Public Health Nutrition: 23(6), 1009–1019 doi:10.1017/S1368980019002313

Analysis of dietary patterns and cross-sectional and longitudinal associations with hypertension, high BMI and type 2 diabetes in Peru

Carmelia Alae-Carew[1,*], Pauline Scheelbeek[1], Rodrigo M Carrillo-Larco[2,3,4], Antonio Bernabé-Ortiz[2,5], William Checkley[6,7] and J Jaime Miranda[2]

[1]Department of Population Health, London School of Hygiene & Tropical Medicine, London WC1E 7HT, UK: [2]CRONICAS Centre of Excellence in Chronic Diseases, Universidad Peruana Cayetano Heredia, Lima, Peru: [3]School of Medicine, Universidad Peruana Cayetano Heredia, Lima, Peru: [4]Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, UK: [5]School of Public Health and Administration, Universidad Peruana Cayetano Heredia, Lima, Peru: [6]Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, Baltimore, MD, USA: [7]Center for Global Non-Communicable Disease Research and Training, Johns Hopkins University, Baltimore, MD, USA

Submitted 14 September 2018: Final revision received 19 March 2019: Accepted 21 May 2019: First published online 28 August 2019

Abstract

Objective: To determine if specific dietary patterns are associated with risk of hypertension, type 2 diabetes mellitus (T2DM) and high BMI in four sites in Peru.

Design: We analysed dietary patterns from a cohort of Peruvian adults in four geographical settings using latent class analysis. Associations with prevalence and incidence of hypertension, T2DM and high BMI were assessed using Poisson regression and generalised linear models, adjusted for potential confounders.

Setting: Four sites in Peru varying in degree of urbanisation.

Participants: Adults aged ≥35 years (*n* 3280).

Results: We identified four distinct dietary patterns corresponding to different stages of the Peruvian nutrition transition, reflected by the foods frequently consumed in each pattern. Participants consuming the 'stage 3' diet, characterised by high proportional consumption of processed foods, animal products and low consumption of vegetables, mostly consumed in the semi-urban setting, showed the highest prevalence of all health outcomes (hypertension 32·1 %; T2DM 10·7 %; high BMI 75·1 %). Those with a more traditional 'stage 1' diet characterised by potato and vegetables, mostly consumed in the rural setting, had lower prevalence of hypertension (prevalence ratio; 95 CI: 0·57; 0·43, 0·75), T2DM (0·36; 0·16, 0·86) and high BMI (0·55; 0·48, 0·63) compared with the 'stage 3' diet. Incidence of hypertension was highest among individuals consuming the 'stage 3' diet (63·75 per 1000 person-years; 95 % CI 52·40, 77·55).

Conclusions: The study found more traditional diets were associated with a lower prevalence of three common chronic diseases, while prevalence of these diseases was higher with a diet high in processed foods and low in vegetables.

Keywords
Dietary pattern analysis
Latent class analysis
Peru
Non-communicable diseases
Cardiometabolic risk factors

Unhealthy diet is one of the main modifiable risk factors for the predominant non-communicable diseases (NCD), as it can contribute to the development of conditions such as hypertension and type 2 diabetes mellitus (T2DM), as well as overweight and obesity which are precursors to many NCD[1]. The rise of unhealthy diets in low- and middle-income countries has been in part attributed to a rapid 'nutrition transition', in which traditional diets are being replaced by consumption of more energy-dense Westernised foods, including animal products high in saturated fat and processed foods high in salt, oils and refined sugar[2,3].

The nutrition transition in Peru, an upper-middle-income country, has been taking place at different rates throughout the country due to its diverse geography, nutrition profile and levels of urbanisation[4]. The diet in rural areas of Peru remains in line with a more traditional dietary pattern, which is mostly comprised of potatoes and other tubers[5] and starchy seeds such as quinoa[6], although

*Corresponding author: Email carmelia.alae-carew@lshtm.ac.uk

Public Health Nutrition

there are substantial regional differences in diet. However, as 77·3 % of Peru's inhabitants now live in urban areas[7], this is no longer the case for much of the country; urbanisation being one the drivers underpinning the change in consumption that characterises the nutrition transition towards a Westernised dietary pattern[3]. Examination of food intake trends inferred from food balance sheets over the 1990s have shown increasing consumption of animal products, saturated fat and sugar[2], while energy supply from cereals, roots and tubers has declined as gross domestic product per capita has improved[8]. Mapping of the 'stages' of transition in 2012 based on prevalence of stunting and obesity suggested that some coastal regions of the country had moved away from traditional diets and showed low levels of stunting and a high burden of obesity and other nutrition-related chronic disease. Diets in most other regions of Peru were much more in transition, showing a typical 'double burden' profile with a substantial burden of both stunting and obesity among people consuming a diet similar to the traditional Peruvian diet and people consuming more Westernised diets, respectively[4].

In 2014, NCD accounted for 66 % of deaths in Peru[7]. Hypertension and T2DM are two of the leading risk factors for many of the major NCD, and further characterisation of the estimated local burden of these risk factors is required to develop and support local and regional strategies for prevention and control of NCD[9]. Previous studies in Peru have shown that both overweight and obesity increase the risk of hypertension and T2DM, with obesity being the leading risk factor for both[10,11]. The contribution of obesity to disease risk was found to vary in different parts of the country, and similarly variations in incidence and prevalence of hypertension[10,11] and T2DM[11,12] were found among different parts of the country that vary in degree of urbanisation. In 2012, the prevalence of overweight and obesity in Peru was >30 % in all but one of its twenty-five regions[4]. However, there has been very little examination of the role of diet in the development of obesity and other NCD determinants in a country with extensive environmental and cultural diversity.

The link between nutrition and disease is increasingly being investigated using dietary pattern analysis, which takes into account many of the complexities associated with examining the diet; it is inclusive of eating behaviours, food synergy and nutrient interactions[13]. While it does not take the place of studying single food components, dietary pattern analysis can provide valuable information on the overall effects of diet in order to predict disease risk or aid in a comprehensive approach to prevention strategies[13,14]. No previous dietary pattern analyses have been performed on Peruvian dietary data, a country where diets are heterogeneous and can be difficult to classify. Therefore the present study was undertaken to achieve the following objectives: (i) to characterise dietary patterns in four different locations in Peru; (ii) to examine the cross-sectional relationship of these dietary patterns with hypertension, T2DM and BMI; and (iii) to investigate changes in disease risk over time by assessing the longitudinal association between baseline dietary patterns and the three outcomes. By doing this we aimed to contribute to the evidence on the link between dietary patterns and NCD in resource-constrained settings to further inform targeted intervention strategies.

