Public Health Nutrition: 12(11), 2092–2096 doi:10.1017/S1368980009005278

Short communication
Cost of compliance with daily recommended values of micronutrients among a cohort of Spanish university graduates: the SUN (Seguimiento Universidad de Navarra) Study

Celeste N Lopez[1,2], Miguel A Martinez-Gonzalez[2], Alvaro Alonso[2,3], Almudena Sanchez-Villegas[2,4], Carmen de la Fuente[2] and Maira Bes-Rastrollo[2,*]
[1]Harvard Medical School, 25 Shattuck Street, Boston, MA 02115, USA: [2]Facultad de Medicina, Clinica Universitaria, Universidad de Navarra, Irunlarrea 1, 31080 Pamplona, Spain: [3]Department of Epidemiology and Community Health, University of Minnesota, 1300 2nd Street South, Minneapolis, MN 55455, USA: [4]Department of Clinical Sciences, Universidad de Las Palmas de Gran Canaria, C/Juan De Quesada 30, 35001 Las Palmas De Gran Canaria, Spain

Submitted 1 October 2008: Accepted 30 January 2009: First published online 27 March 2009

Abstract

Objective: Previous studies have shown that highly nutritious diets are more costly, but to date there has been no evaluation of the costs associated with failing to meet micronutrient recommendations in a Spanish population.
Design, setting and subjects: We examined whether daily food consumption costs (classified in quintiles) were associated with failing to meet at least three daily nutritional recommendations out of twenty (including fibre and nineteen micronutrients) in a cross-sectional analysis of baseline data of a cohort of 17 197 Spanish university graduates. Micronutrients and fibre intake were assessed with a validated 136-item FFQ. Average cost of food was calculated from official Spanish government data.
Results and conclusions: As participants presented higher dietary energy cost from their diet, their intake of micronutrients increased significantly. Low dietary energy cost was associated with a higher likelihood of failing to meet three or more recommendations (P for trend $<0{\cdot}001$ across quintiles of dietary cost), the association being stronger among female than male participants (P for interaction between sex and quintile of dietary energy cost $<0{\cdot}001$).

Keywords
Daily recommended values
Diet costs
Micronutrients
Vitamins
Minerals

A balanced diet that includes enough essential micronutrients (vitamins and minerals) and fibre is critical for health promotion. To ascertain if a population is meeting such nutritional needs, culture-specific recommendations and objectives are used. The Spanish Society of Community Nutrition (SENC) and the Nutrition Unit of the WHO Regional Office for Europe have developed objectives based on specific Spanish cultural habits(1). When compliance with these objectives was assessed in a Spanish region (Catalonia), adherence was incomplete in many areas(2). The cost of food is an influencing factor on diet choice. Previous studies in a province of Catalonia have shown that healthier low-energy-density diets are both more costly(3) and associated with a healthier lifestyle(4). In a French population, higher cost was associated with both low energy density and a better provision of nutrients, based on the French Recommended Dietary Allowances(5,6).

The association between daily dietary energy cost and nutritional recommendations could be of interest when initiating nutritional programmes, as some recommendations may be prohibitively expensive for some portions of the population. This fact should be taken into account when implementing nutrition policies. Therefore, our objective was to assess the relationship between daily dietary energy cost and the risk of failing to meet three or more recommendations out of twenty (including micronutrients and fibre).

