status of children [19, 20]. In order to get a global view of the system we computed the principal components of the FOOD and ANTHRO subset.

The interpretation of components (*Table 2*) for food subset is: FOOD1 = quantity of food intake, FOOD2 =

vitamin A, FOOD3 = high fat intake, while ANTHRO subset is decomposed into ANTHRO1 = general “size” or general growth, ANTHRO2 = “brachilinear” body shape, ANTHRO3: “shortness”, high BMI’ pattern. This interpretation stems from the loading pattern: the original variables most correlated (loaded) with components are bolded in *Table 2*.

FOOD1 is a classical “size” component [21] that can be easily considered as “food intake”, is worth noting that variable most loaded on FOOD1 is kcal, *i.e.* the “general summary” of food intake in caloric terms. The same holds for ANTHRO1 that corresponds to the entity of growth.

FOOD2 catches a singular feature of Andean diet: the large use of tubers in the diet characterized by high vitamin A concentration, while ANTHRO2 points to a peculiar “shape” of individuals: subjects with high values of ANTHRO2 have higher WAZA ($r = 0.77$), this increase in weight goes in the opposite direction of both BMI and HAZA (negative correlation with the component).

It is worth noting that components are extracted in

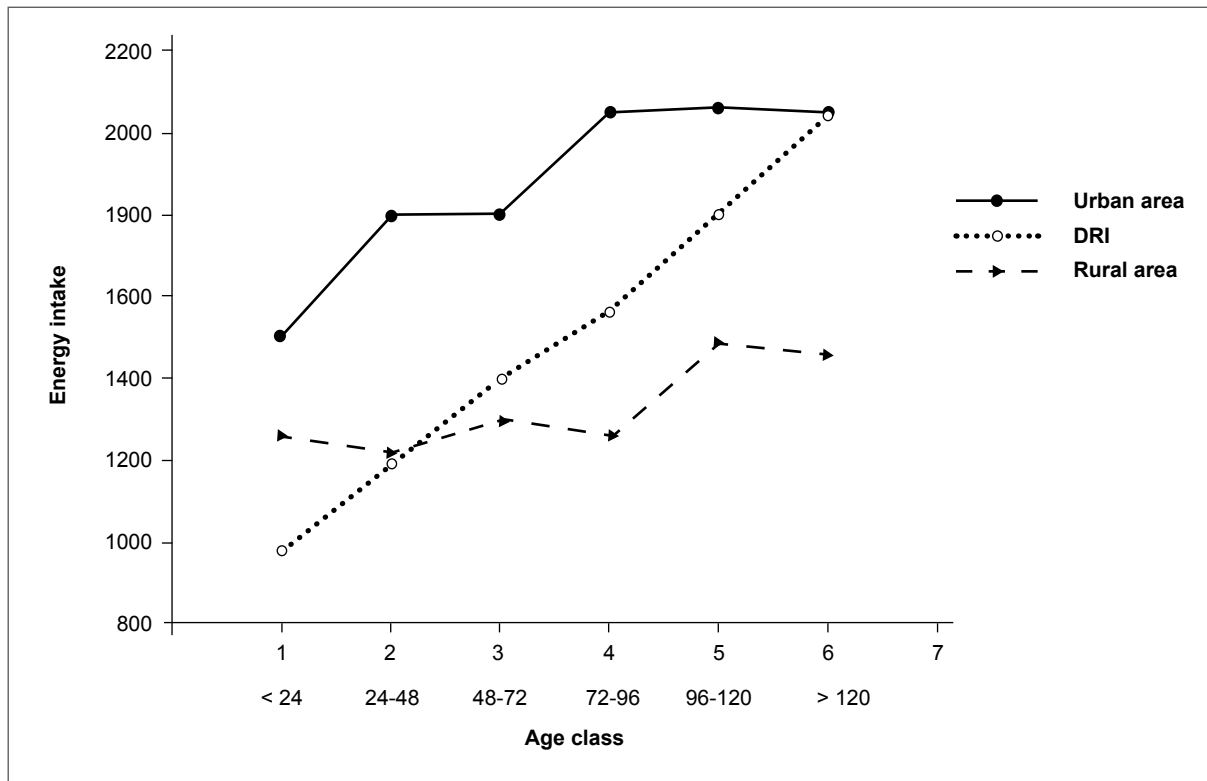


Figure 1
Rural/ urban energy intake for different age classes contrasted with recommended energy intake levels at different age classes (DRI variable). It is worth noting how urban population average energy intake is constantly higher than DRI, while rural population children, thanks to breast-feeding practice, are set at an higher than DRI level at lower ages, while at increasing age their dietary pattern is no more able to reach recommended energy intake levels.

