Estimating the changes in the burdens of cardiovascular diseases and diabetes from dietary and metabolic transitions in Korea 1998-2011

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-013283
Article Type:	Research
Date Submitted by the Author:	04-Jul-2016
Complete List of Authors:	Cho, Yoonsu; Korea University, Department of Public Health Sciences Cudhea, Frederick; Tufts University Friedman School of Nutrition Science and Policy, Friedman School of Nutrition Science & Policy Park, Ju-Hyun; Dongguk University, Department of Statistics Lee, Jong-Tae; Korea University, Department of Public Health Sciences Mozaffarian, Dariush; Friedman School of Nutrition Science and Policy, Tufts University, Friedman School of Nutrition Science & Policy Singh, Gitanjali; Tufts University Friedman School of Nutrition Science and Policy, Friedman School of Nutrition Science & Policy Shin, Min-Jeong; Korea University, Department of Public Health Sciences
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Global health
Keywords:	burden of disease, dietary risk, metabolic risk, cardiometabolic disease, cardiovascular disease

Estimating the changes in the burdens of cardiovascular diseases and diabetes from dietary and metabolic transitions in Korea 1998-2011

Yoonsu Cho[1], Frederick Cudhea[2], Ju-Hyun Park[3], Jong-Tae Lee[1], Dariush Mozaffarian[2], Gitanjali Singh[2,*], Min-Jeong Shin[1,*]

[1]Department of Public Health Sciences, BK21PLUS Program in Embodiment: Health-Society Interaction, Graduate School, Korea University, Seoul 136-701, Republic of Korea, [2]Friedman School of Nutrition Science & Policy, Tufts University, Boston, Massachusetts, USA, [3]Department of Statistics, Dongguk University, Seoul, Republic of Korea

*Correspondence and request for reprints: Singh G and Shin MJ jointly directed this study. **Gitanjali Singh**, Friedman School of Nutrition Science and Policy, Tufts University, 150 Harrison Avenue, Boston, MA 02111, USA; Tel: +1-617-636-3737; E-mail: Gitanjali.Singh@Tufts.edu; **Min-Jeong Shin**, Department of Public Health Sciences, Graduate School, Korea University, Seoul 136-701; Korea University Guro Hospital, Korea University, Seoul 152-703, Republic of Korea); Tel: +82-2-3290-5643; Fax: +82-2-940-2849; E-mail: mjshin@korea.ac.kr

Keywords: burden of disease, dietary risk, metabolic risk, cardiometabolic disease, cardiovascular disease

Word count: 4456

ABSTRACT

OBJECTIVES: Over the past 10 years, the burden of chronic diseases in Korea has increased. However, there are currently no quantitative estimates of how changes in diet and metabolic risks have contributed to these shifting burdens. This study aims to evaluate the contributions of dietary and metabolic factors to cardiometabolic diseases (CMDs) such as cardiovascular conditions, strokes, and diabetes in Korea, and to estimate how these contributions have changed over the past 10 years. **DESIGN AND METHODS:** We used data on the risk factors by sex, age, and year from the Korea National Health and Nutrition Examination Survey. The relative risks for the effects of the risk factors on the cause-specific mortality were obtained from meta-analyses. The population-attributable fraction (PAF) attributable to the risk factors was calculated by using comparative risk assessment approach across sex and age strata (males and females, age groups 25-34, 35-44, 45-54, 55-64, 65-74, and 75+) from 1998 to 2011. **RESULTS:** The results showed that a suboptimal diet and high blood pressure were the main risk factors of CMD mortality in Korea. High blood pressure accounted for 127095.7 (UIs: 121907.0, 132217.5) deaths from CMD. Among the individual dietary factors, a high intake of sodium (42387.0 deaths; UIs: 42387.0, 65093.6) and a low intake of fruits (50243.8 deaths; UI: 40981.4, 59178.2) and whole grains (54248.2 deaths; UIs: 47020.0, 61343.0) were responsible for the highest number of CMD deaths in Korea. **CONCLUSIONS:** The results implicate that metabolic and dietary risk factors were major contributor to CMD mortality in Korea. Providing relative importance of risk factors in Korea, the results can contribute to development of the evidence-based national government policies to manage major risk factors and prevent the mortality from CMDs in Korea.

Main strengths and limitations of study

- This is the first investigation to analyse data from national individual-based surveys to evaluate the diet consumption and its transition over time in Korea.
- The study provides most detailed result, focusing on the nation-specific impacts of dietary and metabolic risk factors on CMDs to identify national priorities for management and prevention of CMDs.
- The analysis of risk factors has focused on selected risk factors including dietary and metabolic risks. The further study with behavioural risk factors is required in current population.

INTRODUCTION

Along with rapid socio-economic changes, cardiometabolic diseases (CMDs) including cardiovascular disease (CVD) and diabetes mellitus (DM) have been the leading cause of global death, killing 38 million people. Corresponding to global trend, the burden of CMDs has dramatically increased in Korea.[1 ,2] According to data from the Korea National Statistics, more than 45% of deaths in Korea are caused by non-communicable diseases such as CVD and DM.[3]

The increased prevalence of suboptimal lifestyles and metabolic risk factors are important modifying risk factors of CMDs.[4-6] Previous global burden of disease (GBD) study reported that the global and regional burdens of chronic diseases were attributable to multiple risk factors and advocated the systematic assessment of multiple dietary risk factors for CMD, called comparative risk assessment (CRA).[7] There have been previous efforts to estimate the comparable contributions of selected dietary and metabolic risk factors based on national estimates from various regions, using CRA approach.[8-11] However, most of the current estimates of dietary factors have focused on Western countries, making it hard to represent the population-specific effects. So far, there is only one study on burden of disease with China population among the Asian countries. The burden of disease study in China emphasized that the necessity of nation-specific estimates for chronic diseases to reflect region specific changes in health and surveillance system.[12]

Similarly, the burden of disease in Korea shows unique characteristics, based on nation's distinctive epidemiological and sociocultural contexts.[1] Korea has experienced rapid socio-cultural changes, including rapid economic growth, and constant westernization, which has been accompanied by ageing society, a decline of physical activity, an increase of energy intake, and an increase of body weight.[1 ,13] In addition, Korea has a unique diet characterized by a higher level of refined carbohydrates and pickled vegetables than Western countries and other Asian countries. To address these nation-specific gaps, it is necessary to characterize and estimate the effects of dietary risk factors on the mortality from chronic disease in Korea population. Yet, with the absence of systematic and comparable methods to estimate the nationally representative burden of risk, it is hard to obtain an accurate estimation of the effects of dietary and metabolic risk factors on CMDs in Korea. The quantitative estimates of the changes in the burdens of CMDs caused by dietary and metabolic transitions could provide a better understanding of the ways changes in diet have contributed to these shifting burdens.

