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Healthy diet indicator and mortality in Eastern European populations: prospective evidence from the HAPIEE cohort

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Abstract

Background/Objectives—Unhealthy diet has been proposed as one of the main reasons for the high mortality in Central and Eastern Europe (CEE) and the former Soviet Union (FSU) but individual-level effects of dietary habits on health in the region are sparse. We examined the associations between the healthy diet indicator (HDI) and all-cause and cause-specific mortality in three CEE/FSU populations.

Subjects/Methods—Dietary intakes of foods and nutrients, assessed by food frequency questionnaire (FFQ) in the Health, Alcohol and Psychosocial Factors in Eastern Europe (HAPIEE) cohort study, were used to construct the HDI which follows the WHO 2003 dietary recommendations. Among 18 559 eligible adult participants (age range: 45-69 years) without history of major chronic diseases at baseline, 1 209 deaths occurred over mean follow up of 7 years. The association between HDI and mortality was estimated by Cox regression.

Results—After adjusting for covariates, HDI was inversely and statistically significantly associated with cardiovascular disease (CVD) and coronary heart disease (CHD) mortality, but not with other cause-specific and all-cause mortality in the pooled sample. Hazard ratios per one standard deviation (SD) increase in HDI score were 0.95 (95%CI 0.89-1.00, p=0.068), 0.90 (0.81-0.99, p=0.030) and 0.85 (0.74-0.97, p=0.018) for all-cause, CVD and CHD mortality, respectively. Population attributable risk fractions for low HDI were 2.9% for all-cause, 14.2% for CVD and 10.7% for CHD mortality.

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Conclusions—These findings support the hypothesis that unhealthy diet has played a role in the high CVD mortality in Eastern Europe.

Keywords

Eastern Europe; healthy diet indicator; mortality; cohort studies

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INTRODUCTION

Diet has often been proposed to be one of the principal reasons for the higher total and cardiovascular disease (CVD) mortality in the countries of Central and Eastern Europe (CEE) and the former Soviet Union (FSU) compared to Western Europe.[1-5] Despite the strong indirect evidence from ecological data,[6,7] few studies examined the link between food or nutrient intakes and health outcomes in CEE/FSU. We found only one study which investigated this relationship by taking into account diet as a whole, using ‘a priori’ diet quality scores.[8]

Predefined diet quality scores are valuable tools to assess nutritional habits of individuals and populations. They reflect a more comprehensive picture of diet than individual food or nutrient intakes and provide a more holistic approach to study the relationship between diet and health.[9-13] Healthy diet indicator (HDI) was originally developed in 1997, reflecting the WHO’s 1990 dietary recommendations for the prevention of chronic diseases.[14,15] Being based on international guidelines, it is often used in cross-cultural settings. It has been shown to be associated with overall and CVD mortality;[15,16] however, no such association was observed in a recent Swedish study using an adapted score.[17]

In this study, we examined the associations between HDI and deaths from all-causes and from major groups of causes of death in three large population-based cohorts in CEE and FSU. We used an updated version of the HDI which was constructed to reflect more recent WHO’s dietary recommendations published in 2003.[18] We hypothesised that higher HDI scores (reflecting better quality diet) would be associated with lower mortality risk.

SUBJECTS AND METHODS

Participants and follow-up

The HAPIEE study was set up to investigate determinants of mortality in CEE and FSU populations.[19] The baseline survey in 2002-2005 recruited population samples of men and women aged 45-69 years (randomly selected from population/electoral registers) in Novosibirsk (Russia), Krakow (Poland) and six cities in the Czech Republic. The study recruited a total of 28 945 persons (overall response rate of 59%). Subjects completed an extensive questionnaire, provided blood sample and underwent an examination. All participants signed informed consent form. The study protocols were approved by ethical committees at University College London and all participating centres.