Methods

Study design and setting

The CRONICAS Cohort Study is a longitudinal ongoing cohort study of NCD progression in distinct geographic areas of Peru, which has been described elsewhere[15]. In short, four study sites were included in the study: two sea-level sites (a highly urbanised area of Lima, the capital, and a semi-urban setting in Tumbes, in the north of the country) and two high-altitude sites (an urban and a rural site in Puno in the south of the country). Beginning in September 2010, the study sought to characterise the baseline prevalence and rate of progression of cardiopulmonary diseases and their risk factors among these different populations. To date, the study has had two rounds of follow-up over a 30-month period. The first follow-up comprised repeated clinical measurements only, while the second follow-up consisted of repeated clinical measurements and blood sampling. For the current analysis, we used data from baseline and the second follow-up, hence covering a 30-month period.

Participants

Using the most recent census available in all study sites, participants were randomly selected using a sex- and age-stratified sampling strategy. Only one individual per household was selected. Those eligible were 35 years or older and had to be a permanent resident in the selected area. Those who were pregnant, bedridden, unable to provide consent, had active tuberculosis or had a physical disability that would prevent measurement of clinical outcomes were excluded. The CRONICAS Cohort Study protocol and informed consent forms were approved by the Ethics Committees at Universidad Peruana Cayetano Heredia and A.B. PRISMA in Lima, Peru, and the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health, in Baltimore, MD, USA.

Data collection

At baseline, participants were visited at home by fieldworkers to verify eligibility criteria and obtain informed consent. Socio-economic, dietary and lifestyle information was gathered by fieldworker-administered paper-based questionnaire, which was adapted from the WHO STEPwise approach for NCD risk factor surveillance[16]. Within this was contained a short version of an FFQ, based

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

on a similar questionnaire designed by an earlier study[17], to obtain information on consumption frequency of certain foods and beverages, selected because either they are commonly eaten foods in Peru or known to be linked to chronic disease[18]. In completing the FFQ participants were asked to report how many times per month or week they consumed foods and beverages within twenty-three categories (see online supplementary material, Supplemental Table S1). Participants were subsequently seen for clinical assessment including blood sampling by a trained technician according to standardised techniques and protocols. Blood pressure was measured using a previously validated automatic monitor (model OMRON HEM-780)[19]. Three readings were taken and an average of the last two measurements was used in the analysis. Blood samples were analysed for fasting plasma glucose level using an enzymatic colorimetric method (GOD-PAP; Modular P-E/Roche-Cobas, Grenzach-Whylen, Germany). Weight was measured using a body composition analyser (model TBF-300A; TANITA Corporation, Tokyo, Japan). The second follow-up comprised repeated completion of subsections of the baseline questionnaire (not including the FFQ) and repeated clinical assessment including blood sampling following the same procedures conducted at baseline.

Variables

The outcomes of interest at baseline and follow up were hypertension, T2DM and high BMI. Hypertension was defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg in participants younger than 60 years, and systolic blood pressure ≥150 mmHg or diastolic blood pressure ≥90 mmHg in those aged 60 years or older, as per the eighth Joint National Committee target blood pressure recommendations[20]. Participants self-reporting a diagnosis of hypertension by a physician or currently prescribed antihypertensive medications were also included in the definition of hypertension. T2DM was defined as fasting plasma glucose level ≥126 mg/dl[21], self-reported diagnosis by a physician or currently prescribed medications for T2DM. High BMI was considered to be BMI ≥25 kg/m^2 to incorporate both overweight (≥25·0–29·9 kg/m^2) and obese (≥30·0 kg/m^2) persons as per the WHO international classification of BMI[22]. All outcome variables were binary.

Dietary patterns were derived from responses to the short version FFQ. Data were aggregated into fourteen food groups (Supplemental Table S1) from which daily frequency of consumption was calculated. Foods were grouped based on similarities in the way the foods are consumed, and similar health impacts. Unrealistic extreme intake values of over ten times daily were excluded. Each food group variable was split into four categories (zero consumption and tertiles of frequency) to reflect proportional consumption frequency of each food group prior to dietary pattern analysis[23,24].

Analyses were adjusted for age (35–44, 45–54, 55–64, 65–74, >75 years old), sex, ethnicity (native Quechua/Aymara, half Spanish/Native, other), education level (none, primary, secondary and further education), currently employed, socio-economic status (based on wealth index indicator derived from assets and household facilities; categorised into tertiles), smoking (never, former, current), heavy alcohol consumption (≥2 nights in the past month of heavy drinking, defined as ≥6 alcoholic drinks), physical activity (low, moderate, high; based on metabolic equivalent score) and watching television (<2 or ≥2 h/d). Baseline measurements were assumed to stay constant throughout the 30-month follow-up period except age, which was updated to age at last follow-up for follow-up analyses.

Statistical methods

Latent class analysis[23,25–27] was used to identify dietary patterns from a set of observed categorical variables. Meaningful latent classes or subgroups of individuals were created based on shared patterns of consumption. Individuals were assigned to a certain dietary pattern group based on similar dietary characteristics. Latent class analysis was performed using Mplus version 7.4 (Muthen & Muthen, Los Angeles, CA, USA) using the fourteen categorical food group variables. A series of models was generated with increasing number of classes from one to seven. Model selection was based on the Akaike information criterion and Bayesian information criterion to compare goodness of fit, entropy to assess the certainty of classification, and pattern interpretability of each model[23,28]. From the selected model, each individual's most likely class membership, as determined by posterior probabilities, was exported into the data set as a new variable. Dietary patterns for each of the classes were described based on the conditional probabilities of reported food groups within each class[26,29].

Tabulation and univariate analyses were used to explore the prevalence of the outcomes and check for collinearity between the exposure variables. Generalised linear models assuming logistic-normal distribution were used to explore the relationship between dietary patterns and prevalence of the three disease outcomes, adjusting for potential confounders using forward selection stepwise regression; likelihood ratio tests were used to assess goodness of fit. The effect of site was assessed using variables for urbanisation (urban, semi-urban, rural) and site (sea level, altitude) within the models; goodness of fit was determined by Akaike information criterion and Bayesian information criterion values. Stratified analysis by site was also carried out to further explore within-site associations; however, there were not enough data to perform individual analysis in each site. For all models, the prevalence ratio (PR) and 95 % CI were obtained for each dietary pattern category, with the dietary pattern showing the highest outcome prevalence chosen as the reference group. Ethnicity was not included in the final model due to collinearity with socio-economic status and education level.

