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Vegetable and fruit consumption, education and plasma vitamin C concentration in Russian and Finnish Karelia, 1992–2002

Laura Paalanen[1,]*, Ritva Prättälä[2], Georg Alfthan[1], Irma Salminen[1] and Tiina Laatikainen[1,3,4]

[1]Department of Chronic Disease Prevention, National Institute for Health and Welfare (THL), PO Box 30, FI-00271 Helsinki, Finland: [2]Department of Lifestyle and Participation, National Institute for Health and Welfare (THL), Helsinki, Finland: [3]Institute of Public Health and Clinical Nutrition, University of Eastern Finland, Kuopio, Finland: [4]Hospital District of North Karelia, Joensuu, Finland

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Abstract

Objective: To examine (i) whether the consumption of fresh vegetables, fruit and berries is associated with plasma vitamin C concentration and (ii) educational differences in plasma vitamin C concentration in two neighbouring areas in Russia and Finland.

Design: Cross-sectional risk factor surveys in 1992, 1997 and 2002. Logistic regression analysis was applied to examine the associations of consumption of selected foods and education with plasma vitamin C concentration.

Setting: District of Pitkäranta in the Republic of Karelia, Russia and North Karelia, Finland.

Subjects: Adults aged 25–64 years: 579 men and 612 women in Pitkäranta; 974 men and 642 women in North Karelia.

Results: The plasma vitamin C concentration was strikingly low in Pitkäranta, Russia across the study years. During the 10 years of monitoring, the mean plasma vitamin C concentration among men ranged from 2·5 to 8·0 μmol/l in Pitkäranta, Russia and from 27·1 to 53·9 μmol/l in North Karelia, Finland. In both areas, daily consumption of fruit was most strongly associated with plasma vitamin C, while the association of fresh vegetable consumption with plasma vitamin C was less consistent. Consumption of berries was less important in explaining plasma vitamin C. In Pitkäranta, the plasma vitamin C concentration was lower among respondents in the lowest education group.

Conclusions: Differences in the consumption of fresh vegetables and fruit resulted in notable differences in vitamin C status between Pitkäranta and North Karelia in spring. In comparative settings, knowledge of local food culture and validation pilots are important before conducting large population surveys.

Keywords
Russia
Finland
Vegetables
Education
Vitamin C

Abundant consumption of fruit and vegetables is emphasized in practically all dietary recommendations. Fruit, vegetables and berries are important sources of numerous nutrients including vitamin C. The evidence on the benefits of fruit and vegetables for lowering the risk of CVD is strong[1]. Although the consumption of fruit and vegetables is often far from optimal, vitamin C deficiency is rare in Western countries at present. In population risk factor surveys conducted in 1992 and 1997 in the Republic of Karelia in north-western Russia, extremely low plasma vitamin C concentrations were reported among men[2,3]. Plasma vitamin C was measured among a sub-sample of men in the district of Pitkäranta, Republic of Karelia, Russia and in North Karelia, Finland. The measurements showed that vitamin C concentrations were normal in North Karelia but extremely low in Pitkäranta in springtime. Differences in the vitamin C content of the diet in the two areas explain the greater part of the differences in plasma vitamin C. Smokers with the same vitamin C intake as non-smokers have lower plasma vitamin C concentration[4,5]. High smoking prevalence among men in Pitkäranta may explain a smaller part of the lower plasma vitamin C concentrations in Pitkäranta compared with North Karelia.

In Finland, the main sources of vitamin C are fruit, including berries (57 % and 60 % for men and women, respectively), and vegetables and vegetable dishes (22 % and 20 % for men and women, respectively)[6]. To our knowledge, corresponding data are not available from Russia. The consumption of fruit and vegetables is commonly higher among women than among men and in higher educational groups compared with lower educational groups[7–9]. We have previously demonstrated that since 1992, the overall consumption of fresh vegetables

*Corresponding author: Email laura.paalanen@thl.fi © The Authors 2013

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and fruit has increased in Pitkäranta in the Republic of Karelia[10]. Meanwhile, the educational differences in the consumption of fresh vegetables and fruit have increased[10]. On the whole, the level and pattern of fresh vegetable and fruit consumption in Pitkäranta have approached those in North Karelia. The overall level of fruit and vegetable consumption is nevertheless lower in Pitkäranta than in North Karelia. From 1992 to 2002, daily consumption of fresh vegetables varied between 10–25 % and 44–72 %, daily consumption of fruit between 2–32 % and 43–82 %, and the consumption of berries at least twice weekly between 6–17 % and 38–69 % in Pitkäranta and North Karelia, respectively[10].