Deaths in the three cohorts were ascertained using local death registers in Krakow and Novosibirsk and national death register in the Czech Republic. The mean follow-up time was 7.0 years. In addition to all causes, we investigated the major groups of causes of death:

CVD (ICD-10 codes I00-I99), CHD (I20-I25), stroke (I60-I69), cancer (C00-D48) or causes other than those above (non-CVD-non-cancer). Information on the cause of death was not available for 65 participants (0.4% of the analytical sample). These subjects were included in the analysis if the outcome was all-cause mortality, but excluded when the association between HDI and cause-specific mortality was analysed.

Dietary assessment

Dietary data collection from the study participants has been described in detail elsewhere.[20] Briefly, a semi-quantitative food frequency questionnaire (FFQ), based on the instrument developed by Willett and colleagues[21] subsequently modified for the Whitehall II study[22], was used to assess participants' dietary habits in the previous three months. The list of foods and drinks on the FFQ consisted of 136, 147 and 148 items in the Czech Republic, Russia and Poland, respectively. Nutrient intake levels were calculated using the McCance and Widdowson Food Composition Database, local food composition tables, US Department of Agriculture nutrient database (one item) and manufacturer data (one item).

The validity of the FFQ regarding fruit, vegetable and micronutrient intake data was assessed by estimating correlations with plasma biomarker concentrations measured in a central laboratory (CTSU, Oxford) in a random sub-sample of participants. Table S1 in supplementary material shows the partial Pearson's correlation coefficients between fruit, vegetable, vitamin C, beta-carotene intakes from FFQ and vitamin C and beta-carotene plasma concentrations. On the whole, correlations were similar to other published large scale studies,[23-25] suggesting acceptable validity of the dietary data in HAPIEE study for fruit, vegetable, vitamin C and beta-carotene intakes.

Construction of the HDI scores

The HDI was constructed to reflect the WHO's dietary recommendations for the prevention of chronic diseases published in 2003.[18] From the 15 dietary items listed in the WHO guideline, nine were included in the score. Total fat, total polyunsaturated fatty acids, monounsaturated fatty acids and total carbohydrates were excluded to avoid overlap with other components of the score, and sodium was also excluded because information was unavailable. As opposed to the dichotomised scoring method used in the original HDI study,[15] we applied continuous scoring to reflect the fact that the health effect of various nutritional factors does not follow definite cut-off points, and to provide greater variation between individuals. The scoring criteria for the different components, together with the median (IQR) component scores by cohort and sex, are shown in table 1.

Analytical sample

We excluded individuals whose mortality data could not be linked to the baseline questionnaire due to missing national ID number or refusal to be followed up (n=1 183), participants with more than 15 missing FFQ answers (n=644) and those who answered '*no*' to the question whether the foods and drinks listed in the FFQ are representative of their diet (n=737). Energy misreporting was assessed using the energy intake (EI) to basal metabolic rate (BMR) ratio.[26] In order to exclude those who reported implausible dietary data, participants in the lowest and highest 1% of the EI/BMR distribution were excluded from

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the analysis (n=523). To avoid potential reverse causation bias, we also omitted 7 299 subjects with prevalent CVD, diabetes or cancer. A total of 18 559 participants (5 632 Czechs, 6 278 Poles and 6 649 Russians) were included in the analysis.

Handling of covariates with missing data

There were 1 374 participants (7.4% of the analytical sample) with missing data in at least one of the following covariates: marital status, BMI, smoking, education, household amenities score and physical activity. Sensitivity analysis showed that characteristics such as age, sex or alcohol intake could explain most (but not all) of the association between "missingness" and above mentioned covariates with missing data in all three cohorts. For this reason we could assume that these data were missing at random and we could carry out multiple imputation using the "mi impute chained" command in STATA version 12.1. Ten imputed datasets were created, and the following predictor variables were included:[27] age, sex, alcohol intake, energy intake, HDI, follow-up time and all-cause mortality. The procedure was carried out separately for each cohort. Further sensitivity analysis showed that imputation did not materially alter the main results when compared to the listwise deletion approach, however, as expected, the confidence intervals became narrower. Results presented here are based on imputed data.