Generalised linear models assuming Poisson distribution using random censoring were used to determine the association of overall and site-specific dietary patterns with incidence of the three outcomes, generating crude and adjusted incidence risk ratio (IRR) and 95 % CI. Participants who already had the condition of interest at baseline were excluded. Analyses of the relationship between dietary patterns and hypertension, T2DM and obesity were performed using the statistical software package Stata version 15.0. Analysis code can be made available on request (https://datacompass.lshtm.ac.uk/).

Results

Population characteristics

Of the 3280 participants, 1064 (32·4 %) were residing in Lima, 599 (18·3 %) in urban Puno, 586 (17·9 %) in rural Puno and 1031 (31·4 %) in Tumbes. Baseline data on hypertension were complete for 3266 (99·6 %) participants, T2DM for 3134 (95·6 %) and BMI for 3112 (94·9 %) participants (Fig. 1). Detailed characteristics of the study population at baseline are shown in Table 1.

Dietary patterns

The four-class latent class analysis model was the preferred model to take forward in the analysis (see online supplementary material, Supplemental Fig. S1) based on optimal Bayesian information criterion, Akaike information criterion and entropy values, and pattern interpretability. Dietary patterns were determined from the percentage distributions of the frequency of intake categories (none, low, moderate, high) of each food group within each class (Supplemental Fig. S2). Table 2 shows the summarised dietary intake patterns which can be labelled as follows based on the stage of the nutrition transition reflected by the diet: ‘stage 1’, traditional diet consisting of high-starch and low-fat foods with low diversity of food groups consumed; ‘stage 2’, elements of the traditional diet remain with increasing range of high-fibre foods as well as high-fat foods consumed; ‘stage 3’, higher in processed foods and animal products that contain high fat and sugar, with less of the traditional high-fibre foods; and ‘stage 4’, with high diversity of food group consumption including high-fibre, high-fat and high-sugar foods, indicative of a fully transitioned diet.

In Fig. 2, we show the distribution of the dietary patterns among the study areas. In Lima 62·6 % of the study population were likely to fall within the stage 4 dietary pattern. In urban Puno, the stage 2 pattern had the highest prevalence at 52·1 %. In rural Puno the majority of the study population were in either the stage 2 (48·1 %) or stage 1 (43·5 %) pattern. In Tumbes, the stage 3 pattern was the one into which the majority of the population (81·4 %) were likely to fall.

Site-specific dietary pattern analysis was also performed. However, characteristics of the site-specific dietary

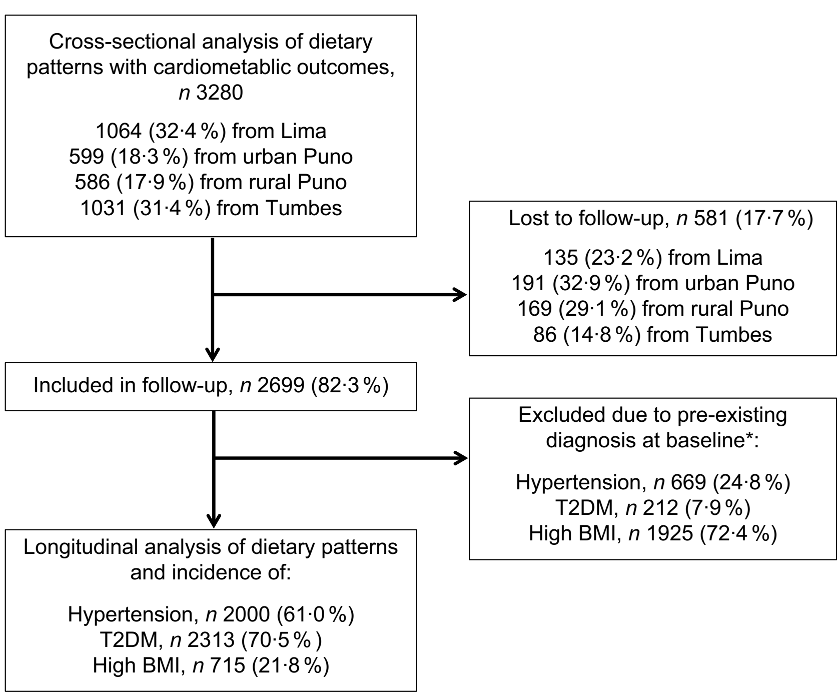

Fig. 1 Inclusion of participants at baseline and follow-up of the CRONICAS Cohort Study 2010–2013. *Incidence calculations were performed separately for each outcome; therefore numbers represent those excluded from calculations for the specified outcome only (T2DM, type 2 diabetes mellitus)

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

Table 1 Baseline participant characteristics of Peruvian adults in the CRONICAS Cohort Study 2010–2013 (*n* 3280) and their distribution according to study site

Sociodemographic characteristic		Overall *n*	Overall %	Lima *n*	Lima %	Urban Puno *n*	Urban Puno %	Rural Puno *n*	Rural Puno %	Tumbes *n*	Tumbes %
Sex	Female	1694	51·7	550	51·7	312	52·1	313	53·4	519	50·3
	Male	1583	48·3	514	48·3	286	47·8	271	46·3	512	49·7
Age group (years)	35–44	785	23·9	250	23·5	143	23·9	131	22·4	261	25·3
	45–54	835	25·5	288	27·1	146	24·4	150	25·6	251	24·4
	55–64	832	25·4	269	25·3	154	25·7	148	25·3	261	25·3
	65–74	550	16·8	196	18·4	112	18·7	94	16·0	148	14·4
	75–92	278	8·5	61	5·7	44	7·4	63	10·8	110	10·7
Education level	None	242	7·4	86	8·1	27	4·5	68	11·6	61	5·9
	Primary	1258	38·4	369	34·7	69	11·5	308	52·6	512	49·7
	Secondary	1071	32·7	424	39·9	165	27·6	175	29·9	307	29·8
	Further	707	21·6	191	17·3	338	56·4	35	6·0	150	14·6
Currently employed	Yes	2114	64·5	693	65·1	373	62·3	449	76·6	599	58·1
	No	1164	35·5	370	34·8	226	37·7	137	23·4	431	41·8
Socio-economic status	Lowest	1052	32·1	130	12·2	144	24·0	422	72·0	356	34·5
	Middle	1108	33·8	390	36·7	167	27·9	149	25·4	402	39·0
	Highest	1120	34·2	544	51·1	288	48·1	15	2·6	273	26·5
Smoking	Never	1857	56·6	414	38·9	382	63·8	444	75·8	617	56·6
	Former	1052	32·1	498	46·8	157	26·2	104	17·8	293	28·4
	Current	370	11·3	152	14·3	60	10·0	37	6·3	121	11·7
Heavy alcohol consumption	No	3106	94·7	1006	94·6	560	93·5	569	97·1	971	94·2
	Yes	174	5·3	58	5·5	39	6·5	17	2·9	60	5·8
Physical activity	Low	1036	31·6	201	18·9	126	21·0	150	25·6	559	54·2
	Moderate	1812	55·2	645	60·6	390	65·1	362	61·8	415	40·3
	High	428	13·1	217	20·4	81	13·5	73	12·5	57	5·5
Watching television	<2 h/d	1875	57·2	543	51·0	325	54·3	501	85·5	506	49·1
	≥2 h/d	1403	42·8	520	48·9	274	45·7	84	14·3	525	50·9
Hypertension	No	2433	74·2	772	72·6	443	74·0	502	85·7	716	69·5
	Yes	833	25·4	287	27·0	148	24·7	83	14·2	315	30·6
T2DM*	No	2862	87·3	951	89·4	475	79·3	520	88·7	916	88·9
	Yes	272	8·3	86	8·1	50	8·4	21	3·6	115	11·2
High BMI*,†	No	904	27·6	225	21·2	132	22·0	304	51·9	243	23·6
	Yes	2208	67·3	783	73·6	411	68·6	253	43·2	761	73·8