No up-to-date data on plasma vitamin C levels in Pitkäranta or North Karelia have been available since 1997. Therefore our aims in the current study were to examine: (i) whether different dietary sources of vitamin C are associated with plasma vitamin C concentration in the district of Pitkäranta in the Republic of Karelia, Russia and in North Karelia, Finland in spring 1992, 1997 and 2002; and (ii) educational differences in plasma vitamin C concentration in the two areas.

Methods

Study sites and population

The Republic of Karelia in Russia and North Karelia in Finland are neighbouring areas with 296 km of common border. They partly shared a common history until the end of World War II, when parts of the formerly Finnish Karelia – including our study site, the district of Pitkäranta – were annexed to the Soviet Union. The Republic of Karelia is part of the Russian Federation. In the district of Pitkäranta, there are some 24 000 inhabitants[11], about half of whom live in the city of Pitkäranta[12]. The distance from Pitkäranta to the Finnish border is about 100 km. North Karelia is the easternmost province of Finland, with 166 000 inhabitants in 2011[13].

The main data were collected in cross-sectional risk factor surveys in 1992, 1997 and 2002. The surveys were conducted from January to April in North Karelia and from March to April in Pitkäranta. The samples were stratified with each 10-year age group having an equal number of men and women. The study protocol included an extensive self-administered questionnaire on health behaviours (smoking, use of alcohol, food habits and physical exercise) and a personal health examination including measurements of height, weight, blood pressure and drawing of blood samples. The questionnaires were mailed to the respondents in advance. The respondents were asked to fill in the questionnaire at home and bring them to the survey site. The survey methodology has been described in more detail previously[14,15]. The methodology followed closely the WHO MONICA (monitoring trends and determinants in cardiovascular disease) protocol[16]. The age range of respondents in the study was 25–64 years. The survey samples and response rates are presented in Table 1.

Measurements

Data on socio-economic position and food consumption were derived from the self-administered questionnaire.

Table 1 Survey samples and participants (*n*) in the risk factor surveys and plasma vitamin C sub-samples from the district of Pitkäranta, Republic of Karelia, Russia and the province of North Karelia, Finland, spring 1992, 1997 and 2002

	Pitkäranta, Republic of Karelia, Russia				North Karelia, Finland			
	Men		Women		Men		Women	
	Risk factor survey	Vitamin C sub-sample	Risk factor survey	Vitamin C sub-sample	Risk factor survey	Vitamin C sub-sample	Risk factor survey	Vitamin C sub-sample
1992								
Original sample	500	157		†	1000	336		†
Cleaned sample*	495				988			
Participants	380	117			673	224		
Participation rate (%)	77	75			68	67		
1997								
Original sample	499	499	501	501	1000	400		†
Cleaned sample*	486	486	500	500				
Participants	309	244	440	338	712	191‡		
Participation rate (%)	64	50	88	68	71	48		
2002								
Original sample	500	500	500	500	1000	1000	1000	1000
Cleaned sample*	472	472	481	481	994	994	993	993
Participants	263	218	342	274	664	559§	762	642‖
Participation rate (%)	56	46	71	57	67	56	77	65

*Persons who had died or moved away from the study area between drawing the sample and the time of the health examination as well as persons who were in prison at the time of the study were excluded from the cleaned sample.
†Plasma vitamin C was not determined from the samples of women in 1992 in Pitkäranta and in 1992 and 1997 in North Karelia.
‡Vitamin C could not be measured in North Karelia 1997 from all samples due to technical difficulties with metaphosphoric acid used at the field laboratory.
§The plasma samples of fifty-seven men from North Karelia in 2002 were omitted because of thawing.
‖The plasma samples of sixty-one women from North Karelia in 2002 were omitted because of thawing.

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Education was chosen to indicate socio-economic position. Education was measured as the total number of years of education. The years of education were divided into tertiles (high, intermediate and low) within each 10-year birth cohort in the two areas, separately for men and women. This relative education variable was used because the educational systems differ between Finland and Russia, and it is not possible to define simpler categories that would aptly describe the respondents' educational level in a comparable manner. In addition, the data included persons born between the years 1928 and 1977 and the mean years of education have risen over time.

Food consumption

In the food frequency section of the self-administered questionnaire, the respondents were asked to report on their food consumption during the preceding half-year period in 1992. In 1997 and 2002, the question concerned the entire preceding year (12 months). Three dichotomous outcome variables were formed for the analyses: (i) daily consumption of fresh vegetables; (ii) daily consumption of fruit; and (iii) consumption of fresh or frozen berries at least twice weekly. Fruit consumption did not include berry consumption. Daily consumption included daily and almost daily consumption. For berries the variable was dichotomized differently from fruit and vegetables because daily consumption of berries was very uncommon.