Experimental methods

The subjects, methods for recruitment and collection of data from the participants of the prospective cohort study Seguimiento Universidad de Navarra (Follow-up Study of the University of Navarra; SUN) have been described in detail in a previous publication(7). Briefly, the recruitment of this dynamic cohort began in December 1999 and, as of the time of the present analysis performed in February

*Corresponding author: Email mbes@unav.es

2008, it included 19 057 subjects with a mean age of 38·6 (SD 12·2) years, 60 % of whom were women. We excluded those with extreme values of energy intake (<3350 or >16 748 kJ/d (<800 or >4000 kcal/d) for men, <2094 or >14 655 kJ/d (<500 or >3500 kcal/d) for women)[8] (n 1700) to deal with under- and over-reporters and with biologically implausible values for height and weight (n 160), and 17 197 participants remained. These participants were analysed for the association between dietary energy cost and dietary quality, as defined by compliance with daily recommended values of essential micronutrients, taking the recommended daily intakes for folate, Ca, Na from table salt, iodine and dietary fibre according to the most current data proposed by SENC[1]. For the remaining micronutrients, we obtained the recommended values published by SENC in its last available reference book[9] except for vitamin E, due to specifications for sex[10]. We conducted sensitivity analyses taking the Estimated Average Requirement when available or the Adequate Intake, as proposed by the US National Academy of Sciences, as the recommended daily intake for individuals[11].

Participants completed a semi-quantitative FFQ that has been validated previously in Spain[12]. Calculations of nutrient intake were done using two of the most up-to-date food composition tables for Spain[13,14]. Micronutrients and fibre were adjusted for total energy intake through the residual method to provide a measure of micronutrient intake uncorrelated with total energy intake, thus isolating the variation in nutrient intake due only to the nutrient composition of the diet and not from the overall food consumption. This subsequently decreases the measurement error inherent in nutritional epidemiology assessment methods[15]. Micronutrients examined were: Na, Zn, iodine, Se, folic acid, P, Mg, K, Fe, Ca, vitamins B_{12}, B_6, B_3, B_2, B_1, A, C, D and E. Fibre was also examined.

The cost of daily food consumption was derived from the Ministry of Industry, Tourism and Commerce of Spain[16]. The total daily cost of food (€/d) for each subject was calculated by multiplying the mean price of each food item per gram by the quantity in grams the subject indicated that he/she consumed in an average day and summing across all food items. To define dietary energy cost (€/4187 kJ; €/1000 kcal) we divided the total food consumption cost (€/d) by the total dietary energy intake (kJ/d) and multiplied by 4187. The participants were then divided into quintiles of dietary energy cost.

Continuous variables are expressed as means and standard deviations, and categorical variables as percentages. To assess differences between dietary energy cost quintiles we used ANOVA for continuous variables and the two-tailed Fisher exact test for categorical variables.

Since the prevalence rate ratio is more interpretable and easier to understand than the prevalence odds ratio and the odds ratio can strongly overestimate the prevalence rate ratio with frequent outcomes[17], we ran Poisson regression models with robust standard errors to estimate the age-adjusted prevalence rate ratios (PRR) and their 95 % confidence intervals for failing to meet three or more recommendations. In multivariate analyses we adjusted for smoking, marital status and employment. We considered those participants in the highest quintile of daily dietary energy cost as the reference category.

Analyses were performed with SPSS version 15·0 (SPSS Inc., Chicago, IL, USA) and STATA version 8·0 (STATA Corporation, College Station, TX, USA) statistical software packages.

Results

As participants presented higher dietary energy cost from their diet, their intake of micronutrients increased significantly (Table 1). Among all participants, the average number of recommendations which participants failed to meet was 5·2 (95 % CI 5·1, 5·2). Those micronutrients with the highest levels of failing to meet recommendations among all participants were vitamin E (79·7 %), vitamin D (72·9 %), folic acid (43·6 %), fibre (46·9 %) and Fe (52·6 %; results not shown). We found a statistically significant interaction ($P < 0·001$) between daily cost (quintiles) and sex. Thus, we stratified the analyses by sex. The multivariate-adjusted PRR for failing to meet three or more nutritional recommendations was highest among those participants in the lowest quintile of dietary energy cost. The PRR for the first *v.* the fifth quintile of daily dietary energy cost was 1·43 (95 % CI 1·38, 1·49), P for trend <0·001 among males and 1·62 (95 % CI 1·56, 1·68), P for trend <0·001 among females (Table 2). When we conducted additional analyses, choosing not meeting at least two or four recommendations as the cut-off point, the results were consistent (P for trend <0·001 for both cut-off points) but the magnitude of the estimates was higher as the cut-off increased from two to four recommendations (data not shown). In addition, when we performed continuous analyses considering as outcome the percentage of the recommendations met by the participant (nineteen micronutrients and fibre intake = 100 %) using multivariate linear regression, those male participants with the highest dietary energy cost presented an adjusted mean of 21 % (95 % CI 20, 21 %) higher percentage of meeting recommendations in comparison with those participants in the first quintile. For women the difference was 17 % (95 % CI 16, 17 %; data not shown).