T2DM, type 2 diabetes mellitus.
*Values do not add up due to missing data.
†High BMI defined as ≥25 kg/m^2 to incorporate both overweight and obesity.

Table 2 Summarised food group dietary patterns, obtained using latent class analysis, among Peruvian adults in the CRONICAS Cohort Study 2010–2013 (*n* 3280). Percentages are the conditional probability of a class member falling into the stated category of intake frequency of the stated food group

Food group	Class 1: stage 1 diet	%	Class 2: stage 2 diet	%	Class 3: stage 4 diet	%	Class 4: stage 3 diet	%
Whole grains			Low whole grains	66·5				
Refined grains	Low refined grains	84·5	Low refined grains	79·4	Moderate refined grains	47·5	Moderate refined grains	66·2
Dairy	Low dairy	46·9	Low dairy	60·5	High dairy	41·8		
Red meat			Low red meat	42·1	Moderate red meat	36·2	Moderate red meat	52·2
					High red meat	35·4		
Poultry	Low poultry	48·8	Low poultry	72·8	High poultry	44·7	Moderate poultry	53·0
	No poultry	41·3						
Vegetables (veg)	No green veg	61·8	Low green veg	53·0	High green veg	50·3	Low cooked veg	81·0
	No raw veg	68·1	Low raw veg	48·3	Moderate raw veg	40·5		
	High cooked veg	46·9	Moderate cooked veg	55·6	Moderate cooked veg	50·6		
Fruit	Low fruit	55·2	Low fruit	43·4	High fruit	60·2	Moderate fruit	40·4
Seafood							High seafood	44·8
Potatoes	High potato	73·8	High potato	65·8			Moderate potato	49·1
Legumes	No legumes	46·9	Low legumes	61·7	Moderate legumes	47·9	Moderate legumes	55·3
Egg	Low egg	45·6	Low egg	63·6			Low egg	60·8
UPF	Low UPF	81·7	Low UPF	58·7	High UPF	46·7	Moderate UPF	45·4
							High UPF	44·4

UPF, ultra-processed foods.

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

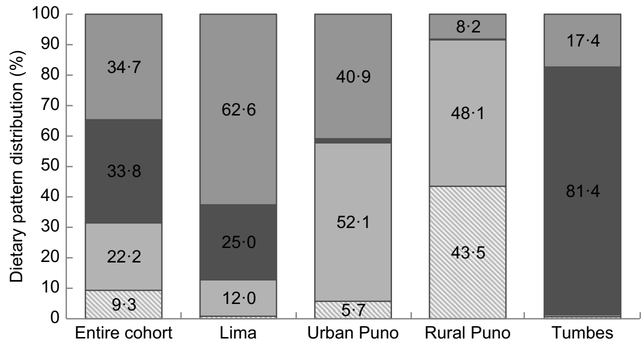

Fig. 2 Overall dietary pattern (▨, stage 1; ▒, stage 2; ■, stage 3; ▩, stage 4) prevalence among Peruvian adults in the CRONICAS Cohort Study 2010–2013 (*n* 3280) and distribution according to study site

patterns did appear to reflect the patterns obtained by dietary pattern analysis of the cohort in its entirety (see online supplementary material, Supplemental Table S2). Therefore, the overall dietary patterns were used in further analyses rather than the site-specific patterns.

Association of dietary patterns with cardiometabolic outcomes

A total of 833 (25·5 %) study participants had hypertension at baseline, 272 (8·7 %) had T2DM and 2208 (71·0 %) had BMI ≥25 kg/m^2. Prevalence of each outcome varied by dietary pattern (Table 3): prevalence of hypertension and T2DM was highest among participants with the stage 3 dietary pattern. High BMI was more prevalent in those with the stage 4 (76·6 %), stage 3 (75·1 %) and stage 2 (67·7 %) dietary patterns than in those with the stage 1 pattern (41·3 %). Participants with the stage 1 dietary pattern had the lowest prevalence of all three outcomes. Although numbers were small, some site-specific patterns were observed within Lima, where prevalence of hypertension was highest among those with the stage 3 dietary pattern (33·6 %; see online supplementary material, Supplemental Table S3).

Table 3 Baseline prevalence of cardiometabolic outcomes by dietary pattern among Peruvian adults in the CRONICAS Cohort Study 2010–2013 (*n* 3280)

	Hypertension (*n* 3266)		T2DM (*n* 3134)		High BMI* (*n* 3112)	
	%	*P* value†	%	*P* value†	%	*P* value†
Stage 1	18·2	<0·001	3·9	0·001	41·3	<0·001
Stage 2	20·1		6·9		67·7	
Stage 3	32·1		10·7		75·1	
Stage 4	24·5		8·9		76·6	

T2DM, type 2 diabetes mellitus.
*High BMI defined as ≥25 kg/m^2 to incorporate both overweight and obesity.
†Significance test derived from Pearson's χ^2 test.