Vitamin C determinations

Plasma vitamin C reflects short-term dietary intake of vitamin C, with best temporal correlation when the 7 d of intake immediately preceding the blood sample are estimated[17]. Plasma vitamin C concentrations were determined from either a sub-sample or the total sample of survey participants in the two areas in 1992, 1997 and 2002. The samples and participants are reported in Table 1. All vitamin C determinations were performed in the same laboratory at the National Public Health Institute (the present National Institute for Health and Welfare), Helsinki, Finland. From Pitkäranta, the data included only men in 1992 and both sexes thereafter. From North Karelia, the data for 1992 and 1997 included men only, and the data for 2002 included both sexes.

Venous blood specimens were taken into 10 ml evacuated heparin tubes after 4 h of fasting. In 1992 and 1997, plasma was separated within 1 h by centrifugation and 0·5 ml of plasma was transferred to a tube containing 4·5 ml of 5 % (v/v) metaphosphoric acid supplied by the analysing laboratory in Helsinki and frozen immediately to −70°C with dry ice. The samples were transported in dry ice in batches to Helsinki, Finland, where they were stored at −20°C for less than 6 months before analysis. Plasma total vitamin C (ascorbic acid + dehydroascorbic acid) was determined from metaphosphoric acid extracts with an automated fluorimetric method using *ortho*-phenylenediamine[18] in the 1992 and 1997 surveys. The precision of the method between assay batches was determined on aliquots of stabilized plasma samples stored at −20°C. In 1992, the precision was 4·7 CV % (ten assay batches, *n* 22) and in 1997 4·5 CV % (thirty-five assay batches, *n* 75). The detection limit of the method for plasma was 0·6 μmol/l. Vitamin C could not be measured in North Karelia in 1997 from all samples due to technical difficulties with the metaphosphoric acid used at the field laboratory. The reason remained unknown, but was linked to stabilized sample tubes, which did not precipitate the plasma proteins.

In 2002, instead of the metaphosphoric acid used in 1992 and 1997, trichloroacetic acid was used for heparin plasma stabilization. Also, the method was changed to an HPLC method using electrochemical detection[19], which measured only ascorbic acid (without reducing dehydroascorbic acid to ascorbic acid). The plasma samples were stored at −20°C at a field laboratory until transfer on dry ice to Helsinki, Finland, where the samples were stored at −70°C until plasma vitamin C determination in 2003–2005. The precision of the method was 5·4 CV % (eleven assay batches, *n* 33). The detection limit for the method was 2 μmol/l.

As the method of plasma vitamin C determination changed over the study period, the absolute levels of plasma vitamin C concentrations cannot be directly compared across study years. Taking all method variables into account for both methods, we estimated that the mean plasma vitamin C concentration was approximately 13 % lower in 2002 compared with 1992 and 1997[19]. In 2002, as a result of a change in method, only the concentration of ascorbic acid was determined. As the absolute levels of plasma vitamin C were not comparable over time, we divided the plasma vitamin C concentrations into tertiles within each study, separately for men and women (Table 2). The tertile variable was used in the statistical analyses. Henceforth, we use the term 'vitamin C' for all years.

Because of the instability of vitamin C, the plasma samples were extremely susceptible to deterioration from e.g. temperature changes and freezing conditions. Transferring plasma samples from study sites to the laboratory in Helsinki, Finland brought an extra challenge to the study protocol. One tube box from North Karelia in 2002, with samples from forty-five men and forty-one women, had thawed during transport. An additional thirty-two samples (twelve men, twenty women) were identified in quality control as damaged or destroyed, most likely as a result of thawing. These 118 samples were omitted from the analyses.

Statistical methods

The data from Pitkäranta and North Karelia were analysed separately. All analyses were performed separately for men and women. Logistic regression analysis was used to

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Table 2 Mean plasma vitamin C concentration (μmol/l), cut-off points for plasma vitamin C tertiles (μmol/l) and number of participants in the tertiles in Pitkäranta, Republic of Karelia, Russia and North Karelia, Finland, in spring 1992, 1997 and 2002*