Using the North American daily micronutrient recommended intakes the results were similar especially for men. Among women the magnitude of the association was even higher (data not shown).

We ran sensitivity analyses without adjusting micronutrients for total energy intake through the residual method. The results were exactly the same for women but the magnitude of the estimates was slightly lower among men. However, the P for trend remained statistically

Table 1 Characteristics of the cohort of 17 197 participants: the SUN (Seguimiento Universidad de Navarra) Study

	Quintile of daily dietary energy cost (€/4187 kJ)										
Cost per kJ (€/4187 kJ)	1 (*n* 3440)		2 (*n* 3439)		3 (*n* 3440)		4 (*n* 3438)		5 (*n* 3440)		
	≤2·5		2·51–2·81		2·82–3·16		3·17–3·65		≥3·66		
	% or Mean	SD	% or Mean	SD	% or Mean	SD	% or Mean	SD	% or Mean	SD	*P* value*
Men (%)	48·1	–	44·1	–	40·2	–	37·3	–	32·1	–	<0·001
Age (years)	35·0	11·2	36·9	11·6	38·9	12·0	40·1	12·2	42·2	12·9	<0·001
Smoking (%)											<0·001
Current smokers	22·1	–	22·9	–	22·1	–	22·6	–	21·3	–	
Former smokers	22·4	–	26·9	–	29·9	–	32·8	–	38·4	–	
Marital status (%)											<0·001
Single	51·7	–	45·8	–	42·2	–	38·6	–	37·8	–	
Married	45·3	–	50·7	–	53·7	–	55·5	–	54·4	–	
Widowed	0·6	–	0·6	–	0·9	–	1·1	–	1·9	–	
Separated	1·5	–	1·9	–	2·2	–	3·2	–	4·0	–	
Other	0·8	–	0·9	–	1·1	–	1·6	–	1·9	–	
Employment status (%)											<0·001
Full time	77·9	–	79·0	–	81·5	–	81·8	–	81·9	–	
Part time	9·6	–	9·2	–	8·1	–	8·3	–	7·2	–	
Housewife	3·5	–	3·5	–	3·6	–	2·6	–	3·1	–	
Unemployed	6·8	–	5·7	–	4·0	–	4·2	–	3·1	–	
Retired	2·3	–	2·5	–	2·9	–	3·2	–	4·8	–	
Micronutrient intake											
Zn (mg/d)	14	6	16	8	17	8	18	10	22	16	<0·001
Iodine (μg/d)	324	167	332	178	336	188	334	199	345	227	0·008
Vitamin E (mg/d)	7·1	2·6	6·9	2·9	6·8	3·1	7·0	3·2	7·0	3·6	0·095
Vitamin D (μg/d)	3·0	1·5	3·4	1·9	3·5	2·1	3·8	2·4	4·5	3·1	<0·001
P (mg/d)	1719	266	1821	287	1887	324	1960	340	2201	458	<0·001
Na from salt (mg/d)	3738	1124	3786	1467	3885	1798	4077	2220	4330	3058	<0·001
Na (mg/d)	3131	1054	3164	1432	3260	1757	3468	2187	3775	3003	<0·001
Mg (mg/d)	375	56	389	61	404	68	420	78	471	103	<0·001
K (mg/d)	4140	758	4375	835	4587	963	4810	1078	5641	1611	<0·001
Fe (mg/d)	16	2	16	3	17	3	17	3	19	5	<0·001
Ca (mg/d)	1115	289	1170	331	1200	361	1233	397	1360	507	<0·001
Vitamin B_{12} (μg/d)	8·3	3·4	8·9	3·7	9·3	4·0	9·8	4·7	11·2	6·2	<0·001
Vitamin B_6 (mg/d)	2·3	0·5	2·5	0·5	2·6	0·6	2·8	0·7	3·3	0·9	<0·001
Vitamin B_3 (mg/d)	38	6	40	7	41	7	43	8	47	10	<0·001
Vitamin B_2 (mg/d)	2·0	0·4	2·1	0·4	2·2	0·5	2·2	0·5	2·5	0·6	<0·001
Vitamin B_1 (mg/d)	1·7	0·3	1·7	0·3	1·8	0·3	1·8	0·4	2·0	0·5	<0·001
Vitamin A (μg/d)	1493	785	1643	914	1839	1124	1968	1261	2546	1976	<0·001
Se (μg/d)	92	25	96	26	97	29	98	31	100	34	<0·001
Vitamin C (mg/d)	217	87	239	100	263	117	285	134	362	194	<0·001
Folic acid (μg/d)	320	95	347	113	370	121	392	132	476	201	<0·001
Fibre (g/d)	21	8	24	8	27	9	30	10	35	13	<0·001