Prevalence rates

Crude and adjusted models of the association of dietary patterns with prevalence of cardiometabolic outcomes are shown in Table 4. The covariates 'site' and 'level of urbanisation' were introduced separately into the models, however made little difference to model fit; hence the simpler model without these covariates was selected to report results. There was no evidence of effect modification between either of these two covariates and other potential confounders.

Overall, the stage 3 diet was associated with the highest burden of disease in the cardiometabolic outcomes and was therefore used as a reference diet to estimate prevalence ratios.

Hypertension

After adjusting for potential confounders, those with the stage 1 diet were shown to be 39 % less likely to have hypertension compared with those with the stage 3 diet (PR = 0·61; 95 % CI 0·46, 0·81); those with a stage 2 diet were shown to be 43 % less likely to be hypertensive as compared with the stage 3 group (PR = 0·57; 95 % CI 0·48, 0·68). Within Lima, a reduction in prevalence of approximately 30 % was reported for those with the stage 4 diet (PR = 0·70; 95 % CI 0·58, 0·86) and the stage 2 diet (PR = 0·69; 95 % CI 0·51, 0·93) as compared with the stage 3 reference diet. In rural Puno, the stage 1, 2 and 4 dietary patterns were associated with a much lower prevalence of hypertension (stage 1: PR = 0·08; 95 % CI 0·02, 0·27; stage 2: PR = 0·05; 95 % CI 0·01, 0·19; stage 4: PR = 0·16; 95 % CI 0·05, 0·52) compared with the stage 3 dietary pattern (see online supplementary material, Supplemental Table S4). However, study power was lower when running the models by site, creating more uncertainty in the estimates.

Type 2 diabetes mellitus

The prevalence of T2DM was almost three times higher in those with the stage 3 diet compared with those with the stage 1 diet (PR = 0·29; 95 % CI 0·09, 0·99). There was no statistically significant difference in prevalence of T2DM between the two other diets (stage 2 and 4); however, a (non-significant) trend could be observed in both overall and site-specific data sets in which the lowest prevalence of T2DM was found among those with a stage 1 diet followed by stage 2, stage 4 and stage 3.

High BMI

Those with the stage 1 diet had the lowest prevalence of high BMI, which was 37 % lower (PR = 0·63; 95 % CI 0·55, 0·72) in comparison to those with the stage 3 reference diet.

Incidence rates

A total of 2669 (81·4 %) participants completed follow-up of blood pressure; 2536 (76·9 %) for blood sugar; and

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

Table 4 Association between dietary pattern and hypertension, type 2 diabetes mellitus (T2DM) and high BMI† at baseline and follow-up among Peruvian adults in the CRONICAS Cohort Study 2010–2013. Average follow-up period 30 months

	Incidence per 1000 person-years	95% CI	Crude				Fully adjusted†			
			PR	95 % CI	IRR	95 % CI	PR	95 % CI	IRR	95 % CI
Hypertension	46·07	40·15, 52·86								
Stage 3	63·75	52·40, 77·55	1	Reference	1	Reference	1	Reference	1	Reference
Stage 1	28·88	15·03, 55·51	**0·57**	**0·43, 0·75**	**0·36**	**0·19, 0·71**	**0·61**	**0·46, 0·81**	**0·34**	**0·18, 0·64**
Stage 2	31·77	21·63, 46·65	**0·63**	**0·53, 0·75**	**0·44**	**0·29, 0·67**	**0·57**	**0·48, 0·68**	**0·44**	**0·29, 0·66**
Stage 4	39·39	31·39, 50·50	**0·77**	**0·67, 0·87**	**0·63**	**0·47, 0·84**	**0·76**	**0·67, 0·86**	**0·69**	**0·51, 0·94**
T2DM	21·34	17·72, 25·70								
Stage 3	18·91	13·76, 25·99	1	Reference	1	Reference	1	Reference	1	Reference
Stage 1	13·36	5·02, 35·61	**0·36**	**0·16, 0·86**	0·55	0·20, 1·51	**0·29**	**0·09, 0·99**	0·64	0·22, 1·87
Stage 2	21·42	13·67, 33·59	**0·64**	**0·45, 0·91**	1·00	0·59, 1·72	0·73	0·53, 1·01	1·00	0·55, 1·80
Stage 4	24·92	18·89, 32·89	0·84	0·66, 1·07	1·31	0·87, 1·98	0·86	0·67, 1·09	1·32	0·84, 2·05
High BMI	95·21	80·63, 112·43								
Stage 3	89·57	67·24, 119·21	1	Reference	1	Reference	1	Reference‡	1	Reference‡
Stage 1	80·12	49·81, 128·89	**0·55**	**0·48, 0·63**	0·71	0·43, 1·19	**0·63**	**0·55, 0·72**	0·78	0·45, 1·37
Stage 2	133·77	96·49, 185·44	**0·90**	**0·85, 0·96**	1·25	0·85, 1·83	**0·93**	**0·88, 0·99**	1·32	0·87, 1·99
Stage 4	85·93	62·78, 17·61	1·02	0·97, 1·07	0·92	0·63, 1·35	0·97	0·92, 1·02	0·95	0·64, 1·42

T2DM, type 2 diabetes mellitus; PR, prevalence ratio; IRR, incidence risk ratio.
Results with $P < 0·05$ shown in bold.
*High BMI defined as ≥25 kg/m^2 to incorporate both overweight and obesity.
†Adjusted for age, sex, education level, currently working, socio-economic status, smoking, heavy drinking, physical activity, watching television and high BMI.
‡Adjusted for age, sex, education level, currently working, socio-economic status, smoking, heavy drinking, physical activity and watching television.

2619 (79·8 %) completed follow-up of BMI. Of those who returned for follow-up, 669 were excluded from hypertension incidence calculations, 212 from T2DM incidence calculations and 1925 from incidence of high BMI calculations due to pre-existing diagnosis at baseline. Overall, 203 new cases of hypertension were identified, 111 new cases of T2DM and 139 new cases of overweight and obesity.

Incidence of hypertension was highest among individuals consuming the stage 3 dietary pattern (63·75 per 1000 person-years; 95 % CI 52·40, 77·55). In comparison to this diet, a reduction in hypertension incidence of 66, 56 and 31 % was found for those with the stage 1, 2 and 4 diets, respectively, after adjustment for confounders (stage 1: IRR = 0·34; 95 % CI 0·18, 0·64; stage 2: IRR = 0·44; 95 % CI 0·29, 0·66; stage 4: IRR = 0·69; 95 % CI 0·51, 0·94). Incidence of T2DM was highest among those consuming the stage 3 dietary pattern (24·92 per 1000 person-years; 95 % CI 18·89, 32·89), and incidence of high BMI was highest among those with the stage 2 pattern (133·77 per 1000 person-years; 95 % CI 96·49, 185·44). There was no evidence for a difference in the risk of T2DM or high BMI among the dietary patterns.