			Cut-off points for plasma vitamin C tertiles (μmol/l)			Number of participants			
Data	Sex	Mean plasma vitamin C (μmol/l)	Lowest tertile	Middle tertile	Highest tertile	Lowest tertile	Middle tertile	Highest tertile	Total
Pitkäranta									
1992	Men	2·5	0·57	1·14–6·25	6·81–32·93	95	11	11	117
1997	Men	8·0	0·28–2·27	2·84–6·81	7·38–65·86	81	79	84	244
	Women	22·1	0·28–7·38	7·95–24·42	24·98–102·20	116	110	112	338
2002	Men	5·0	0	0·40–3·24	3·29–43·78	73	73	72	218
	Women	12·6	0–2·95	3·07–14·82	14·99–66·38	93	89	92	274
North Karelia									
1992	Men	53·9	2·21–47·52	47·64–60·70	60·75–112·99	75	74	75	224
1997	Men	27·1	0·57–19·31	19·87–32·93	33·50–82·90	64	65	62	191
2002	Men	37·3	0–27·88	28·05–43·89	44·00–134·23	185	187	187	559
	Women	43·6	2·56–35·43	35·49–49·68	49·85–189·08	213	215	214	642

*In 1992 and 1997, metaphosphoric acid was used for plasma stabilization and plasma vitamin C measurement included ascorbic acid and dehydroascorbic acid. In 2002, as a result of change in method, only the concentration of ascorbic acid was determined.

examine the associations of plasma vitamin C levels with the consumption of foods rich in vitamin C and plasma vitamin C levels with education separately for each study year and for all study years combined. As the plasma vitamin C concentrations were relatively low in the middle tertile, especially in Pitkäranta, we decided to combine the middle and lowest plasma vitamin C tertiles and use them as the reference category. The data from Pitkäranta in 1992 were omitted from the logistic regression analyses as the distribution was so skewed; ninety-five out of 117 observations (81 %) only reached the detection limit (0·6 μmol/l) and were categorized into the lowest tertile (Table 2).

The logistic regression analyses included the following models. First, we analysed the association of plasma vitamin C with consumption of selected foods (fresh vegetables, fruit and berries). Each food variable was included in the analyses individually. The results are presented (i) with no adjustments, (ii) adjusted for age using age as a continuous variable and (iii) adjusted for age and education (Table 3). Second, to study the association of plasma vitamin C with each of the selected foods independent from the consumption of the other foods, analyses adjusting for the remaining food variables were performed. These results are also presented adjusted for age and adjusted for age and education (Table 4). Third, we analysed the associations of education with plasma vitamin C levels. The results (odds ratios and 95 % confidence intervals) are presented with no adjustments and with age adjustment (Table 5).

The analyses were carried out with the Stata statistical software package version 11·2.

Results

Plasma vitamin C concentration in Pitkäranta and North Karelia

Among men, the mean plasma vitamin C concentration ranged from 2·5 to 8·0 μmol/l in Pitkäranta, Russia and from 27·1 to 53·9 μmol/l in North Karelia, Finland (Table 2). Among women, the mean plasma vitamin C concentration ranged from 12·6 to 22·1 μmol/l in Pitkäranta. The mean plasma vitamin C concentration was 43·6 μmol/l among women in North Karelia in 2002.

Association of vegetable, fruit and berry consumption with plasma vitamin C concentration

When the food variables were included in the analyses one by one, only daily consumption of fruit was significantly associated with plasma vitamin C concentration among men in Pitkäranta (Table 3). Among women, daily consumption of fresh vegetables and consumption of berries at least twice weekly in addition to daily consumption of fruit were associated with plasma vitamin C. In North Karelia, daily consumption of fresh vegetables and daily consumption of fruit were significantly associated

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Table 3 The associations of daily consumption of fresh vegetables, daily consumption of fruit and consumption of berries at least twice weekly with high plasma vitamin C concentration in Pitkäranta, Republic of Karelia, Russia in 1997 and 2002 and in North Karelia, Finland in 1992, 1997 and 2002. The reference category comprised the middle and lowest vitamin C tertiles