The aim of the current study was to evaluate the contributions of dietary and metabolic factors to chronic diseases such as CVD, stroke, and DM in Korea. We also aimed to estimate the trends these contributions have changed over the past 10 years.

METHODS

We conducted a population-level comparative risk assessment analysis (CRA) of 6 dietary and 4 metabolic factors in order to estimate the number of deaths from chronic diseases in Korea. Detailed information on CRA is available elsewhere.[7] Briefly, using CRA, we estimated the number of deaths that would have been prevented within the period of analysis if the current distribution of each risk factor exposure had been changed to a hypothetical alternative distribution.

Selection of risk factors

Dietary and metabolic factors in this analysis were selected based on the following criteria, as described previously:[9 ,14] 1) the risk factors presented probable or convincing evidence of effects on cardiovascular diseases, strokes, or DMs and 2) data from the nationally representative health and nutrition survey in Korea was available. The dietary factors included low intakes of fruit, vegetables, and whole grains, and high intakes of processed meats, unprocessed meats (red meats), and sodium (Table 1). The metabolic factors included high levels of fasting plasma glucose (FPG), total cholesterol (TC), systolic blood pressure (SBP), and body mass index (BMI).

Table 1. Data sources for age, sex, and year-specific estimates of dietary intakes, metabolic risk factor exposure levels, optimal risk factor distributions, the etiologic effects of risk factors on disease, and disease-specific mortality.

Dietary risks	Definition	Data source (Available year)	Theoretical minimum risk exposure level	Related disease outcomes
Low intake of fruits[1]	Average daily consumption of fruits (fresh, frozen, cooked, canned, or dried, excluding salted or pickled fruits)	KNHANES (1998-2011)	300 ± 30 g/day	IHD, ISTK, HSTK
Low intake of vegetables[2]	Average daily consumption of vegetables (fresh, cooked, canned, or dried vegetables)	KNHANES (1998-2011)	400 ± 40 g/day	IHD, ISTK, HSTK
Low intake of whole grains	Average daily consumption of whole grains such as barley, and cereal	KNHANES (1998-2011)	125 ± 12.5 g/day	IHD, ISTK, HSTK, DM
High intake of processed meats	Average daily consumption of meats processed by smoking, curing, salting or addition of chemical preservatives (ham, and sausage)	KNHANES (1998-2011)	0 ± 0 g/day	IHD, DM
High intake of unprocessed meat	Average daily consumption of red meats (beef, and pork, excluding poultry, fish and eggs).	KNHANES (1998-2011)	14.3 ± 1.43 g/day	DM
High intake of sodium	Average daily intake of sodium from all sources	KNHANES (1998-2011)	2000 ± 200 mg/day	Blood pressure mediated effect (CVD)
Metabolic risks	**Definition**	**Data source (Available year)**	**Theoretical minimum risk exposure level**	**Related disease outcomes**
High fasting plasma glucose	Serum fasting plasma glucose, measured in mmol/L	KNHANES (1998-2011)	4.9 ± 0.3 mmol/L	IHD, stroke
High total cholesterol	Serum total cholesterol, measured in mmol/L	KNHANES (1998-2011)	3.8 ± 0.6 mmol/L	IHD, ISTK
High systolic blood pressure	Systolic blood pressure, measured in mmHg	KNHANES (1998-2011)	115 ± 6 mmHg	IHD, HSTK, ISTK, other CVD
High body mass index	Body-mass index, measured in kg/m^2	KNHANES (1998-2011)	21 ± 1 kg/m^2	IHD, ISTK, DM, other CVD
Relative risks by age and sex [24][3]	**Description**	**Data source**		
Effect of fruits on IHD, ISTK, and HSTK	Published meta-analyses of 9, 10, and 7 cohorts studies, respectively [16]	Data were from US and European cohorts including 241,190 participants and 5,603 cases of IHD, 329,204 participants and 5,517 cases of ISTK, and 175,035 participants and 1,535 case of HSTK, respectively		
Effect of vegetables on IHD, ISTK, and HSTK	Published meta-analyses of 9, 9, and 7 cohorts studies, respectively [16]	Data were from US and European cohorts including 229,937 participants and 6,288 cases of IHD, 309,135 participants and 5,376 cases of ISTK, and 175,035 participants and 1,535 case of HSTK, respectively		

Effect of whole grains on CVD, IHD, and DM	Published meta-analyses of 7, 6, and 10 cohorts studies, respectively [15, 17]	Data were from US, European, and Asian cohorts including 285,217 participants and 7,005 cases of CVD, 284,682 participants and 4,837 cases of IHD, and 385,686 participants and 19,829 case of DM, respectively
Effect of processed meats on IHD, and DM	Published meta-analyses of 6, and 9 cohorts studies, respectively [19, 22]	Data were from US, European, and Asian cohorts including 614,062 participants and 21,308 cases of IHD, and 372,391 participants and 26,234 cases of DM, respectively
Effect of unprocessed meats on DM	Published meta-analyses of 10 cohorts studies [22]	Data were from US, European, and Asian cohorts including 447,333 participants and 28,206 cases of DM
Effect of sodium on CVD	Published meta-analyses of 11 cohorts studies [23]	Data were from US, European, and Asian cohorts including 299,785 participants and 9,346 cases of CVD
Linear effects of sodium on blood pressure	Published original analyses of 103 randomized clinical trial studies [21, 23]	Data were from US, European, and Asian randomized clinical trial including 6,970 participants
Effect of metabolic risk on CVD, and DM	Published meta-analyses of 123 cohorts studies [14]	Data were from US, European, and Asian cohorts including 1.42 million participants
Cause-specific total mortality by year, age, and sex	**Description**	
Data on causes of death	Vital-registration systems	Data were obtained from the national statistics in Korea (KOSIS).