Discussion

The present study demonstrates an association between food group consumption patterns and hypertension, T2DM and high BMI in a cohort of Peruvian adults, and that the distribution of these patterns differs between the diverse geographic areas of Peru. An interesting trend in prevalence of cardiometabolic outcomes among the different diets was seen, with prevalence lowest in the more traditional stage 1 and 2 diets, and higher in the stage 3 and 4 dietary patterns, which contain more processed foods and animal products. Thus, our results support the use of dietary pattern analysis in furthering understanding of the impact of dietary risk factors in NCD development.

Although no dietary diversity scoring was undertaken within the study, and therefore no formal conclusions on the impact of dietary diversity can be drawn, the dietary patterns most prevalent in highly urbanised Lima and semi-urban Tumbes incorporated higher consumption of a greater number of food groups in comparison to highland Puno, inclusive of ultra-processed foods (UPF), animal products, refined grains, seafood and fruit. This is in keeping with the benefits of greater availability and affordability of such products that result from urbanisation. Dietary diversity is encouraged in public health messages to ensure requirements of essential nutrients are met[30]; however, health outcomes may differ depending on the nature of the foods comprising the different interpretations of diversity[31]. For example, patterns of consumption typical of a Western diet high in a range of animal products, refined

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

carbohydrates and processed foods are linked to higher rates of NCD and NCD-related mortality, whereas diets high in diverse fruits, vegetables and whole grains and low in processed foods are associated with better outcomes[32–35]. Consistent with this, results presented here show that the diets with comparatively higher intake frequency of UPF, refined grains and animal products were associated with greater prevalence of hypertension, T2DM and high BMI, and incidence of hypertension.

Rates of sale of UPF products in Peru were among the fastest growing in Latin America from 2000 to 2013, and fast-food purchases (typically high in refined carbohydrates and processed meat) doubled during this time making Peru one of the biggest consumers of fast foods in the region[36]. Consumption of UPF is associated with an increase in BMI[37], higher prevalence of obesity[38] and incidence of hypertension[39]. Sugar-sweetened beverages, a form of UPF, are the preferred choice of drink by an alarming amount throughout the country[40] and their consumption is also associated with obesity and T2DM[41,42]. In Peru, sugar-sweetened beverage consumption is much higher in urban and coastal areas than in rural or highland parts of the country[43], giving further support to the finding of the present study that the dietary patterns more prevalent in the urban and semi-urban coastal settings had higher risk of cardiometabolic outcomes.

Interestingly, of the dietary patterns more in line with the typical Western diet, the stage 3 pattern most consumed in Tumbes was associated with a higher prevalence of the cardiometabolic outcomes than the stage 4 pattern more prevalent in Lima. This is in keeping with previous studies demonstrating that the semi-urban coastal area of Tumbes had a worse cardiometabolic risk profile than the urban capital Lima[10,11]; but is somewhat surprising given the extensive research linking degree of urbanisation to obesity and NCD risk, especially in low- and middle-income country settings[44,45]. As the predominant dietary pattern of Lima had a higher comparative frequency of fruit and vegetable intake, it may be that a more diverse diet inclusive of these foods confers some protection. This can be supported by many previous studies using dietary pattern analysis to examine the relationship between diet and NCD risk[24,32,35,46].

The predominant dietary pattern of Tumbes was the only pattern with high frequency of fish and seafood consumption, consistent with Tumbes being a coastal area known for its seafood dishes. Fish, in particular oily fish, are an important source of n-3 fatty acids which are known to have cardiovascular and anti-inflammatory benefits, and accordingly fish consumption has been associated with lower cardiovascular risk profiles when included as part of the 'healthier' diet in dietary pattern studies[32,35]. However, this effect may depend on the type of fish and how it is cooked, as well as other components of the diet, such as fruits, vegetables and whole grains. In Tumbes the population may eat healthy fish; however, the diet does not appear to be complemented by a high intake of vegetables and whole grains, and the potential benefits may be limited by consumption of UPF, as increased consumption of UPF has previously been associated with a greater risk of hypertension[39]. As the dietary patterns in the current study are model-driven based on consumption frequency of multiple food groups, it is difficult to distinguish the negative effect of the high salt and saturated fat content of the UPF from the potentially positive effect of fish, or absent effect of other components.

The dietary pattern with the most favourable cardiometabolic risk profile, the stage 1 diet, was most widely consumed in rural Puno. Incidence of hypertension and T2DM are lowest at this highland site in comparison to Lima and Tumbes[10,12], which would be consistent with a diet lower in UPF and higher in vegetables. Low energy intake suggested by the low dietary diversity may also help to explain the lower incidence of T2DM and hypertension, for which overweight and obesity are risk factors[47]. A previous study in Puno reported a mean energy intake of 5439 kJ/d (1300 kcal/d)[18], in keeping with the lower prevalence of overweight and obesity associated with the dietary patterns commonly consumed in this high-altitude area. While a low cardiometabolic risk profile is encouraging, the low mean energy intake is likely to indicate a high level of undernutrition and micronutrient deficiency in the area, especially if there is a low diversity of food groups consumed as our findings suggest. In the 2012 Peruvian nutrition transition mapping, Puno was one of the many areas undergoing rapid nutrition transition and experiencing the double burden of nutrition-related disease[4]. Programmes and policies in Peru therefore face the challenge of addressing micronutrient deficiency by increasing availability and affordability of a diverse range of foods associated with reduced health risk, such as fruits, vegetables and whole grains[32,35,46], while being careful not to contribute to the increasing burden of obesity and NCD by promotion of high-sugar and high-fat foods.

The exact length of time for dietary changes to be reflected in clinical outcomes is unknown, therefore longitudinal analysis was performed to explore the role of diet as a risk factor for cardiometabolic outcomes over time. However, results at follow-up were less robust than for cross-sectional analysis due to a relatively short follow-up period and smaller sample size. Nevertheless, the stage 3 diet mostly consumed in semi-urban Tumbes was associated with the highest incidence of hypertension, consistent with Tumbes having the highest incidence of hypertension among the study sites in a previous study[10]. This suggests an interplay between diet, location and chronic disease, further exploration of which was limited in the current study by paucity of data when individually analysing the association of dietary patterns with the outcomes in each site but could be the focus of future studies.