	Unadjusted		Adjusted for age		Adjusted for age and education	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
Pitkäranta						
Men*						
1997						
Fresh vegetables	1·22	0·53, 2·83	1·25	0·54, 2·91	1·24	0·53, 2·92
Fruit	3·17	1·24, 8·09	3·05	1·19, 7·84	2·83	1·10, 7·31
Berries	0·57	0·18, 1·79	0·54	0·17, 1·74	0·49	0·15, 1·58
2002						
Fresh vegetables	1·19	0·55, 2·58	1·23	0·56, 2·69	1·13	0·48, 2·64
Fruit	3·58	1·74, 7·36	4·12	1·95, 8·71	4·08	1·78, 9·35
Berries	1·64	0·58, 4·60	1·62	0·57, 4·59	1·47	0·48, 4·48
1997 and 2002						
Fresh vegetables	1·19	0·68, 2·10	1·23	0·69, 2·18	1·19	0·66, 2·16
Fruit	3·27	1·86, 5·76	3·44	1·94, 6·09	3·17	1·76, 5·72
Berries	0·98	0·46, 2·08	0·95	0·45, 2·03	0·82	0·38, 1·78
Women						
1997						
Fresh vegetables	3·22	1·86, 5·59	3·34	1·92, 5·82	3·00	1·70, 5·29
Fruit	5·64	3·12, 10·18	5·53	3·03, 10·09	4·92	2·67, 9·07
Berries	1·76	0·90, 3·43	1·82	0·93, 3·56	1·73	0·87, 3·47
2002						
Fresh vegetables	1·92	1·11, 3·33	2·01	1·15, 3·52	1·86	1·06, 3·27
Fruit	2·57	1·53, 4·33	2·58	1·53, 4·36	2·42	1·42, 4·11
Berries	1·96	1·04, 3·71	2·11	1·10, 4·03	1·92	0·99, 3·71
1997 and 2002						
Fresh vegetables	2·48	1·69, 3·65	2·59	1·75, 3·83	2·36	1·59, 3·51
Fruit	3·47	2·38, 5·06	3·41	2·34, 4·97	3·14	2·14, 4·61
Berries	1·86	1·17, 2·94	1·96	1·23, 3·12	1·81	1·12, 2·91
North Karelia						
Men						
1992						
Fresh vegetables	1·80	1·02, 3·18	1·90	1·07, 3·40	1·75	0·97, 3·16
Fruit	2·15	1·18, 3·91	2·23	1·21, 4·10	2·19	1·19, 4·06
Berries	1·08	0·62, 1·90	1·37	0·75, 2·50	1·32	0·72, 2·42
1997						
Fresh vegetables	1·18	0·64, 2·18	1·30	0·70, 2·44	1·05	0·54, 2·03
Fruit	2·28	1·22, 4·25	2·39	1·27, 4·49	2·20	1·16, 4·17
Berries	0·73	0·39, 1·38	0·84	0·43, 1·65	0·75	0·38, 1·50
2002						
Fresh vegetables	1·48	1·04, 2·11	1·48	1·04, 2·12	1·50	1·04, 2·16
Fruit	1·34	0·94, 1·91	1·36	0·95, 1·94	1·40	0·98, 2·00
Berries	0·97	0·67, 1·39	1·01	0·69, 1·46	1·04	0·71, 1·52
1992, 1997 and 2002						
Fresh vegetables	1·48	1·13, 1·94	1·51	1·15, 1·98	1·43	1·09, 1·89
Fruit	1·63	1·24, 2·13	1·67	1·28, 2·20	1·67	1·27, 2·19
Berries	0·94	0·72, 1·24	1·04	0·78, 1·38	1·03	0·77, 1·37
Women						
2002						
Fresh vegetables	1·10	0·77, 1·57	1·08	0·76, 1·54	1·04	0·72, 1·50
Fruit	1·51	1·05, 2·16	1·49	1·04, 2·14	1·48	1·02, 2·14
Berries	1·26	0·90, 1·77	1·23	0·86, 1·75	1·25	0·87, 1·78

*The data from Pitkäranta in 1992 were omitted from the logistic regression analyses because of the skewed distribution in plasma vitamin C concentration.

with plasma vitamin C concentration at most time points among men, while among women only consumption of fruit reached significance. No significant associations between regular consumption of berries and plasma vitamin C concentration were seen in North Karelia.

Adjusting for the other selected food variables (fresh vegetables, fruit and berries) weakened the associations slightly (Table 4). In Pitkäranta, daily consumption of fruit remained the only significant food variable associated with plasma vitamin C after adjusting for vegetables and berries among men. When the results were adjusted for consumption of fresh vegetables and fruit, the association of the consumption of berries with plasma vitamin C fell short of significance among women. In 1997, fresh vegetables and fruit, and in 2002, fruit were associated with plasma vitamin C concentration. Among men in North Karelia, daily consumption of fruit in 1992 and 1997 and fresh vegetables in 2002 were

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Table 4 The associations of daily consumption of fresh vegetables, daily consumption of fruit and consumption of berries at least twice weekly with high plasma vitamin C concentration in Pitkäranta, Republic of Karelia, Russia in 1997 and 2002 and in North Karelia, Finland in 1992, 1997 and 2002. Adjusted for vegetable, fruit and berry consumption. The reference category comprised the middle and lowest vitamin C tertiles