KNHANES, Korea National Health and Nutrition Examination Survey; IHD, ischemic heart disease; ISTK, ischemic stroke; HSTK , haemorrhagic stroke; DM, diabetes; CVD, cardiovascular disease.

[1] Fruit intake in 2001-2011 included intake of fruit juice because KNHANES did not separate fruit juice from fresh fruits within relevant years.

[2] Vegetables did not include Korean cabbage since most of Korean cabbage is salted/pickled, and the etiologic effects do not included salted/pickled vegetables. .

[3] Relative risks for diet-disease relationships were obtained from ongoing meta-analyses of published literature.

Data sources

The exposure distribution for each risk factor was obtained from the Korea National Health and Nutrition Examination Survey (KNHANES). The relative risk for each risk factor and disease was collected from published systematic reviews and meta-analyses of epidemiological studies,[14-24] and the number of deaths by specific cause was taken from the Korea Statistics (KOSIS).

Dietary factors The dietary factors were obtained from KNHANES, a nationwide cross-sectional survey conducted by the Ministry of Health and Welfare annually since 1998. The details of KNHANES are available elsewhere,[25] Briefly, KNHANES is composed of three sections: a health interview, a health examination, and a nutrition survey. A nationally representative sample was chosen among the Korean population using household records provided by the Population and Housing Census in Korea. Twenty households from each survey section were selected using a stratified, multistage probability cluster sampling method that considered each participant's geographical area, age, and sex. We used five rounds of KHHANES (1998-2011) to estimate the transitional effect over the years. Sixty-three items of the food frequency questionnaire (FFQ) data from the KNHANES were used to assess the intake amount of each dietary factor. The FFQ evaluated how often the subjects had consumed each particular food over the prior 12 months on a 10-point scale (9 = 3 times per day, 8 = twice per day, 7 = once per day, 6 = 4–6 times per week, 5 = 2–3 times per week, 4 = once per week, 3 = 2–3 times per month, 2 = once per month, 1 = 6–11 times per year, and 0 = almost never). The ten-point scale units were converted into the daily consumed amount by multiplying the serving size according to the Korea Rural Development Administration (KRDA) guideline,[26] The mean and standard deviation (SD) of the intake of each dietary factor by sex, age, and year were estimated using the residual method after adjusting for the total energy intake.[27] Among the participants in the KNHANES, we limited the CRA analyses to those who had no missing data in the nutrition survey. Participants with implausible data and an upper or lower 3SD to the mean value were also excluded. Subjects who intake rice less than 1 time per day across the year were excluded to reflect dietary habit of Korean. After exclusion, the total sample size for 1998-2011 was about 42,000.

Metabolic factors The levels of the metabolic factors were also obtained from the KNHANES. The anthropometric measurements were obtained by trained experts who followed standardized protocols. The body weights and heights of the subjects were measured to the nearest 0.1 kg and 0.1 cm, respectively. The BMI was calculated as the weight (kg) / height squared (m^2). The systolic blood pressure (SBP) was measured with a mercury sphyngmomanometer (Baumanometer, New York, NY, USA) applied to the right arm in the sitting position. To assess the serum levels of the biochemical markers, blood samples were collected from an antecubital vein after 10-12 hours of fasting. The levels of FPG (mmol/L) and TC (mmol/L) were measured using a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan).

Etiological effects of risk factors on disease-specific mortality Each risk factor and disease was paired based on convincing evidence (Table 1). We obtained the relative risk (RR) of cardiovascular disease, stroke, and diabetes mortality (or incidence) per unit of exposure from the most recent published systematic reviews, meta-analyses of randomized controlled trials, and observational studies.[14 ,24]

Theoretical minimum-risk distributions To measure the mortality effects for all populations' levels of exposure according to dietary factors in order to allow for comparison, we used an optimal level (Table 1). This is known as theoretical minimum-risk exposure distribution (TMRED), which is based on epidemiological studies or the levels observed in low-exposure populations. The TMRED for risk factors with protective effects was defined as the intake levels at which they had beneficial effects (e.g., a high intake of fruit, vegetables, and whole grains). The standard level of the optimal intake for protective factors was based on the levels observed in populations with a high intake. For dietary factors with harmful effects (e.g., a high intake of processed or unprocessed meats, and sodium, and high levels of FPG, SBP, BMI, and TC), the optimal level was obtained from the exposure levels associated with the lowest level of harm. For those risk factors for which zero exposure led to minimum risk, and has been observed in some population subgroup around the world (e.g., processed meats), the TMREDs were zero.

Disease-specific deaths The number of disease-specific deaths by sex, age, and year was obtained from the KOSIS, which provides official statistics for Korea. The KOSIS provided data on the mortality from 235 causes between 1998 and 2011. The causes of mortality from the KOSIS were coded following the International Classification of Disease. In the present study, we used the mortality data for deaths attributable to diabetes mellitus (DM, E10-E14), ischemic heart disease (IHD, I20-I25), ischemic stroke (I63, I67), haemorrhagic stroke (I60-I62), aortic aneurysm and dissection (AA, I71), hypertensive heart disease (HHD, I11), and rheumatic heart disease (RHD, I00-I09). The number of cause-specific deaths over the years was aggregated by age and sex group.

Statistical analyses

Estimation of deaths attributable to dietary intake We calculated the population-attributable fraction (PAF) for each continuous risk factor with the following equation:

$$\mathrm{PAF} = \frac{\int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}(x)\,\mathrm{d}x - \int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}'(x)\mathrm{d}x}{\int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}(x)\,\mathrm{d}x}$$

where x was the level of exposure and m was the maximum exposure level. $\mathrm{P}(x)$ represented the actual distribution of the exposure in the population, while $\mathrm{P'}(x)$ was the optimal level of exposure distribution. $\mathrm{RR}(x)$ was the RR of the mortality at exposure level x.