Statistical analysis

We used simple, multinomial and ordered logistic regression to compare HDI scores between covariate categories, and p-values of the crude and age, sex, country and energy intake adjusted comparisons were reported.

Cox regression was used to investigate the association between the HDI score and all-cause and cause-specific mortality. The estimated hazard ratios (HR) indicated the change in mortality risk by one standard deviation (SD) increase in HDI score. One SD was equal to 8.93 points in the HDI score.

Because no interactions between countries and HDI were detected, we calculated the results of the Cox regression in the pooled sample, as well as by country cohorts. The analyses were conducted in three steps. First, HDI was adjusted for age (continuous), sex and cohort. Second, HDI was further adjusted for the highest level of education (primary or less, vocational, secondary, university), household amenities score (number of household amenities possessed; 0-5: low, 5-7: moderate, 8-12: high), marital status (married/cohabiting, single/divorced/widowed), alcohol intake (abstainers; moderate drinkers: <15g/day for women, <30g/day for men; heavy drinkers: ≥15g/day for women, ≥30g/day for men), smoking (non-, ex-, current smokers), physical activity (inactive, moderately active, active; based on cross-tabulating the sex specific quartiles of leisure time physical activity expressed in MET-hours/day with occupational activity categories[28-30]) and energy intake (MJ/day continuous). BMI was not included; as it could be on the causal pathway, controlling for BMI might lead to over-adjustment. Finally, we assessed whether the differences in death rates between cohorts could be explained by HDI by comparing age-sex-adjusted hazard ratios with the Czech cohort before and after additionally adjusting for HDI.

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Population attributable risk (PAR%) for quartiles of HDI was calculated with the standard formula for polytomous risk factors.[31]

All statistical analyses were carried out using the 12.1 version of the statistical software STATA *(StataCorp, Texas, USA).*

RESULTS

Baseline characteristics

Table 2 describes the demographic, socio-economic and lifestyle characteristics of the study participants in the whole sample and by cohorts. The proportion of females was higher than males in all study centres, and there was no significant difference in the median age between centres and genders. Energy intake in Russia was higher than in the other two cohorts in both sexes but BMI was increased only in females, which is consistent with the relatively high proportion of Russian men who were physically active.

HDI by covariate categories

Table 3 presents the mean (SD) HDI scores by covariate categories. The differences in HDI score between country cohorts were due to different scores for specific HDI components (table 1). In particular, the intakes of n-3 and n-6 polyunsaturated fatty acids and mono/disaccharides were further from the WHO recommendations amongst Polish participants compared to Czechs and Russians, which resulted in lower component scores, and consequently, lower overall HDI score in this cohort.

HDI scores were higher in women and older participants, and scores were lower in heavy drinkers and current smokers. Surprisingly, the mean HDI score seemed lower in people with higher education and in subjects with higher household amenities score.

Cox regression models

Table 4 shows the results of the Cox regression analysis of the pooled sample and in each cohort. In the pooled sample, HDI was inversely and statistically significantly associated with CVD and CHD mortality but not with deaths from other causes. As a result, there was an inverse but statistically not significant association with all-cause mortality. Most cohort specific results were similar; there were statistically significant associations between HDI and both CVD and CHD mortality in the Russian cohort and with all-cause mortality in the Polish cohort. The adjustment for covariates (model 2) resulted in a small attenuation in the strengths of most associations but did not radically change the pattern of results.

When HDI was classified into four categories, the results indicated an approximately linear relationship between HDI score and CVD and CHD mortality (Table S2 and figure S1 in supplementary material).

When the analysis included subjects with prevalent diabetes, CVD or cancer (increasing the sample size to 25 858), we found no significant associations between HDI and CVD or CHD mortality but there was a suggestion of an inverse association with non-CVD-non-cancer mortality and with all-cause mortality (Table S3 in supplementary material). This finding

supports the view that people who are diagnosed with chronic diseases are likely to improve their diet as a result of their condition, and that this reverse causation can have significant impact on the associations observed.