	Model 1*		Model 2†		Model 3‡	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
Pitkäranta						
Men§						
1997						
Fresh vegetables	1·02	0·43, 2·43	1·06	0·44, 2·52	1·06	0·44, 2·54
Fruit	3·40	1·30, 8·93	3·27	1·24, 8·61	3·03	1·14, 8·05
Berries	0·48	0·14, 1·58	0·46	0·14, 1·54	0·43	0·13, 1·43
2002						
Fresh vegetables	0·95	0·41, 2·19	0·99	0·42, 2·30	0·94	0·38, 2·35
Fruit	3·55	1·71, 7·35	4·08	1·92, 8·67	4·10	1·78, 9·45
Berries	1·54	0·51, 4·61	1·49	0·48, 4·57	1·47	0·44, 4·94
1997 and 2002						
Fresh vegetables	1·03	0·57, 1·86	1·06	0·58, 1·93	1·06	0·57, 1·96
Fruit	3·29	1·86, 5·83	3·45	1·94, 6·15	3·20	1·77, 5·80
Berries	0·86	0·39, 1·88	0·82	0·37, 1·82	0·74	0·33, 1·64
Women						
1997						
Fresh vegetables	2·12	1·16, 3·88	2·17	1·18, 3·99	2·03	1·09, 3·77
Fruit	4·45	2·40, 8·26	4·25	2·26, 8·01	3·89	2·05, 7·40
Berries	1·16	0·55, 2·43	1·18	0·56, 2·48	1·16	0·55, 2·45
2002						
Fresh vegetables	1·35	0·74, 2·47	1·39	0·76, 2·57	1·33	0·72, 2·47
Fruit	2·20	1·26, 3·82	2·16	1·24, 3·78	2·08	1·19, 3·66
Berries	1·44	0·73, 2·86	1·54	0·77, 3·07	1·45	0·72, 2·92
1997 and 2002						
Fresh vegetables	1·69	1·11, 2·58	1·76	1·15, 2·70	1·65	1·07, 2·55
Fruit	2·85	1·91, 4·25	2·74	1·83, 4·09	2·60	1·73, 3·91
Berries	1·25	0·76, 2·05	1·31	0·79, 2·06	1·25	0·75, 2·07
North Karelia						
Men						
1992						
Fresh vegetables	1·70	0·93, 3·11	1·72	0·93, 3·16	1·57	0·85, 2·93
Fruit	2·04	1·09, 3·85	2·02	1·06, 3·83	2·03	1·07, 3·86
Berries	0·76	0·41, 1·41	0·96	0·50, 1·85	0·96	0·50, 1·85
1997						
Fresh vegetables	1·17	0·61, 2·27	1·24	0·63, 2·41	1·01	0·51, 2·04
Fruit	2·37	1·25, 4·48	2·39	1·26, 4·54	2·27	1·19, 4·35
Berries	0·62	0·31, 1·23	0·72	0·35, 1·47	0·69	0·33, 1·41
2002						
Fresh vegetables	1·44	1·00, 2·09	1·44	0·99, 2·08	1·43	0·97, 2·09
Fruit	1·29	0·90, 1·86	1·30	0·90, 1·88	1·33	0·92, 1·92
Berries	0·85	0·58, 1·24	0·87	0·59, 1·29	0·90	0·61, 1·34
1992, 1997 and 2002						
Fresh vegetables	1·44	1·08, 1·91	1·43	1·08, 1·90	1·35	1·01, 1·81
Fruit	1·59	1·20, 2·11	1·61	1·22, 2·14	1·62	1·22, 2·15
Berries	0·78	0·58, 1·04	0·85	0·63, 1·15	0·86	0·64, 1·17
Women						
2002						
Fresh vegetables	0·92	0·63, 1·35	0·91	0·62, 1·34	0·89	0·60, 1·32
Fruit	1·50	1·02, 2·20	1·49	1·02, 2·20	1·49	1·01, 2·19
Berries	1·22	0·86, 1·73	1·18	0·82, 1·70	1·20	0·83, 1·73

*Model 1 was adjusted for the consumption of fresh vegetables, fruit and berries.
†Model 2 was adjusted for age and the consumption of fresh vegetables, fruit and berries.
‡Model 3 was adjusted for age, education and the consumption of fresh vegetables, fruit and berries.
§The data from Pitkäranta in 1992 were omitted from the logistic regression analyses because of the skewed distribution in plasma vitamin C concentration.

associated with plasma vitamin C concentration after adjustment for the two other food variables. Among North Karelian women, the results resembled those not adjusted for other food variables; only the association of the consumption of fruit with plasma vitamin C was statistically significant in 2002.