The PAF estimates the proportional reduction in disease-specific deaths that would occur if the risk factor exposure was at the optimal level. We calculated the number of deaths from IHD, ischemic stroke, haemorrhagic stroke, DM, and CVD attributable to causally-related risk factors by multiplying their PAF by the total-specific mortality. We conducted all analyses separately by sex, age group (25-34, 35-44, 45-54, 55-64, 65-74, and 75+ yrs), and year (1998, 2001, 2005, 2007, 2008, 2009, 2010, 2011). We restricted the analyses to ≥25 yrs as the data on the risk factors and the mortality data were limited.

Estimation of uncertainty We calculated the uncertainty of the attributable mortality as caused by the sampling variability. To quantify the uncertainty for the attributable deaths, we applied a second order Monte Carlo simulation to each risk factor. Briefly, this simulation approach combines the uncertainties of the exposure distributions and the RRs in each age-sex group. We generated 1000 draws from the exposure distribution for each age-sex group as characterized by its mean and standard error (which was assumed to be normal). Independently from the exposure, we drew 1000 times the log-normal distribution of the RR for each risk factor on the disease outcomes. Those draws were used to generate 1000 mortality estimates for each age-sex group, and they reported 95% of the uncertainty intervals (UIs) based on the resulting distributions of the 1,000 estimated attributable deaths. All analyses were conducted using Stata 12.0 and R v.3.2.2.

RESULTS

Distribution of dietary and metabolic risk factors by sex, age, and year

Across the time period of analysis, all dietary factors in Korea showed non-optimal levels. The national intakes of protective dietary factors (fruits, vegetables, and whole grains) were lower than the TMRED, while the intakes of harmful dietary factors (processed meats, unprocessed meats, and sodium) were higher than the TMRED. As shown in Figure 1, the intakes of fruits and whole grains increased by 60% from 78.1 ± 2.9 g/day in 1998 to 125.3 ± 5.4 g/day in 2011 and 120% from 4.4 ± 0.3 g/day in 1998 to 9.64 ± 0.6 g/day in 2011, respectively, while among protective dietary factors, the intakes of vegetables decreased by 43% (238.2 ± 6.0 g/day to 136.5 ± 4.7 g/day). Among harmful dietary factors, the consumption of processed meats and red meats increased by 69% (1.8 ± 0.1 g/day to 3.0 ± 0.2 g/day) and 11% (34.7 ± 1.2 g/day to 38.4 ±1.8 g/day), respectively, while the consumption of sodium decreased by 2% (4929.2 ± 163.8 g/day to 4830.2 ± 118.2 mg/day). Between 1998 and 2011, the intake patterns for all dietary factors were similar between men and women, except for fruits and whole grains (Figure 1). The consumption of fruits and whole grains was consistently higher in women than in men over the years, whereas the consumption of other dietary factors was lower in women than in men over the years (Figure 1).

Between 1998 and 2011, levels of metabolic risk factors in Korea on average were higher than optimal distribution. The distribution of metabolic factors in the total population varied little by year. Among metabolic risk factors, BMI and TC increased by 5% (23.0 ± 0.1 kg/m2 to 23.6 ± 0.1 kg/m2) and 3% (4.89 ± 0.04 mmol/L to 4.88 ± 0.04 mmol/L), whereas FPG and

SBP have decreased by 5% (5.6 ± 0.1 mmol/L to 5.4 ± 0.0 mmol/L) and 6% (130.7 ± 1.0 mmHg to 120.5 ± 0.7 mmHg), respectively (Figure 1). Between 1998 and 2011, the levels of BMI, FPG, SBP, and TC increased with age in women, whereas the BMI and TC showed a decreasing trend in elderly men (Supplementary figures S1 and S2). Younger women showed more favourable levels of all metabolic factors than men. For example, women aged 25-34 yrs showed optimal SBP levels across the years (ranged from 101.5 ± 0.4 mmHg to 112.6 ± 0.3 mmHg). Similarly, younger men had more favourable levels of metabolic factors than older men.

CVD, stroke, and DM mortality by age, sex, and year

Over the analysis period (1998-2011), CVD, stroke, and DM were responsible for 259,203 men's deaths and 316,479 women's deaths (total: 575,682 deaths) in Korea (Supplementary Table S1). Deaths from chronic diseases showed a dramatic increase between 1998 and 2007, followed by a slight decrease after 2008. Deaths from CMD increased over the analysis period, except for haemorrhagic stroke. Elderly women showed a higher mortality from diseases than men across the years.

CVD, stroke, and DM mortality attributable to dietary risk factors by year

Between 1998 and 2011, low intakes of fruits and whole grains and high intakes of sodium were the leading dietary risk factors of chronic disease mortality in Korea (Figure 2). The ranking of the dietary factors varied over the years. Low fruit intake was the leading dietary risk factor of CMD mortality in 1998 accounting for 6834.5 CMD deaths (UIs: 5794.3, 7756.6), and its effects showed a decreasing trend over the years. After 1998, low whole grains intake became the leading dietary risk factor of CMD mortality, which is responsible for 54248.2 deaths (UIs: 40981.4, 59178.2) during study period. A high intake of sodium was responsible for the highest number of CMD deaths from 2001 to 2007 [9888.3 death (UIs: 8165.0, 11341.1) and 9171.6 death (UIs: 6866.2, 11212.8), respectively]. The risk of a high intake of sodium showed a slightly decreasing pattern. Although it was not ranked as the highest dietary factor, the risk of a low intake of vegetables also showed an increasing pattern over the years [2290.5 deaths (UIs: 1725.7, 2868.2) to 4072.0 deaths (UIs: 2926.7, 5143.8); Table 2]. The high intakes of meats had almost no effects on Koreans over the years.