We also assessed the effects on mortality of the original HDI score, based on the earlier dichotomous scoring method by Huijbregts and colleagues in 1997.[15] We found no association between this “original” HDI and mortality outcomes (Table S4 in supplementary material).

The population attributable risk fractions, using the highest HDI quartile as reference group, were 2.9% for all-cause mortality, 14.2% for CVD mortality and 10.7% for CHD mortality (not shown in table). However, the differences in all-cause and CVD mortality between the cohorts, with the Czech cohort as the reference category, did not change considerably after adjustment for the HDI scores, suggesting that HDI explains little of the differences in mortality between these populations (Table 5).

DISCUSSION

In this large prospective cohort study in CEE and FSU, we found significant inverse associations of HDI with mortality from CVD and CHD, but not with stroke, cancer or non-CVD-non-cancer causes of death. The population attributable risk fractions for CVD due to unhealthy diet, assessed by the WHO dietary guidelines operationalised as HDI, was not trivial. The results also indicated that although the average HDI score differed significantly between healthy general population samples of Czechs, Poles and Russians, this difference in dietary habits explained a relatively small proportion of the mortality differences between the cohorts.

Several limitations of the study need to be considered when interpreting the results. First, the moderate response rates, restricted age range and the lack of participants from rural areas affect the generalizability of the results to national trends. However, response rates were similar to other surveys in CEE/FSU,[32,33] and previous analysis showed that the actual response rates were probably higher than those reported here.[19] The restriction of the cohorts to selected urban centres, and absence of rural population samples mean that the results cannot be automatically extrapolated to whole countries. Although levels and trends in mortality in the participating study centres reflect national-level data,[34] dietary habits in the larger towns and cities included in our study may not fully represent national nutritional status. However, the lack of national representativeness does not affect the internal validity of the findings regarding the association between HDI and mortality.

The second major issue, common to most nutritional epidemiology, relates to measurement of diet. FFQ has well known limitations; it tends to be semi-quantitative, rather than fully quantitative, and it tends to over- or underestimate dietary intakes.[35,36] Consequently, assigning HDI scores may be imprecise, although it is likely that the ranking of subjects (in term of HDI) is unbiased. The misclassification is likely to be random, leading to underestimating the effects of diet on mortality. This may be one of the explanations of the relatively weak associations of HDI with mortality in our study.

Third, although the FFQ has been validated regarding the intakes of fruits, vegetables and selected micronutrients, other components of the HDI were constructed using dietary data which has not been confirmed by other assessment method or biomarkers.

Finally, one may also speculate about the cultural suitability of HDI. Although it was developed to provide international guidance, it may not be fully applicable to all populations. Dietary recommendations and food based dietary guidelines are not completely similar in the three countries, and also show some differences from those in Western Europe.[37] Local guidelines take local deficiencies and dietary habits into account, and therefore may be more strongly associated with mortality as the more global one from the WHO. It is possible that adapting the score to country-specific nutritional guidelines may further improve its ability to predict mortality. A further disadvantage of HDI is that it is primarily based on nutrients and not foods, which can make the results difficult to interpret for public health promotion purposes.

This study also has important strengths. This is by far the largest study of diet and mortality in CEE and FSU to date. Given the high mortality and, anecdotally, poor diet in Eastern Europe, this study fills in important gap in what is known about nutrition and health in the region. Although FFQ is not a flawless instrument, we used a version very similar to those used in other major cohort studies, and, given the central protocol across all centres for this study, the measurements are comparable across cohorts. The study is sufficiently large to provide good statistical power to detect meaningful associations with most mortality outcomes investigated.

Similar to our findings, international literature on the association of HDI with cause-specific mortality is not entirely consistent. Although several studies showed inverse associations with CVD, no relationship between diet quality scores and cancer mortality has often been reported.[10] Possible reasons for such inconsistencies may be heterogeneity of aetiology of different cancer types, the length of follow up needed for cancer to develop and low statistical power to assess site-specific cancers.