Table 2
Correlation coefficients (loadings) between original variables and principal components

A	Loading pattern		
	FOOD1	FOOD2	FOOD3
kcal	0.9858	- 0.0733	- 0.1434
Proteins	0.9074	- 0.1513	0.2064
Carbohydrates	0.8522	0.0224	- 0.5199
Fats	0.8574	- 0.1792	0.4127
Vitamine A	0.3740	0.9201	0.1155
% explained variance	68	18	10
B	Loading pattern		
	ANTHRO1	ANTHRO2	ANTHRO3
WHZ	0.9101	0.3543	- 0.1518
WAZ	0.6118	0.7700	0.1452
HAZ	0.8725	- 0.4283	-0.1970
BMIZ	0.8075	- 0.5200	0.2739
% explained variance	65	29	4

The original variables most correlated (loaded) with components are bolded in Table 2

Table 3
Descriptive statistics for all the observed groups together with ANOVA significance

A					
Descriptive statistics					
Rural area		Malnutrition = No			
Variable name	N	Mean	SD	Minimum	Maximum
FOOD1	46	-0.650*	0.737*	-2.135*	1.024
FOOD2	46	-0.161	1.060	-1.505	4.078
FOOD3	46	0.326	1.069	-2.374	3.590
ANTHRO1	46	0.229^	0.650^	-0.972	1.672
ANTHRO2	46	-0.087	0.457	-1.747	0.984
ANTHRO3	46	0.000	0.942	-1.108	3.307
Rural area		Malnutrition = Yes			
Variable name	N	Mean	SD	Minimum	Maximum
FOOD1	33	-0.778*	0.656*	-2.654*	0.498
FOOD2	33	-0.022	0.427	-0.814	1.548
FOOD3	33	-0.145	0.838	-1.933	2.059
ANTHRO1	33	-0.079^	1.396^	-2.352^	4.249
ANTHRO2	33	-0.173	1.750	-1.753	6.939
ANTHRO3	33	0.079	0.986	-2.923	1.889
B					
Descriptive statistics					
Urban area		Malnutrition = No			
Variable Name	N	Mean	SD	Minimum	Maximum
FOOD1	60	0.679*	0.734*	-1.201*	1.825*
FOOD2	60	0.015^	0.574^	-1.015^	2.239^
FOOD3	60	-0.144	0.945	-1.679	2.401
ANTHRO1	60	0.027*	0.620*	-1.015*	1.497*
ANTHRO2	60	0.335*	0.517*	-0.925*	2.298*
ANTHRO3	60	-0.319*	0.489*	-1.235*	1.454*
Urban area		Malnutrition = Yes			
Variable name	N	Mean	SD	Minimum	Maximum
FOOD1	20	0.739*	0.726*	-1.181*	1.794*
FOOD2	20	0.363^	2.029^	-1.642^	8.471
FOOD3	20	-0.078	1.133	-1.077	2.148
ANTHRO1	20	-0.479*	1.568*	-3.007*	2.610
ANTHRO2	20	-0.517*	1.062*	-2.828*	1.793
ANTHRO3	20	0.825*	1.669*	-1.237*	6.086

FOOD1 = quantity of food intake; FOOD2 = vitamin A; FOOD3 = high fat intake; ANTHRO1 = general "size" or general growth; ANTHRO2 = "brachilinear" body shape; ANTHRO3: "shortness", high BMI pattern. * statistically significant results obtained in terms of between malnourished and normal subjects in the two groups, ^borderline effects, SD standard deviation.

an unsupervised way by the algorithm so mirroring the correlation structure present in the data set [22]. The components are by construction each other independent so what observed in minor components is decoupled by the main (68% and 65% respectively) order parameter (food intake and general growth respectively) and constitute "shape" factors whose variation follows other directions with respect to "size" components [21].