Table 2. Number of cardiometabolic mortality attributable to each risk factor from 1998 to 2011 with 95% uncertainty intervals

Risk factor	Disease	Percentage of death (95% UI)							
		Year							
		1998	2001	2005	2007	2008	2009	2010	2011
Low intake of fruits	HSTK	4534.2 (3866.1-5090.0)	4534.2 (3866.1-5090.0)	4193.5 (3516.3-4827.5)	3137.3 (2579.3-3678.7)	2852.6 (2378.1-3316.1)	2922.0 (2413.5-3382.6)	2726.0 (2251.4-3175.2)	3030.6 (2513.3-3519.5)
	ISTK	1118.0 (944.2-1283.1)	1118 .0 (944.2-1283.1)	1427.8 (1177.4-1655.9)	1544.3 (1228.8-1857.6)	1640.4 (1320.2-1998.1)	1573.5 (1262.2-1876.3)	1390.2 (1107.6-1655.1)	1440.6 (1123.9-1753.8)
	TSTK	5652.2 (4977.4-6259.1)	5621.3 (4899.3-6298.8)	4681.6 (4049.5-5331.2)	4492.9 (3934.0-5087.0)	4495.5 (3892.6-5072.8)	4116.2 (3548.6-4673.1)	4471.2 (3858.4-5035.8)	4292.9 (3705.6-4872.1)
	IHD	1182.3 (984.0-1383.5)	1182.3 (984.0-1383.5)	1344.9 (1100.6-1581.6)	1440.7 (1133.5-1753.5)	1676.1 (1317.5-2038.2)	1577.0 (1245.1-1904.0)	1604.1 (1269.7-1963.4)	1774.6 (1373.1-2188.6)
Low intake of vegetables	HSTK	1402.7 (1038.4-1776.1)	1763.7 (1306.3-2187.8)	1496.4 (1105.3-1871.9)	1670.8 (1244.9-2082.8)	1683.2 (1268-2076.9)	1638.3 (1226.8-2042.3)	1751.1 (1347.6-2163.3)	1640.0 (1207.7-2033.8)
	ISTK	483.3 (343.4-622.6)	827.6 (589.0-1088.2)	1049.7 (704.2-1424.8)	1429.4 (947.2-1953.6)	1295.2 (855.5-1726.1)	1204.4 (772.6-1619.1)	1159 .0 (704.1-1601.2)	1158.3 (683.8-1611.9)
	TSTK	1886.0 (1501.6-2260.8)	2591.2 (2062.2-3080.7)	2546.1 (2009.4-3093.5)	3100.2 (2436.7-3763.6)	2978.3 (2399.7-3572.8)	2842.7 (2255.6-3429.5)	2910.1 (2310.3-3462.7)	2798.4 (2153.0-3424.0)
	IHD	404.5 (343.9-469.6)	665.7 (560.0-781.0)	837.7 (683.2-983.4)	1211.4 (1004.7-1433.1)	1107.1 (924.0-1289.6)	1164.3 (957.9-1372.9)	1235.5 (1008.3-1463.6)	1273.6 (1035.2-1498.2)
Low intake of whole grains	HSTK	1936.3 (1755.8-2107.3)	1982.9 (1804.4-2172.5)	1569.3 (1416.3-1720.8)	1360.7 (1232.4-1491.8)	1308.2 (1179.5-1438.3)	1209.7 (1091.9-1324.7)	1253.2 (1134.9-1374.9)	1175.8 (1053.4-1281.4)
	ISTK	949.3 (844.3-1048.0)	1380.4 (1221.0-1530.5)	1589.7 (1377.9-1798.5)	1558.7 (1341.8-1777.6)	1406.8 (1219.4-1605.6)	1241.7 (1056.4-1409.3)	1188.5 (1010.5-1369.9)	1139.1 (962.7-1318.4)
	TSTK	2885.5 (2692.6-3093.6)	3363.2 (3125.9-3597.8)	3158.9 (2890.3-3419.9)	2919.4 (2663.8-3163.5)	2715.0 (2491.2-2953.8)	2451.4 (2239.1-2661.4)	2441.7 (2230.9-2653.2)	2314.9 (2111.7-2521.9)
	IHD	1341.6 (1182.7-1499.2)	1778.1 (1563.6-1987.0)	2064.5 (1789.8-2337.5)	2188.3 (1856.8-2504.1)	1940.3 (1664.9-2209.5)	1947.2 (1671.9-2225.6)	1995.9 (1694.7-2276.4)	2022.8 (1713.4-2314.7)
	DM	2136.6 (1829.1-2440.7)	2389.2 (2060.6-2744.4)	2325.4 (1980.0-2650.3)	2167.2 (1827.2-2497.9)	1954.9 (1648.5-2243.2)	1833.2 (1554.4-2096.9)	1927.1 (1623.4-2229.7)	1985.6 (1656.4-2316.4)
High intake of processed meats	IHD	16.0 (11.2-21.0)	24.9 (17.5-32.8)	27.0 (19.3-35.4)	19.2 (12.5-26.0)	17.3 (11.6-23.1)	16.0 (10.9-21.4)	19.2 (13.3-25.5)	20.5 (13.8-27.0)
	DM	18.9 (15.6-22.3)	26.6 (22.3-31.3)	26.2 (21.3-31.0)	16.7 (13.5-19.9)	14.6 (11.9-17.1)	12.2 (10.1-14.5)	15.9 (13.2-18.8)	16.8 (14.1-19.7)
High intake of unprocessed meats	DM	220.4 (155.4-288.7)	204.7 (151.1-262.8)	152.2 (109.3-193.2)	152.3 (107.1-195.5)	107.5 (78.5-135.3)	97.0 (70.7-124.5)	100.2 (72.8-128.0)	95.6 (70.0-122.3)
High intake of sodium	HSTK	2107.4 (1749.1-2489.5)	3404.0 (2859.9-3919.9)	2195.6 (1745.3-2693.1)	2123.1 (1665.1-2540.5)	1202.3 (934.8-1455.4)	1559.0 (1288.0-1846.6)	1402.4 (1137.8-1686.9)	1680.4 (1415.6-1989.4)
	ISTK	995.6 (813.4-1175.2)	2417.9 (2052.0-2796.0)	2340.1 (1856.2-2905.3)	2424.1 (1858.8-2971.0)	1020.5 (740.2-1322.1)	1293.4 (1033.1-1550.8)	1326.4 (1059-1610.4)	1496.3 (1237.6-1765.6)
	TSTK	3103.0 (2694.1-3527.4)	5821.9 (5151.3-6465.9)	4535.7 (3821.5-5307.4)	4547.1 (3842.1-5269.3)	2222.8 (1819-2609.8)	2852.4 (2456.7-3220.3)	2728.7 (2350.3-3099.8)	3176.7 (2786.9-3543.7)
	AA	46.6 (39.0-54.5)	107.6 (91.6-123.6)	118.5 (97.7-142.5)	125.8 (102.8-151.5)	70 .0 (55.6-85.7)	88.5 (73.6-102.6)	92.6 (77.3-107.9)	120.3 (102.0-139.4)