It has been proposed that dietary factors made an important contribution to the high mortality rates in countries of CEE and FSU. Ecological studies have shown strong correlations of consumption of various types of fats and fresh fruits/vegetables with national mortality rates,[1,6,38] and two studies found low concentrations of antioxidant vitamins in Eastern European population samples.[39,40] Our results confirm these previous findings and suggest that unhealthy diet plays an important role in the high CVD mortality rates of Eastern European populations. The fact that our analysis included only cohorts from CEE and FSU populations should be considered interpreting the finding that HDI explained only small proportion of the between-cohort mortality differences. Wider selection of populations with more variation in mortality and diet and other instruments to assess diet quality would help to clarify the extent of which unhealthy diet contributes to the East-West mortality divide.

Dietary habits can be improved by education or other forms of public health interventions.[41,42] Our results suggest that a healthier diet would lead to reduced CVD

burden in CEE and FSU. However, further studies focusing on individual foods and food groups in relation to health outcomes are necessary to identify which area of the diet needs special attention, so that more effective public health campaigns can be designed in this region.

On the whole, although HDI may not be the perfect measure of diet quality, our results suggest that poor diet has an impact on CVD mortality in CEE and FSU countries. These findings are consistent with existing evidence that diet quality is associated with CVD, and they support the hypothesis that diet has played a role in the high mortality in Eastern Europe.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Scoring criteria of the HDI score and median component scores by country and sex

Components of the HDI scores	Scoring criteria			Median scores (IQR)					
	0 point	0 - 10 points	10 points	CZECH		POLISH		RUSSIAN	
				Males	Females	Males	Females	Males	Females
SFAs, *energy%*	>15	10-15	0-10	2.3 (0.0-5.4)	3.3 (0.2-6.6)	0.0 (0.0-3.2)	1.0 (0.0-4.6)	0.3 (0.0-3.7)	1.5 (0.0-4.9)
n3-PUFAs, *energy%*	>3	0-1 or 2-3	1-2	4.2 (3.3-5.4)	4.5 (3.5-5.6)	3.2 (2.4-4.3)	3.0 (2.2-4.0)	5.4 (4.2-7.3)	6.2 (4.9-8.6)
n6-PUFAs, *energy%*	>13	0-5 or 8-13	5-8	4.7 (3.7-5.7)	4.5 (3.5-5.6)	3.4 (2.6-4.5)	3.1 (2.4-4.2)	6.6 (4.7-8.8)	7.5 (5.5-9.8)
Trans fatty acids, *energy%*	>2	1-2	<1	9.7 (7.8-10.0)	9.8 (7.7-10.0)	9.7 (7.4-10.0)	9.9 (7.8-10.0)	10.0 (9.2-10.0)	10.0 (10.0-10.0)
Mono- and disaccharides, *energy%*	>30	10-30	0-10	4.4 (2.3-6.5)	2.5 (0.0-4.7)	4.4 (2.5-6.2)	2.8 (0.7-4.8)	6.2 (4.8-7.6)	5.1 (3.2-6.6)
Protein, *energy%*	>25	0-10 or 15-25	10-15	6.9 (4.9-8.6)	7.6 (5.7-9.4)	6.8 (5.2-8.3)	7.1 (5.4-8.6)	7.4 (5.8-8.9)	7.8 (5.8-9.6)
Cholesterol, *mg/day*	>400	300-400	0-300	10.0 (1.5-10)	10.0 (6.1-10.0)	0.3 (0.0-8.1)	6.5 (0.0-10.0)	0.0 (0.0-2.3)	2.2 (0.0-10.0)
Fruits/vegetables, *g/day*	0	0-400	>400	10.0 (6.3-10.0)	10.0 (9.4-10.0)	10 (7.2-10.0)	10 (8.6-10.0)	8.2 (6.0-10.0)	9.5 (6.8-10.0)
NSP, *g/day*	0	0-20	>20	7.7 (5.9-10.0)	8.8 (6.6-10.0)	9.0 (7.1-10.0)	9.1 (7.0-10.0)	8.7 (7.2-10.0)	8.4 (6.8-10.0)