Associations of education with plasma vitamin C concentration

Plasma vitamin C concentration tended to be lower among respondents in the middle and low education tertiles compared with the highest tertile among both genders in Pitkäranta (Table 5). In North Karelia, plasma

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Table 5 The associations of education with high plasma vitamin C concentration in Pitkäranta, the Republic of Karelia, Russia in 1997 and 2002 and in North Karelia, Finland in 1992, 1997 and 2002. The reference category comprised the middle and lowest vitamin C tertiles

		Unadjusted		Adjusted for age		
	Education tertile	OR	95 % CI	OR	95 % CI	*P* value*
Pitkäranta						
Men†						
1997	High	1·00	–	1·00	–	
	Intermediate	0·53	0·29, 0·96	0·49	0·27, 0·90	0·02
	Low	0·58	0·28, 1·19	0·59	0·28, 1·23	0·16
2002	High	1·00	–	1·00	–	
	Intermediate	0·35	0·18, 0·67	0·31	0·16, 0·61	0·001
	Low	0·10	0·04, 0·26	0·09	0·03, 0·25	<0·001
1997 and 2002	High	1·00	–	1·00	–	
	Intermediate	0·44	0·28, 0·68	0·40	0·26, 0·63	<0·001
	Low	0·27	0·15, 0·47	0·27	0·15, 0·47	<0·001
Women						
1997	High	1·00	–	1·00	–	
	Intermediate	0·83	0·49, 1·39	0·86	0·51, 1·45	0·57
	Low	0·28	0·15, 0·52	0·27	0·14, 0·51	<0·001
2002	High	1·00	–	1·00	–	
	Intermediate	0·79	0·43, 1·44	0·85	0·46, 1·57	0·61
	Low	0·46	0·25, 0·87	0·46	0·24, 0·86	0·02
1997 and 2002	High	1·00	–	1·00	–	
	Intermediate	0·81	0·55, 1·20	0·86	0·58, 1·27	0·44
	Low	0·36	0·23, 0·56	0·35	0·23, 0·55	<0·001
North Karelia						
Men						
1992	High	1·00	–	1·00	–	
	Intermediate	0·64	0·31, 1·29	0·65	0·32, 1·34	0·24
	Low	0·54	0·28, 1·05	0·51	0·26, 1·01	0·054
1997	High	1·00	–	1·00	–	
	Intermediate	0·63	0·29, 1·36	0·62	0·28, 1·36	0·23
	Low	0·50	0·24, 1·05	0·49	0·23, 1·02	0·06
2002	High	1·00	–	1·00	–	
	Intermediate	0·67	0·43, 1·04	0·67	0·43, 1·04	0·07
	Low	0·94	0·61, 1·43	0·94	0·62, 1·44	0·81
1992, 1997 and 2002	High	1·00	–	1·00	–	
	Intermediate	0·65	0·46, 0·91	0·65	0·47, 0·92	0·01
	Low	0·73	0·53, 1·00	0·72	0·53, 1·00	0·05
Women						
2002	High	1·00	–	1·00	–	
	Intermediate	1·03	0·68, 1·54	1·04	0·69, 1·56	0·85
	Low	0·75	0·51, 1·13	0·76	0·51, 1·13	0·17

**P* value for age-adjusted figures.
†The data from Pitkäranta in 1992 were omitted from the logistic regression analyses because of the skewed distribution in plasma vitamin C concentration.

vitamin C was lower in the lowest education tertile compared with the highest tertile among men in 1992 (borderline significance, $P = 0·054$). The differences were more apparent when the data for 1992, 1997 and 2002 were combined. For women, data were available for 2002 only. No educational differences were seen among women in North Karelia.

Discussion

The plasma vitamin C concentrations were remarkably low even in 2002 in Pitkäranta in the Republic of Karelia, Russia. In both Pitkäranta (Russia) and North Karelia (Finland), the consumption of fruit was most strongly associated with the plasma vitamin C concentration. The association of fresh vegetable consumption with plasma vitamin C was less consistent, while the consumption of berries was practically insignificant in explaining plasma vitamin C. In Pitkäranta, plasma vitamin C varied by education with higher concentrations in the higher education groups. The educational differences were less evident in North Karelia.