	HHD	297.8 (250.7-347.7)	1314.1 (1084.2-1527.8)	1090.8 (843.1-1348.2)	1311.2 (972.1-1630.9)	329.2 (177.7-510.9)	441.3 (324.1-576.2)	561.4 (420.3-705.3)	694.6 (543.0-854.6)
	RHD	5.4 (4.3-6.7)	16.6 (12.7-20.6)	24.4 (18.4-30.3)	21.9 (16.6-27.6)	11.5 (8.7-14.5)	13.3 (10.7-16.2)	12.9 (9.9-16.4)	15.7 (12.0-19.7)
	IHD	1178.0 (959.5-1393.1)	2628.1 (2156.2-3076.8)	2815.9 (2078.3-3666.0)	3165.6 (2353.5-4042.8)	1373.1 (1034.8-1764.1)	2008.8 (1587.9-2427.5)	2031.6 (1555.1-2537.2)	2482.8 (1960.8-3059.3)
High fasting plasma glucose	TSTK	1920.4 (1843.1-2000.5)	1943.4 (1831.8-2057.5)	1804 (1663.9-1951.2)	1762.5 (1588.3-1909.2)	1756.7 (1656.7-1856.1)	1672.4 (1574.4-1774)	1581.8 (1477.7-1689.5)	1537.1 (1442.8-1630.2)
	IHD	1205 (1149.2-1263.5)	1464.1 (1373.1-1560.0)	1807.6 (1642.3-1970.2)	2047.5 (1843.3-2250.6)	1878.2 (1758-1999.4)	2037.6 (1921.1-2162.6)	2039.5 (1895.2-2190.6)	2127.9 (1984.1-2269.2)
High total cholesterol	ISTK	531.8 (519.2-544.6)	655.5 (639.3-672.7)	526.6 (508.8-544.1)	498.4 (479.8-517.7)	419.3 (406.6-432)	349.1 (338.6-359.7)	317.5 (308.2-326.2)	291.4 (282.9-299.4)
	IHD	2389.0 (2330.7-2446.8)	3453.6 (3364.9-3548.1)	3849.6 (3678.7-4018.6)	4314.4 (4114.2-4518)	3833.7 (3698-3961.9)	3751.0 (3613.3-3878.4)	3855.5 (3684.9-4025.3)	3940.9 (3791.2-4079.0)
High systolic blood pressure	HSTK	6343.0 (6190.5-6501.5)	4330.3 (4182.0-4475.8)	3080.6 (2936.6-3226.0)	2778.7 (2680.3-2878.4)	3394.1 (3312.1-3475.2)	3506.6 (3412.9-3598.8)	2853.9 (2761.7-2942.2)	6343.0 (6190.5-6501.5)
	ISTK	5220.6 (5013.2-5427.0)	5502.9 (5225.7-5784.5)	4386.4 (4079.3-4696.4)	3732.7 (3540-3914.1)	4336.9 (4174.6-4498.9)	4086.9 (3912.0-4271.9)	3331.6 (3151.5-3509.0)	5220.6 (5013.2-5427.0)
	TSTK	10157.0 (10007.8-10304.7)	11563.6 (11308.3-11804.9)	9833.1 (9522.9-10150.6)	7467.0 (7124.7-7806.8)	6511.4 (6300.0-6731.9)	7731.0 (7547.5-7922.6)	7593.4 (7393.5-7805.2)	6185.6 (5981.5-6387.9)
	IHD	5624 (5416.7-5819.3)	6119.1 (5815.5-6416.9)	5315.0 (4942.8-5672.4)	4364.2 (4145.9-4576.7)	5905.2 (5702.1-6103.6)	6052.2 (5823.7-6290.0)	5270.7 (5012.7-5509.4)	5624.0 (5416.7-5819.3)
	HHD	945.9 (926.1-962.5)	945.9 (926.1-962.5)	2863.8 (2766.8-2955.7)	2195.7 (2092.6-2291.4)	2158.9 (1997.8-2315.8)	1641.7 (1558.8-1724.9)	1716.0 (1661.9-1768.0)	1781.6 (1715.5-1849.9)
	RHD	19.3 (18.8-19.9)	38.8 (37.2-40.5)	56.3 (53.7-58.6)	37.4 (34.8-39.8)	34.0 (32.4-35.7)	34.8 (33.5-36.0)	41.6 (40.1-43.2)	32.9 (31.4-34.3)
	AA	174.7 (170.1-179.0)	230.7 (222.2-238.6)	267.2 (254.1-281.3)	219.3 (205.6-233.4)	211.9 (201.8-222.2)	255.6 (246.9-265.3)	267.5 (257.4-277.7)	242.2 (231.1-253.9)
High body mass index	HSTK	2161.2 (2108.7-2218.3)	2599.7 (2537.3-2659.4)	2171.3 (2112.5-2224.9)	1870.3 (1807.3-1934.1)	1750.4 (1712.0-1791.9)	1655.3 (1619.0-1691.9)	1655.7 (1618.1-1697.0)	1559.2 (1522.2-1599.1)
	ISTK	625.6 (600.9-649.8)	1095.7 (1042.1-1147.9)	1311.0 (1233.4-1393.1)	1306.9 (1219.5-1393.2)	1109.3 (1055.7-1161.0)	989.9 (943.1-1035.1)	953.5 (899.3-1006.4)	877.6 (832.3-920.9)
	TSTK	2786.8 (2730.9-2848.2)	3695.3 (3614.9-3773.7)	3482.3 (3390.5-3577.8)	3177.2 (3070.6-3283.4)	2859.7 (2794.1-2924.7)	2645.2 (2586.6-2702.3)	2609.1 (2542.0-2676.5)	2436.9 (2376.1-2491.7)
	IHD	997.1 (961.7-1033.6)	997.1 (961.7-1033.6)	1694.8 (1627.9-1766.5)	2188.2 (2067.7-2305.8)	2427.3 (2274.5-2574.8)	2042.7 (1956.6-2125.4)	2122.3 (2033.2-2209.7)	2190.2 (2079.9-2303.0)
	DM	2822.6 (2716.9-2924.3)	3977.4 (3841.1-4121.2)	4265.1 (4096.8-4455.6)	4129.4 (3921.8-4346.4)	3591.6 (3461.0-3722.6)	3469.3 (3350.8-3608.0)	3697.3 (3535.0-3861.1)	3727.6 (3589.1-3877.1)
	HHD	225.5 (211.6-240.1)	801.1 (730.4-873.5)	725.1 (656.6-797.2)	946.7 (849.4-1041.0)	688.8 (638.8-744.2)	617.7 (573.6-660.0)	695.4 (643.4-748.9)	684.9 (632.6-739.4)