FOOD3 points to the balance between fats and carbohydrates: high values of FOOD3 points to a diet richer in fats. ANTHRO3 explains only the 4% of total variance and it is again a shape factor pointing to relatively minor balances between body dimensions.

Having selected such general hidden variables, we looked for their variations and relations with the children living area (rural/urban) and age. As expected FOOD1 shows a marked and statistically significant difference between rural and urban areas (rural FOOD1 mean = -0.70, urban FOOD1 mean = 0.69, $p < 0.0001$ at t-test).

This result is mirrored by the statistically significant difference (Chi-square = 5.03 $p < 0.02$) of malnutrition prevalence in the two sets (42% in rural vs 25% in urban). All the other components do not show any statistically relevant difference between the two groups.

Considering (ANTHRO3) component, the natural variability among children is large at both ends of general distribution (< 20 and > 120 months) whereas ANTHRO2 is meaningful (relevant variation among statistical units) only for the children aged less than 20 months. Under 20 months children have higher BMI than the reference population in general (WHO standard), and rural more than urban (Student's t-test on ANTHRO2, $p \leq 0.0005$), due to the early weaning in urban children. In children > 20 months we saw a higher caloric intake in the city (males and females), mainly linked with the high fat levels in diet and it is interesting how the diet rich in fats is more common among females ($r = 0.33$ $p < 0.0001$), in rural females also, probably explained by socio-cultural habits. Furthermore the city female eat more than males (males mean food1 is 0.38 and 0.95 for females) but *vice versa* for rural area (males mean food1 is -0.55, for females -0.83), where males eat more than females.

The above results suggest that malnutrition cannot be considered as a purely "quantitative" extreme of dietary intake, moreover the most important component of dietary intake and growth are each other independent on the global data set ($r = 0.05$, NS). This is a direct proof of the need to calibrate interventions on food as for ameliorate malnutrition effects on growth. The main way to do that is to start from the analysis of malnutrition not as an effect but as a "source of variation" of the studied variables. The potential impact of malnutrition *per se* on the anthropometric variables prompted us to analyze our components by a two-way analysis of variance having as sources of variation area of origin (R/U), malnutrition (Y/N) and the interaction between them (Table 3). In order to highlight the interaction between general malnutrition conditions and environmental conditions, Table 3 reports the descriptive statistics for all the malnutrition/area combinations together with the ANOVA significance. For a meaningful interpretation of the Table it is important

to remind components are scaled on the entire data set so to have grand average equal zero and unit standard deviation, so they can be considered as z-scores. This implies that a maximal value near 7 (ANTHRO2, rural area, malnutrition = yes) corresponds to an outlier located at 7 standard deviations from the global mean. The intra-group SD clearly are not bound to unit, but the global population yes, this allows to appreciate the entity of the variability of each sub-group, thus rural area/no malnutrition is a very compact group as for ANTHRO2 (SD = 0.457) while urban area/malnutrition = yes is very dispersed as FOOD2 (SD = 2.029).

Besides the already described effect on FOOD1, only in the urban area we are able to observe statistically significant difference in terms of anthropometric components: all the extracted components show statistically significant results in the urban area between malnourished and normal subjects.

As a matter of fact both ANTHRO2 and ANTHRO3 gave rise to highly statistically significant result in terms of both malnutrition *per se* and malnutrition per area interaction ($p < 0.01$ and $p < 0.02$ for ANTHRO2; $p < 0.0009$ and $p < 0.0013$ for ANTHRO3), while ANTHRO1 showed a statistically significant effect as for malnutrition effect ($p < 0.001$) independently of the area of origin.

These results show that general growth (ANTHRO1) is affected by Malnutrition (as largely expected) independently of the area of origin, while ANTHRO2 and ANTHRO3, the "shape" dimensions of growth showed a link with malnutrition only for urban subset, this comes from the general differences in morphology between rural and urban areas, with rural population being much less variable than urban consistently with their higher genetic commonality.