Continuous variables are expressed as means and standard deviations and categorical variables as percentages.
*The *P* value was calculated through ANOVA for continuous variables and Fisher's exact test for categorical variables.

significant ($P < 0.001$) and the comparison between extreme quintiles did not change substantially (first *v.* fifth quintile of dietary energy cost: PRR = 1·29 (95 % CI 1·24, 1·36); data not shown).

Discussion

In a large cohort of Spanish university graduates, we have found that high dietary energy cost of daily food consumption is associated with a higher likelihood of meeting the recommendations for daily intake of micronutrients and fibre. Our results are consistent with previous research in this area that has shown similar results in other populations[6], as well as evidence that there is a higher cost associated with consuming diets of higher nutritional value in regard to micronutrients and energy density[4,6], even though this evidence was based on smaller sample sizes. We hypothesized that these results would be consistent in our population, and the association we have found (stronger among females) is important for further research and possibilities of policy changes or changes in clinical practice in Spain.

Limitations of our study include the inability to generalize the data to the general Spanish population because of the high educational level of the participants. While these participants may have a higher income than the less educated Spanish population to spend on food, the results are reasonably free of confounding by socio-economic status (SES) because the participants we examined all had a fairly similar SES. Although similar educational level does not guarantee similar income, educational level has

Table 2 Prevalence rate ratio (PRR) for failing to meet three or more recommendations for micronutrient intake with the fifth quintile as the reference category, the SUN (Seguimiento Universidad de Navarra) Study