The values were expressed as population attributable death number for each risk factors (95% Uncertainty Intervals). HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; AA, aortic aneurysm and dissection; HHD, hypertensive heart disease; RHD, rheumatic heart disease.

CVD, stroke, and DM mortality attributable to metabolic risk factors by year

With regard to metabolic risk factors, high levels of SBP stood out as the leading metabolic risk of CMD mortality over the years, responsible for 127095.7 CMD deaths (UIs: 121907.0, 132217.5; Figure 2). Although high SBP appeared as the leading risk factor over the years, the contribution of the blood pressure decreased over the decade of the analysis period, from 15468.8 deaths (UIs: 15124.3, 15812.6) in 1998 to 13494.8 deaths (UIs: 12863.8, 14099.6) in 2011 (Table 2). A non-optimal BMI was responsible for the second-most number of deaths over the analysis years. High levels of TC and PFG had smaller effects than the SBP and BMI over the analysis period (Supplementary Figure S3).

CVD, stroke, and DM mortality attributable to dietary and metabolic risk factors by age and sex

The number of CMD deaths caused by dietary and metabolic risk factors increased with age, in line with the increase in the number of CMD deaths in the older age groups. However, the attributable fraction of these risk factors decreased with the age (Supplementary Figure S4 and S5), particularly for dietary risk factors. Older age groups showed higher attributable fractions of metabolic risks such as SBP and FPG, while in participants aged 25-44 yrs, the highest proportion of CMD deaths was attributable to dietary risk factors and several metabolic risk factors, including the BMI and TC. In the younger population, the SBP and FPG showed no or little effect on CMD deaths, as younger men and women had optimal metabolic levels (Supplementary Figure S4 and S5). The proportion of CMD deaths caused by low intakes of fruits and whole grains and high intake of sodium were greater among men than women, while no noticeable difference was observed in the deaths caused by other dietary factors (Supplementary Table S2). The deaths from CMD caused by metabolic risk factors were consistently greater among men than women (Supplementary Table S2).

DISCUSSION

The present study evaluated and quantified the contribution of 6 dietary risk factors and 4 metabolic risk factors attributable to CVD, stroke, and DM mortality in Korea by age and sex from 1998 to 2011 using comparable methods. While confirming the importance of high blood pressure to CMD mortality, the results also showed that a suboptimal diet had been the leading factor of CMD mortality in Korea since 1998. This was consistent with an earlier GBD study reporting that suboptimal diet is the leading risk factor for chronic disease in most regions of the world.[4 ,28]

With trends of increased prevalence of metabolic risk factors in Korea, this study demonstrates the effect of convincing metabolic risks on CMD mortality in Korean population. In accordance with previous GBD study, high SBP is the leading risk factor with high BMI as the leading risk.[28 ,29] Corresponding to previous GBD study,[30] approximately 50% of stroke and 45% of IHD deaths were attributable to high blood pressure in Koreans. The result on SBP is consistent with global or national trends of blood pressure, including modest decreased levels of SBP.[30-32] On the contrary to blood pressure, the risk of high BMI increased overtime globally, accompanying with adverse obesity related changes in metabolic condition.[2] Nearly 45% of diabetes burden and 20% of IHD burden are attributable to obese in Korean. Metabolic risk is a physiological indicators, which is related to shorten life expectancy through increasing possibility of developing CVDs.[9 ,10] Furthermore, attributable burden of metabolic risks have considered as mediator of other risks including changes in the diet, and decreasing levels of physical activity.[33 ,34] The results from metabolic risks suggest that the need for adoption and implementation of effective interventions to reduce the burden of metabolic risk factors.

Following metabolic risks, we found that among individual dietary factors, a high intake of sodium and low intakes of fruits and whole grains were responsible for the highest CMD mortality in Korea. Suboptimal dietary patterns are linked to a substantial burden of morbidity, mortality, and medical costs.[35] According to a previous study, dietary or strongly diet-related factors are expected to cause nearly 75% of all deaths and 60% of all disability-adjusted life years by 2020.[4 ,36] The most noticeable feature of dietary risks in Korea was that the intakes of fruits, vegetables, and whole grains were much lower than the levels recommended by the TMRED and World Health Organisation (WHO) guideline.[37 ,38] The intake of sodium was also much higher than the guideline. The causes of this problem might be nation-specific and multifaceted. The low intake of whole grains and high intake of sodium in Korea are partly due to the country's unique dietary habits, including the regular consumption of seasoned soup, salt fermented food, and refined rice. Furthermore, the reduced intakes of fruits and vegetables could reflect changes in lifestyle and factors linked to the economic transition in Korea, such as increased food prices.[39] Along with adoption of Westernised lifestyle, the increased fast food consumption and westernised diet have also aggravated dietary problems. Moreover, the increased participation of women in the workforce has contributed to reducing the time available to prepare healthy food.[40] These findings highlight the need for interventions to improve the accessibility and affordability of healthy foods to reduce CMD risks in Korea.