SFA – saturated fatty acid, PUFA – polyunsaturated fatty acid, NSP – non-starch polysaccharides energy% – percentage of daily alcohol-free energy intake

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Table 2

Baseline socio-demographic and lifestyle characteristics of the analytical sample

		CZECH		POLISH		RUSSIAN		ALL
		Males	Females	Males	Females	Males	Females	
n (%)		**2555 (45)**	**3077 (55)**	**3003 (48)**	**3275 (52)**	**3022 (45)**	**3627 (55)**	**18 559 (100)**
Median age, *years* (IQR)		**56.9 (51.1-63.3)**	**56.4 (50.9-62.7)**	**56.1 (50.5-62.5)**	**55.1 (50.1-61.5)**	**57.0 (51.4-63.7)**	**56.5 (50.7-63.8)**	**56.3 (50.7-63.0)**
Median BMI, *kg/m²* (IQR)		**27.4 (25.2-30.0)**	**26.7 (24.0-30.1)**	**27.1 (24.8-29.6)**	**27.0 (24.0-30.7)**	**25.9 (23.3-28.8)**	**29.2 (26.0-33.1)**	**27.2 (24.5-30.5)**
Median energy intake, *MJ/day* (IQR)		**8.6 (7.1-10.5)**	**7.8 (6.3-9.7)**	**9.5 (7.8-11.6)**	**8.6 (7.1-10.3)**	**11.4 (9.5-13.8)**	**9.7 (8.0-11.7)**	**9.3 (7.5-11.4)**
		%	%	%	%	%	%	%
Marital status[1]	Single/divorced/wid.	16.0	30.5	12.0	31.8	12.0	38.8	24.4
	Married/cohabiting	84.0	69.5	88.0	68.2	88.0	61.2	75.6
Education[1]	Incomplete/primary	5.2	15.4	8.1	10.9	10.6	8.4	9.9
	Vocational	43.5	29.0	26.0	14.9	20.8	30.8	27.0
	Secondary University	31.3	44.1	33.1	43.1	37.4	32.8	37.1
	University	19.9	11.5	32.7	31.1	31.2	28.0	26.0
Household	Low	11.8	17.5	14.1	21.2	23.7	34.8	21.2
amenities score[1]	Moderate	39.1	44.2	43.9	46.7	49.1	46.6	45.2
	High	49.1	38.3	42.0	32.1	27.2	18.6	33.6
Smoking habits[1]	No smoker	34.9	53.9	30.2	49.7	25.8	84.2	48.1
	Ex-smoker	33.1	20.7	32.0	19.6	21.7	4.3	21.0
	Current smoker	32.0	25.4	37.8	30.7	52.4	11.5	30.9
Alcohol intake	Abstainers	9.2	32.8	29.4	61.3	17.7	32.2	31.4
	Moderate drinkers	78.1	63.0	68.1	37.8	71.8	67.0	63.7
	Heavy drinkers	12.8	4.2	2.5	0.9	10.5	0.9	4.9
Physical activity[1]	Inactive	46.8	53.3	47.8	51.5	40.2	51.6	48.7
	Moderately active	39.3	38.8	41.8	40.9	41.3	40.1	40.4
	Active	13.9	7.9	10.4	7.6	18.5	8.3	10.9