	Quintile of daily dietary energy cost					
Men	1 (lowest) (*n* 1398)	2 (*n* 1401)	3 (*n* 1380)	4 (*n* 1377)	5 (*n* 1383)	*P* for trend
Daily food cost (€/4187 kJ; median)	2·2	2·6	2·9	3·3	3·9	
Number of recommendations not met (median)	7	6	5	4	3	
Cases (%) of subjects non-compliant with ≥3 recommendations	98·4	94·8	89·1	80·3	68·2	
Crude PRR (95 % CI)	1·44 (1·39, 1·50)	1·39 (1·34, 1·44)	1·31 (1·25, 1·36)	1·18 (1·13, 1·23)	1·00 (Ref.)	<0·001
Age-adjusted PRR (95 % CI)	1·42 (1·37, 1·48)	1·37 (1·32, 1·43)	1·30 (1·25, 1·35)	1·17 (1·12, 1·23)	1·00 (Ref.)	<0·001
Multivariate-adjusted* PRR (95 % CI)	1·43 (1·38, 1·49)	1·37 (1·32, 1·43)	1·30 (1·25, 1·35)	1·18 (1·12, 1·23)	1.00 (Ref.)	<0·001
Women	1 (lowest) (*n* 2076)	2 (*n* 2025)	3 (*n* 2025)	4 (*n* 2090)	5 (*n* 2042)	*P* for trend
Daily food cost (€/4187 kJ; median)	2·3	2·7	3·1	3·5	4·2	
Number of recommendations not met (median)	6	5	4	3	3	
Cases (%) of subjects non-compliant with ≥3 recommendations	97·1	90·1	82·8	74·5	59·5	
Crude PRR (95 % CI)	1·63 (1·57, 1·69)	1·52 (1·46, 1·58)	1·39 (1·34, 1·45)	1·25 (1·20, 1·31)	1·00 (Ref.)	<0·001
Age-adjusted PRR (95 % CI)	1·61 (1·55, 1·67)	1·50 (1·44, 1·56)	1·38 (1·33, 1·44)	1·25 (1·19, 1·30)	1·00 (Ref.)	<0·001
Multivariate-adjusted* PRR (95 % CI)	1·62 (1·56, 1·68)	1·51 (1·45, 1·57)	1·39 (1·33, 1·45)	1·25 (1·20, 1·31)	1·00 (Ref.)	<0·001

*Adjusted for age, smoking, marital status and employment.

proved to be influential in the evaluation of SES. Analyses that have taken account of education, occupation, income and employment status have shown that education is the strongest determinant of socio-economic differences in food habits[18] (i.e. restriction was used to control for SES as a confounding factor). Moreover, the very low percentage of participants meeting the recommendations that we observed was found among a relatively more affluent stratum of the population, and it is likely that the problem might in any case be worse among less well-off sectors.

An additional limitation is that our exposure variable was based on answers to FFQ, which present some degree of measurement error inherent in nutritional epidemiology. This withstanding, it is unlikely that the magnitude of the prevalence rate ratio that we have found here could be explained by the potential measurement errors, which are more likely to be non-differential.

The present results contribute to the importance of considering cost when initiating nutritional programmes, as some recommendations may be prohibitively expensive for some portions of the population. Clinicians also should consider the affordability of expensive food items on the part of their patients when counselling them on diet changes for micronutrient deficiencies, as it is possible that those who are not meeting recommendations may not have the economic resources to do so.

Acknowledgements

The SUN Study received funding from the Spanish Ministry of Health (grants PI030678, PI040233, PI070240, PI081943, RD06/0045 and G03/140), the Navarra Regional Government (grants PI41/2005 and PI36/2008) and the University of Navarra. C.N.L. was supported by a Paul Dudley White Travelling Fellowship, Harvard Medical School. The authors declare no conflict of interests. The authors' contributions were as follows. Study concept and design: C.N.L., M.A.M.-G. and M.B.-R.; acquisition of data: M.A.M.-G., C.F. and M.B.-R.; analysis and interpretation of the data: M.B.-R. and M.A.M.-G.; drafting of the manuscript: C.N.L. and M.B.-R.; critical revision of the manuscript for important intellectual content: C.N.L., M.B.-R., A.A., A.S.-V., C.F. and M.A.M.-G.; obtained funding: M.A.M.-G., A.S.-V. and M.B.-R. We thank all members of the SUN Study Group for administrative, technical and material support. We thank participants of the SUN Study for continued cooperation and participation.