The present study is the first to use latent class analysis for the investigation of dietary patterns in Peru and substantially adds to previous studies by examining the prospective

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

relationship of diet with disease burden in regions of the country. In support of studies done elsewhere, the study has found an association between dietary pattern and prevalence of hypertension, T2DM[48] and obesity[24,46,49,50]. Use of this method in the investigation of diet as a risk factor for disease has allowed for examination of the effect of diet as a whole, rather than focusing on specific nutrients and food groups taken out of the context of how food is consumed.

However, there are a number of limitations to consider when interpreting the present findings. First, the results may have been subject to selection bias due to loss to follow-up and missing data. Although sample size was large, final numbers in the analysis of the follow-up data were small due to loss to follow-up, missing data and exclusion of those who already had the outcomes of interest (see Fig. 1). Second, assessment of diet relied on self-reporting in response to a short FFQ, which can lead to non-differential measurement bias that may weaken the strength of the associations; therefore the estimates presented here may be conservative. Third, energy intake was not adjusted for, nor was portion size taken into account, which can make the results of dietary pattern analysis easier to interpret[27]. Latent class analysis was therefore based on frequency of daily consumption rather than quantity in this case. While not able to give an accurate quantitative description of the diet, this did give a qualitative indication of the composition of the diet. Fourth, ethnicity was not included in the final adjusted model due to collinearity with other risk factors. This may have resulted in a portion of the genetic component of disease risk being unaccounted for, leading to an overestimation of the association between diet and the cardiometabolic outcomes. However, the role of genetics in the present study may be relatively small, as participants were mainly of native or mixed native background and therefore likely to have shared ancestry[51]. Lastly, this cohort had a short follow-up period, though because the exact length of time for development of chronic diseases to occur in response to diet is unknown, our results still provide interesting and relevant findings.

Conclusion

In conclusion, the present study revealed clear dietary patterns indicative of consumption habits and diet composition in four different settings in Peru. The distribution of dietary patterns was found to closely reflect the distribution of disease risk profile among the settings, demonstrating that diet may explain some of the variation in disease prevalence among the different areas in addition to urbanisation and socio-economic status, acknowledging that these are all closely linked. Characterising local diets can contribute towards development of locally relevant guidelines for health promotion and disease prevention, for example by discouraging the consumption of commonly eaten foods associated with adverse health outcomes (such as through tax strategies), and informing policies to improve access to a diverse range of food groups associated with lower disease risk.

Acknowledgements

Acknowledgements: The authors would like to thank Dr Rosemary Green of the London School of Hygiene & Tropical Medicine for her advice and guidance on the use of Mplus for latent class analysis. Thanks are also extended to the CRONICAS staff members and field teams for their collection and provision of the data. *Financial support:* This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. *Conflict of interest:* None. *Authorship:* The research question was formulated by C.A.-C. in consultation with P.S. and J.J.M. The data analysis was carried out primarily by C.A.-C. with guidance on the statistical analysis strategy from P.S. and advice on the data set and aspects of the CRONICAS Cohort Study from R.M.C.-L. The article was written by C.A.-C. incorporating contributions from P.S., J.J.M. and R.M.C.-L. Contributions to writing were also provided by A.B.-O. and W.C., in addition to guidance on statistical methods and analysis. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Ethics Committees at Universidad Peruana Cayetano Heredia and A.B. PRISMA in Lima, Peru, and the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health, in Baltimore, MD, USA. Verbal informed consent was obtained from all participants.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980019002313

References

1. World Health Organization (2011) *A Prioritized Research Agenda for Prevention and Control of Noncommunicable Diseases*. Geneva: WHO.
2. Bermudez OI & Tucker KL (2003) Trends in dietary patterns of Latin American populations. *Cad Saude Publica* **19**, Suppl. 1, S87–S99.
3. Popkin BM (1998) The nutrition transition and its health implications in lower income countries. *Public Health Nutr* **1**, 5–21.
4. Chaparro MP & Estrada L (2012) Mapping the nutrition transition in Peru: evidence for decentralized nutrition policies. *Rev Panam Salud Publica* **32**, 241–244.
5. Berti PR, Fallu C & Cruz Agudo Y (2014) A systematic review of the nutritional adequacy of the diet in the Central Andes. *Rev Panam Salud Publica* **36**, 314–323.
6. Oyarzun PJ, Borja RM, Sherwood S *et al.* (2013) Making sense of agrobiodiversity, diet, and intensification of smallholder

https://doi.org/10.1017/S1368980019002313 Published online by Cambridge University Press