[1] including imputed data

Table 3

HDI scores by covariate categories

Covariate[1]	Category	Mean HDI score (SD)	p-value (crude)	p-value (adjusted)[2]
Cohort[3]	Czech	55.8 (8.0)	ref.	ref.
	Polish	49.8 (7.1)	<0.001	<0.001
	Russian	57.3 (9.2)	<0.001	<0.001
Sex[4]	Males	52.7 (8.5)		
	Females	55.7 (8.9)	<0.001	<0.001
Age groups[5]	<50 years	53.6 (8.4)		
	50-54 years	53.7 (8.6)		
	55-59 years	54.2 (8.8)		
	60-64 years	54.8 (9.0)		
	65+ years	55.7 (9.3)	<0.001	<0.001
Marital status[4]	Single/divorced/widowed	55.5 (9.4)		
	Married/cohabiting	53.9 (8.6)	<0.001	0.433
Household	Low	55.8 (9.6)		
amenities score[5]	Moderate	54.3 (8.8)		
	High	53.3 (8.2)	<0.001	0.006
Education[5]	Incomplete/primary	54.8 (9.3)		
	Vocational	55.0 (8.8)		
	Secondary	54.2 (8.7)		
	University	53.6 (8.8)	<0.001	0.003
Education[5]	Low (<8MJ/day) Moderate (8-10MJ/day)	55.7 (8.9) 54.9 (9.6)		
	High (>10MJ/day)	52.9 (8.0)	<0.001	<0.001
BMI[5]	Low (<25kg/m^2)	53.8 (8.8)		
	Moderate (25-30kg/m^2)	54.2 (8.7)		
	High (>30kg/m^2)	55.1 (9.0)	<0.001	<0.001
Alcohol intake[5]	Abstainers	54.2 (9.1)		
	Moderate drinkers	54.4 (8.7)		
	Heavy drinkers	53.7 (8.5)	0.514	0.006
Smoking habits[3]	No smoker	55.6 (9.0)	ref.	ref.
	Ex-smoker	53.6 (8.4)	<0.001	0.772
	Current smoker	52.8 (8.6)	<0.001	<0.001
Physical activity[5]	Inactive	54.6 (9.1)		
	Moderately active	54.4 (8.7)		
	Active	53.8 (8.2)	0.006	0.810

ref. - reference categoy

[1] Only participants with complete data were included;

[2] cohort, sex, age and energy intake adjusted p-values;

[3] p-values calculated with multinomial logistic regression;

[4] p-values calculated with simple logistic regression;

[5] p-values calculated with ordered logistic regression

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Table 4

Results of Cox-regression analysis for the association between HDI and mortality on the pooled and country specific samples (n=18 559)

Cause of death	Sample	Dead/n	Model 1		Model 2	
			HR/SD (95%CI)[1]	p-value	HR/SD (95%CI)[1]	p-value
All-cause	**Pooled**	**1209/18 559**	**0.94 (0.89, 1.00)**	**0.055**	**0.95 (0.89, 1.00)**	**0.068**
	Czech	330/ 5632	0.96 (0.85, 1.08)	0.512	0.97 (0.86, 1.09)	0.611
	Polish	343/ 6278	0.83 (0.72, 0.95)	0.007	0.86 (0.75, 0.98)	0.027
	Russian	536/ 6649	0.99 (0.91, 1.08)	0.879	0.98 (0.90, 1.06)	0.506
CVD	**Pooled**	**423/18 494**	**0.89 (0.81, 0.99)**	**0.030**	**0.90 (0.81, 0.99)**	**0.030**
	Czech	102/ 5630	0.95 (0.77, 1.18)	0.646	0.95 (0.77, 1.17)	0.620
	Polish	92/ 6256	0.94 (0.72, 1.22)	0.632	0.96 (0.74, 1.25)	0.762
	Russian	229/ 6608	0.88 (0.77, 1.00)	0.048	0.87 (0.77, 0.99)	0.029
CHD	**Pooled**	**220/18 494**	**0.85 (0.74, 0.97)**	**0.020**	**0.85 (0.74, 0.97)**	**0.018**
	Czech	43/ 5630	0.94 (0.68, 1.30)	0.698	0.98 (0.71, 1.35)	0.907
	Polish	41/ 6256	0.77 (0.52, 1.14)	0.197	0.84 (0.57, 1.25)	0.400
	Russian	136/ 6608	0.84 (0.71, 1.00)	0.044	0.83 (0.70, 0.97)	0.020
Stroke	**Pooled**	**105/18 494**	**0.95 (0.78, 1.16)**	**0.623**	**0.96 (0.79, 1.16)**	**0.657**
	Czech	17/ 5630	0.89 (0.53, 1.48)	0.644	0.87 (0.52, 1.46)	0.600
	Polish	19/ 6256	1.22 (0.70, 2.14)	0.485	1.20 (0.67, 2.13)	0.540
	Russian	69/ 6608	0.95 (0.76, 1.19)	0.653	0.95 (0.76, 1.19)	0.657
Cancer	**Pooled**	**437/18 494**	**0.98 (0.88, 1.08)**	**0.670**	**0.98 (0.89, 1.09)**	**0.712**
	Czech	153/ 5630	0.96 (0.81, 1.14)	0.654	0.97 (0.82, 1.16)	0.760
	Polish	143/ 6256	0.84 (0.68, 1.04)	0.102	0.86 (0.69, 1.06)	0.151
	Russian	141/ 6608	1.10 (0.94, 1.29)	0.223	1.08 (0.92, 1.27)	0.345
Non-CVD-non-cancer	**Pooled**	**284/18 494**	**0.96 (0.84, 1.09)**	**0.500**	**0.96 (0.84, 1.08)**	**0.474**
	Czech	73/ 5630	0.97 (0.75, 1.25)	0.795	0.98 (0.76, 1.26)	0.881
	Polish	86/ 6256	0.71 (0.54, 0.94)	0.030	0.76 (0.58, 1.00)	0.053
	Russian	125/ 6608	1.08 (0.91, 1.29)	0.379	1.03 (0.87, 1.22)	0.702