References

1. Serra-Majem L & Aranceta J (2001) Nutritional objectives for the Spanish population. Consensus from the Spanish Society of Community Nutrition. *Public Health Nutr* **4**, 1409–1413.
2. Serra-Majem L, Ribas-Barba L, Salvador G, Serra J, Castell C, Cabezas C & Plasencia A (2007) Compliance with dietary guidelines in the Catalan population: basis for a nutrition

policy at the regional level. *Public Health Nutr* **10**, 1406–1414.
3. Schroder H, Marrugat J & Covas M (2006) High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *Int J Obes (Lond)* **30**, 1574–1579.
4. Schroder H, Covas M, Elosua R, Mora J & Marrugat J (2008) Diet quality and lifestyle associated with free selected low-energy density diets in a representative Spanish population. *Eur J Clin Nutr* **62**, 1194–1200.
5. Andrieu E, Darmon N & Drewnowski A (2006) Low-cost diets: more energy, fewer nutrients. *Eur J Clin Nutr* **60**, 434–436.
6. Maillot M, Darmon N, Vieux F & Drewnowski A (2007) Low energy density and high nutritional quality are each associated with higher diet costs in French adults. *Am J Clin Nutr* **86**, 690–696.
7. Segui-Gomez M, Fuente C, Vazquez Z, Irala J & Martinez-Gonzalez M (2006) Cohort profile: the 'Seguimiento Universidad de Navarra' (SUN) study. *Int J Epidemiol* **35**, 1417–1422.
8. Willett WC (editor) (1998) Issues in analysis and presentation of dietary data. In *Nutritional Epidemiology*, 2nd ed., pp. 321–346. New York: Oxford University Press.
9. Sociedad Española de Nutrición Comunitaria (2001) *Guías alimentarias para la población Española: recomendaciones para una dieta saludable*, pp. 249–296, 348. Madrid: IM&C SA.
10. Varela G (1998) Ministerios del Interior, de Educación y Cultura y de Sanidad y Consumo. Nutrición saludable y prevención de los trastornos alimentarios. http://www.mec.es/cide/jsp/plantilla.jsp?id=inn03d&contenido=/espanol/publicaciones/materiales/salud/inn1999ns/pub03b2.html (accessed February 2008).
11. National Academy of Sciences. Institute of Medicine, Food and Nutrition Board (2004) Dietary Reference Intakes: Recommended Intakes for Individuals. http://www.iom.edu/Object.File/Master/21/372/0.pdf (accessed January 2009).
12. Martín-Moreno J, Boyle P, Gorgojo L *et al.* (1993) Development and validation of a food frequency questionnaire in Spain. *Int J Epidemiol* **22**, 512–519.
13. Mataix J (2003) *Tabla de Composición de Alimentos (Food Composition Tables)*, 4th ed. Granada: Universidad de Granada.
14. Moreiras O (2005) *Tablas de Composición de Alimentos (Food Composition Tables)*, 9th ed. Madrid: Ediciones Pirámide.
15. Willett WC & Stampfer M (1998) Implications of total energy intake for epidemiologic analyses. In *Nutritional Epidemiology*, 2nd ed., pp. 273–301 [WC Willett, editor]. New York: Oxford University Press.
16. Gobierno de España, Ministerio de Industria, Turismo y Comercio (2008) Precios Medios Nacionales Ponderados de Venta al Público de Productos de Alimentación 2002–2008. http://www.comercio.es/comercio/bienvenido/Comercio+Interior/Precios+y+Margenes+Comerciales/Bases+de+Datos/pagPreciosmediosnacionalesponderadosdeventaalpublicodeproductosdealimentacion.htm (accessed January 2009).
17. Barros AJD & Hirakata V (2003) Alternatives for logistic regression in cross-sectional studies: and empirical comparison of models that directly estimate the prevalence ratio. *BMC Med Res Methodol* **2**, 21.
18. Roos E, Prättälä R, Lahelma E, Kleemola P & Pietinen P (1996) Modern and healthy? Socioeconimic differences in the quality of diet. *Eur J Clin Nutr* **50**, 753–760.