Malnutrition is more common in rural area and linked with the youngest age (but aged more than 20 months), and the lowest level of fat intake. The variability inside the urban and rural class show that the most age increases, the most fats intake decreases while in the urban area this trend is reversed.

DISCUSSION AND CONCLUSION

Malnutrition is qualitatively and not only quantitatively different from normal nutrition. Dietary intake is not related to general growth in the whole data set, but only with the intermediation of malnutrition status. There is an higher incidence of malnutrition in rural with respect to urban areas.

Perinatal period is the most critical one for differences in anthropometric variables that are not easily rationalized by the level of food intake.

Different dietary patterns in rural and urban area were demonstrated with a marked increase in Fats consumption in urban area especially as for women. This gender-related difference is difficult to explain but again, points to the need of a careful analysis of context when planning an intervention. Even if on a purely hypothetical perspective, it could be of some interest to consider that differences in health service may affect physical growth in the long term. Health facilities for the rural population in the Department of Apurimac are limited to primary care facilities with a nurse or a midwife involved

in the national's plans (MDG) [1]. The efficiency of this project has been criticized especially because the doctors presence in some villages is limited to once a year for deworming and growth measure check. In the present study we noted big differences in health care utilization between rural and urban communities. The synergic effect of malnutrition and infections are well known [23] and several factors may be related to the low HAZ, WHZ and WAZ found in rural children from 2 to 96 months of age. Some studies support the view that the slow physical growth of Amerindian children living in the Andean ecosystem is a developmentally mediated response to an energy limited social environment [6, 7] but we should consider also the genetic difference between them, indeed the rural ones come from villages situated in the higher lands (communities located between 3000 and 4000 m of altitude) and they are still pure Quechua, while the urban come from the multiethnic capital city Abancay (2350 mt).

Our studies show that rural children older than two years are taller than urban that caught up with the rural in height and weight during childhood (6-8 years) and pre-puberty stages (> 10 years) exceeding them in weight for height ratio and BMI Z-scores in pre adolescence showing a different body shape according to the high calories level diet they receive. The height gap between urban and rural children is 8 cm (Table 1), towards urban children, supporting energy limited social environment hypothesis.

Socio-cultural elements such as breast feeding, weaning practices, intra family food distribution, diet and child rearing practices could be strictly related with the differences in physical growth between rural and urban children [6]. In our study population growth retardation during the first two year of life in urban children was probably due to the habits of short breast feeding in the city due to the mother's job commitments. Indeed, breastfeeding is practiced by almost all the rural Quechua mothers, until the second year of life and this is also used as natural contraceptive method. Cessation of breastfeeding, weaning practices and the impact of socio demographic and environmental factors could explain in part why nutritional status in rural children decreased after the second year. After breastfeeding, rural mothers face difficulties to find specific foods for weaning and they start immediately the adults' diet very reach in tubers and cereals, especially sweet corn, and poor in fats and proteins. The decoupling between growth and food consumption and in general the non-linear link between malnutrition and dietary intake in rural area, is hypothetically linked to the high physical activity and family agricultural job. If the all family is out of home all day, children (aged 20 to 72 months) have their meals not depending on their nutritional needs but on mothers' busy day. It means that they use to eat only at early morning and dinner, as highlighted in our interviews.

We have also to consider that in rural areas (especially those situated near 4000 m of altitude), it is hard to find different food from that people can produce by themselves (with a very low m and variable with seasons, consumption of meat proteins). But, when the school

starts, children start to eat meals and snacks thanks to the many nutritional programs for fighting malnutrition run by the Peruvian Government. On the contrary, for urban children school means undergoing to a much regular diet and for most of them, increasing movement (walking to school, less time for buy and eat "junk food", watching TV and computer) and sports. And, not considering the malnourished, but normal children at the same dietary intake, we can see that urban ones are heavily related to high BMI while rural are mainly with shortness and light body.

The long term effects of norms and values of differences in quantity and quality of food available for children, the preparation and spacing of meals, as well as the interaction of the Andean agricultural cycle with

food availability and household activities of spouses could also result in differences in physical growth between rural /urban children [6].

All in all we want to stress the need of a careful socio-cultural analysis as a prerequisite for any public health intervention against malnutrition.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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