Model 1: adjusted for age, sex, cohort

Model 2: adjusted for age, sex, cohort, education, household amenities score, marital status, smoking, alcohol intake, energy intake, physical activity

[1] effect of one standard deviation (SD) increase in the score; CVD - cardiovascular disease; CHD - coronary heart disease

Table 5

Hazard ratios of cohort differences in all-cause and CVD mortality with and without adjustment for HDI (n=18 559)

Cause of death	Strata	Cohort	Model 1		Model 2		
			HR (95% CI)	p-value	HR (95% CI)	p-value	Percentage change in HR[1]
All-cause	Pooled	Czech	1.0		1.0		
		Polish	1.18 (1.01, 1.38)	0.035	1.14 (0.97, 1.34)	0.114	−3.4%
		Russian	1.97 (1.70, 2.27)	<0.001	1.98 (1.71, 2.28)	<0.001	+0.5%
	Males	Czech	1.0		1.0		
		Polish	1.06 (0.87, 1.29)	0.559	1.03 (0.84, 1.26)	0.767	−2.8%
		Russian	2.20 (1.85, 2.62)	<0.001	2.20 (1.85, 2.62)	<0.001	0%
	Females	Czech	1.0		1.0		
		Polish	1.48 (1.13, 1.92)	0.002	1.41 (1.07, 1.85)	0.015	−4.7%
		Russian	1.51 (1.16, 1.97)	0.004	1.54 (1.18, 2.00)	0.001	+2.0%
CVD	Pooled	Czech	1.0		ref.		
		Polish	1.08 (0.81, 1.45)	0.602	1.01 (0.75, 1.36)	0.963	−6.5%
		Russian	2.86 (2.23, 3.67)	<0.001	2.89 (2.25, 3.71)	<0.001	+1.0%
	Males	Czech	1.0		1.0		
		Polish	0.83 (0.58, 1.20)	0.319	0.77 (0.53, 1.13)	0.181	−7.2%
		Russian	3.04 (2.27, 4.08)	<0.001	3.05 (2.27, 4.09)	<0.001	+0.3%
	Females	Czech	1.0		1.0		
		Polish	1.82 (1.10, 3.02)	0.020	1.72 (1.02, 2.89)	0.042	−5.5%
		Russian	2.42 (1.50, 3.91)	<0.001	2.47 (1.53, 3.99)	<0.001	+2.0%

Model 1: adjusted for age, sex

Model 2: adjusted for age, sex, HDI

[1]Compared to model 1;