Regrettably, the methods of vitamin C determination changed during the study period, which hampers direct comparisons of absolute vitamin C concentrations between the study points although not between study areas. Plasma vitamin C concentrations were overall notably higher in North Karelia (Finland) compared with the district of Pitkäranta (Russia). In Pitkäranta, the concentrations were extremely low during spring at all study points. It seems that even though the consumption of fruit and vegetables has increased since 1992 in Pitkäranta[10], no notable increase in plasma vitamin C has occurred in the meantime, as the concentrations were remarkably

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low even in 2002. The change in the method of plasma vitamin C determination does not fully explain this discrepancy. One possible explanation is that the measurements have been performed in late spring and the consumption of fruit and vegetables may still have been quite low at that time of the year in 2002 in Pitkäranta. Further, the vitamin C content of fruit and vegetables available may be lower during spring than during other seasons as they have to be imported during spring and vitamin C is prone to degradation during storage[20].

The overall public health situation in Russian Karelia is poor and the importance of low vitamin C concentration in this connection can be speculated. Regarding North Karelia, it is noteworthy that though the plasma vitamin C concentrations were higher on the Finnish side of the Finnish–Russian border, the vitamin C concentrations were not optimal in Finnish Karelia either, which might have influenced overall morbidity in North Karelia as well. In Finland, however, mortality has continuously decreased and particularly mortality from CVD. A majority of the decrease in mortality is due to a decrease in traditional risk factors like smoking, blood pressure and cholesterol, but it cannot be explained by these factors alone[21]. It has been discussed whether improved nutrition, including the intake of antioxidants, might be one of the factors behind decreased mortality rates. In Russia, the low intake of antioxidant vitamins like vitamin C should be seriously taken into account as a public health concern.

Educational differences in the consumption of fruit and vegetables have been confirmed in several countries[7,8]. Educational differences in plasma vitamin C concentrations have been studied less extensively. In our study, educational differences in plasma vitamin C concentrations were shown in Pitkäranta, while only borderline significant educational differences were found in North Karelia. It can be assumed that the educational differences in Pitkäranta were emphasized by the fact that the measurements were performed in spring, when fresh vegetables and fruit would be available mainly from retail outlets favouring individuals with a higher income. The educational differences in plasma vitamin C could possibly have been smaller in the summer or autumn when the supply from grocery shops and study participants' own gardens is better. During spring, when the main data were collected, the availability of fresh vegetables is poorer and the prices higher compared with summer and autumn. At least in Finland there are seasonal variations in food habits[22], which should be taken into account as an important issue when exploring food consumption and nutrient intake. According to our analyses, the plasma vitamin C concentrations were manifestly greater in autumn compared with spring in Pitkäranta in 1997[23], suggesting seasonal variation in food habits in Pitkäranta as well.

Measuring food consumption always entails sources for error. In our study, the food frequency section of the self-administered questionnaire concerned the previous 6 months in 1992 and the previous 12 months in 1997 and 2002. However, it is likely that the respondents have estimated their food consumption on the grounds of a shorter preceding period than instructed. A study among women in China found that the respondents reported different lifetime fruit and vegetable consumption depending on the time of year when their food consumption was queried[24]. The results suggest that the food consumption of preceding months may be emphasized in the respondents' answers even though their lifetime consumption is being inquired about. Further, in our study, food consumption was not measured quantitatively, and food and nutrient intakes could not be calculated in absolute amounts. On the other hand, an advantage of non-quantitative FFQ is that they are easy to complete as the respondent does not have to estimate portion sizes. Quantitative FFQ usually contain over 100 foods and may thus be tedious to fill out. The food frequency section in our study only included twenty to forty-two foods or food groups. Even though the FFQ in our study was simple and had been modified to suit the local circumstances, the respondents may have understood the questions differently in the two areas, which remains a possible source of error. Despite our simple and qualitative measure of food consumption, frequent use of fresh vegetables and fruit was associated with vitamin C intake. This result suggests that even the short questionnaire methods can provide relevant information on vitamin C intake in different populations.

Our study only included the consumption of fresh vegetables. Frozen, tinned and pickled vegetables were excluded, although in Russia it is customary to consume many sorts of vegetables in pickled form. During preparation, vitamin C is destroyed in pickled vegetables. During spring, vegetable consumption is likely to concentrate around these pickled vegetables that do not contain vitamin C.

A further limitation of our study is that we did not have plasma vitamin C measurements for both sexes at all study points and the methodology of vitamin C determination changed over the years. Even so, we are not aware of corresponding, comparable data of higher quality from the two areas. A strength in the vitamin C determinations is that they were performed in the same laboratory in Finland, which minimizes the errors between the areas within each study year.

Conclusions

On the basis of our present results as well as our previous findings[10], simple questions on the consumption of fresh vegetables and fruit seem to be a feasible, simple and effective measure of the quality of diet and its vitamin C content. As the importance of vegetables and fruit varies according to the target population of the study, it is important to include both indicator questions in future survey questionnaires.

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