family farming in the highland Andes of Ecuador. *Ecol Food Nutr* **52**, 515–541.
7. World Health Organization (2014) Noncommunicable diseases (NCD) country profiles. https://www.who.int/nmh/countries/2014/per_en.pdf?ua=1 (accessed July 2017).
8. Food and Agriculture Organization of the United Nations (2017) FAOSTAT: Peru: country indicators. http://www.fao.org/faostat/en/#country/170 (accessed September 2017).
9. World Health Organization (2008) *2008–2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases*. Geneva: WHO.
10. Bernabé-Ortiz A, RM Carrillo-Larco, Gilman RH *et al.* (2017) Impact of urbanisation and altitude on the incidence of, and risk factors for, hypertension. *Heart* **103**, 827–833.
11. Bernabe-Ortiz A, RM Carrillo-Larco, Gilman RH *et al.* (2016) Contribution of modifiable risk factors for hypertension and type-2 diabetes in Peruvian resource-limited settings. *J Epidemiol Community Health* **70**, 49–55.
12. Bernabe-Ortiz A, RM Carrillo-Larco, Gilman RH *et al.* (2016) Geographical variation in the progression of type 2 diabetes in Peru: the CRONICAS cohort study. *Diabetes Res Clin Pract* **121**, 135–145.
13. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**, 3–9.
14. Fung TT, Willett WC, Stampfer MJ *et al.* (2001) Dietary patterns and the risk of coronary heart disease in women. *Arch Intern Med* **161**, 1857–1862.
15. Miranda JJ, Bernabe-Ortiz A, Smeeth L *et al.* (2012) Addressing geographical variation in the progression of non-communicable diseases in Peru: the CRONICAS cohort study protocol. *BMJ Open* **2**, e000610.
16. World Health Organization (2005; updated 2017) WHO STEPwise approach to surveillance (STEPS) manual. http://www.who.int/chp/steps/manual/en/ (accessed August 2017).
17. O'Donnell M, Xavier D, Diener C *et al.* (2010) Rationale and design of INTERSTROKE: a global case–control study of risk factors for stroke. *Neuroepidemiology* **35**, 36–44.
18. McCloskey ML, Tarazona-Meza CE, Jones-Smith JC *et al.* (2017) Disparities in dietary intake and physical activity patterns across the urbanization divide in the Peruvian Andes. *Int J Behav Nutr Phys Act* **14**, 90.
19. Coleman A, Steel S, Freeman P *et al.* (2008) Validation of the Omron M7 (HEM-780-E) oscillometric blood pressure monitoring device according to the British Hypertension Society protocol. *Blood Press Monit* **13**, 49–54.
20. James PA, Oparil S, Carter BL *et al.* (2014) 2014 evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8). *JAMA* **311**, 507–520.
21. World Health Organization (2006) *Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia. Report of a WHO/IDF Consultation*. Geneva: WHO.
22. World Health Organization (2016) *Obesity and Overweight Factsheet*. Geneva: WHO.
23. Leech RM, Worsley A, Timperio A *et al.* (2017) Temporal eating patterns: a latent class analysis approach. *Int J Behav Nutr Phys Act* **14**, 3.
24. Joy EJ, Green R, Agrawal S *et al.* (2017) Dietary patterns and non-communicable disease risk in Indian adults: secondary analysis of Indian Migration Study data. *Public Health Nutr* **20**, 1963–1972.
25. Noor SWB, Ross MW, Lai D *et al.* (2014) Use of latent class analysis approach to describe drug and sexual HIV risk patterns among injection drug users in Houston, Texas. *AIDS Behav* **18**, 276–283.
26. Padmadas SS, Dias JG & Willekens FJ (2007) Disentangling women's responses on complex dietary intake patterns from an Indian cross-sectional survey: a latent class analysis. *Public Health Nutr* **9**, 204–211.
27. Fahey MT, Thane CW, Bramwell GD *et al.* (2007) Conditional Gaussian mixture modelling for dietary pattern analysis. *J R Stat Soc Ser A (Stat Soc)* **170**, 149–166.
28. Tein J, Coxe S & Cham H (2013) Statistical power to detect the correct number of classes in latent profile analysis. *Struct Equ Modeling* **20**, 640–657.
29. Berlin KS, Williams NA & Parra GR (2014) An introduction to latent variable mixture modeling (part 1): overview and cross-sectional latent class and latent profile analyses. *J Pediatr Psychol* **39**, 174–187.
30. Steyn N, Nel J, Nantel G *et al.* (2006) Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutr* **9**, 644–650.
31. de Oliveira Otto MC, Padhye NS, Bertoni AG *et al.* (2015) Everything in moderation-dietary diversity and quality, central obesity and risk of diabetes. *PLoS One* **10**, e0141341.
32. Heidemann C, Schulze MB, Franco OH *et al.* (2008) Dietary patterns and risk of mortality from cardiovascular disease, cancer, and all causes in a prospective cohort of women. *Circulation* **118**, 230–237.
33. Mente A, de Koning L, Shannon HS *et al.* (2009) A systematic review of the evidence supporting a causal link between dietary factors and coronary heart disease. *Arch Intern Med* **169**, 659–669.
34. Mozaffarian D, Hao T, Rimm EB *et al.* (2011) Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med* **364**, 2392–2404.
35. van Dam RM, Rimm EB, Willett WC *et al.* (2002) Dietary patterns and risk for type 2 diabetes mellitus in US men. *Ann Intern Med* **136**, 201–209.
36. Pan-American Health Organization (2015) *Ultra-Processed Food and Drink Products in Latin America: Trends, Impact on Obesity, Policy Implications*. Washington, DC: PAHO.
37. Asfaw A (2011) Does consumption of processed foods explain disparities in the body weight of individuals? The case of Guatemala. *Health Econ* **20**, 184–195.
38. Canella DS, Levy RB, Martins APB *et al.* (2014) Ultra-processed food products and obesity in Brazilian households (2008–2009). *PLoS One* **9**, e92752.
39. Mendonca RD, Lopes AC, Pimenta AM *et al.* (2017) Ultra-processed food consumption and the incidence of hypertension in a Mediterranean cohort: the Seguimiento Universidad de Navarra project. *Am J Hypertens* **30**, 358–366.
40. Instituto Nacional de Estadística e Informática (2012) *Consumo de Alimentos y Bebidas 2008–2009*. Lima: INEI.
41. Hu FB & Malik VS (2010) Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav* **100**, 47–54.
42. Schulze MB, Manson JE, Ludwig DS *et al.* (2004) Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA* **292**, 927–934.
43. Lazaro M (2013) Guias alimentarias para la poblacion Peruana. http://www.ins.gob.pe/repositorioaps/0/0/not/temdif32599/PPT%20Gu%C3%ADas%20alimentarias.pdf (accessed September 2017).
44. Popkin BM, Adair LS & Ng SW (2012) Now and then: the global nutrition transition: the pandemic of obesity in developing countries. *Nutr Rev* **70**, 3–21.
45. Albala C, Vio F, Kain J *et al.* (2001) The nutrition transition in Latin America: the case of Chile. *Nutr Rev* **59**, 170–176.
46. Ganguli D, Das N, Saha I *et al.* (2011) Major dietary patterns and their associations with cardiovascular risk factors among women in West Bengal, India. *Br J Nutr* **105**, 1520–1529.
47. Guh DP, Zhang W, Bansback N *et al.* (2009) The incidence of co-morbidities related to obesity and overweight:

a systematic review and meta-analysis. *BMC Public Health* **9**, 88.
48. Daniel CR, Prabhakaran D, Kapur K *et al.* (2011) A cross-sectional investigation of regional patterns of diet and cardio-metabolic risk in India. *Nutr J* **10**, 12.
49. Satija A, Hu FB, Bowen L *et al.* (2015) Dietary patterns in India and their association with obesity and central obesity. *Public Health Nutr* **18**, 3031–3041.
50. Pou SA, del Pilar Díaz M, De La Quintana AG *et al.* (2016) Identification of dietary patterns in urban population of Argentina: study on diet–obesity relation in population-based prevalence study. *Nutr Res Pract* **10**, 616–622.
51. Mao X, Bigham AW, Mei R *et al.* (2007) A genomewide admixture mapping panel for Hispanic/Latino populations. *Am J Hum Genet* **80**, 1171–1178.

Public Health Nutrition