In addition, we quantified the contribution of dietary factors (e.g., sodium) to the burden of CMD deaths as mediated by metabolic risks (e.g., SBP). For example, although high blood pressure has remained the leading risk factor in Korea, it is closely related to the consumption of sodium.[41] The sodium intake in Korea is more than double the WHO dietary recommendation, which in turn increases the risk of hypertensive disease.[32 ,42] The WHO issued a global call for salt management to reduce the prevalence of hypertensive-related diseases in cost-effective ways. In line with the WHO recommendation, the Korean government has been running a low salt campaign since 2005 [43] to achieve an overall reduction in the Korean population's salt intake. As the results have shown, the reduction in dietary salt has been successfully reducing the national sodium intake since 2005, and this has brought about a decrease in CVD deaths. This result implies the possibility that dietary factors may affect the CMD through their effects on changes in metabolic factors, while disease-specific deaths are caused by multiple factors acting simultaneously. Moreover, the results support the theory that a suboptimal diet is affected by the relative influence of the individual level, the community level, and the national level.[44]

On the other hand, our study clearly showed that the mortality burden of dietary risks in Korea had slightly increased since 1998, especially in the younger population. The shifting trends in the burden of CMDs in the Korean population may be due to socioeconomic changes such as rapid economic development and urbanisation. Korea is one of the world's fastest-growing countries, witnessing rapid industrial changes. Those remarkable sociocultural changes have been found to contribute to an unhealthy lifestyle, including dietary risks from the increased availability, affordability, and consumption of unhealthy food.[40 ,45] Additionally, changes in epidemiological trends, including decreased levels of metabolic risks and cardiovascular death rates in Korea, have also been attributed to changes in the magnitude of the burden of CMD risks.[40] The findings from the current study highlight the importance of the epidemiological transition to estimate the population's health.

We also focused on understanding the comparative importance of the risk factors by age-sex specific groups to observe the trends in the disease burden over time. The results showed that the younger population was prone to more harmful dietary risks causing CMD deaths.[46] According to a previous study of the Western population,[47] young adults in Korea tend to have a higher intake of animal products and sugar-sweetened drinks. Due to their metabolic status, people aged under 50 are more easily influenced by their dietary intake than the elderly. A longitudinal cohort study demonstrated that higher intakes of fruits and vegetables in young adulthood were responsible for lower odds of prevalent CVDs.[48] Additionally, high levels of exposure to dietary and metabolic risks were responsible for a large number of CMD deaths, particularly in men. A previous study reported that this gender difference was not only attributable to biological differences,[49] but also to differences in socioeconomic status and lifestyle, including health awareness and diet quality.[49 ,50] The results suggest that political initiatives to prevent CMD mortality should be taken based on an understanding of the age-sex specific effects.

Our analysis had several strengths. To our knowledge, this was the first investigation to analyse data from national individual-based surveys to evaluate the diet consumption and its transition over time in Korea. The results provide most detailed result, focusing on the nation-specific impacts of dietary and metabolic risk factors on CMDs to identify national priorities for management and prevention of CMDs. Additionally, we obtained and used the most up-to-date aetiological effect sizes of the diet–disease relationships. We used RRs from meta-analyses of observational studies adjusted for major confounders. We also accounted for uncertainty in the current risk factor levels, the effects of the risk factors on the CMD mortality, and the current cause-specific mortality by age, sex, and time, propagating this uncertainty into the final results.

Potential limitations should also be considered when interpreting our findings. The dietary amount data were imputed based on the FFQ rather than investigated actual amount. Therefore, there is a possibility of over-estimate or under-estimate of intake amount, comparing to actual intake amount. However, FFQ in the KNHANES has substantial reproducibility and validity, [51] measuring long term dietary pattern for specific target population.[52] Second, we could not divide fruits into fresh fruit and fruit juice or vegetables into pickled vegetables and fresh vegetables, as the KNHANES did not investigate those items separately. To account for this, in the vegetable category, we excluded Korean cabbage, i.e. kimchi, which is the major source of pickled vegetables in the Korean diet. However, there is a possibility that the vegetable intake was underestimated as the daily intakes of kimchi in Korea represent 40-50% of the daily total vegetable intake of Koreans.[53] Third, the latest exposure data were excluded from the main results as the KNHANES had adopted different methods in recent years. Fourth, although we used the confounder-adjusted RR, the possibility of residual confounding cannot be excluded. Sixth, the analysis of risk factors has focused on selected risk factors including dietary and metabolic risks. The further study with behavioural risk factors is required in current population.

In summary, we found that both metabolic and dietary risk factors were major contributors to CMD mortality in Korea, and we investigated their relative importance over the years. Our findings highlight the need for the adoption, implementation, and evaluation of dietary recommendations reflecting shifting trends for the prevention of CMDs in Korea. Moreover, the findings provide robust and comparable levels quantifying the effects of major metabolic risk factors on CMDs. The results of the current study can contribute to the development of evidence-based national government policies to manage and improve the major risk factors of CMDs in Korea.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology [NRF-2015R1A2A1A15054758 to MJS]). MJS and GS conceived the study and MJS acquired the data. YC, FC and GS developed the statistical analysis plan. YC and JHP analysed the data. YC, GS and MJS prepared the first draft of manuscript. YC, JTL, DM, GS, MJS contributed to the writing of the manuscript. All authors reviewed and agreed on the manuscript.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

DATA SHARING STATEMENT

No additional data are available.

Figure legend

Figure 1. Trends in (A) diet and (B) metabolic risk factors in Korea from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests ($p < 0.05$). SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose**.**

Figure 2. Mortality from cardiometabolic disease attributable to individual dietary and metabolic risk factors, by disease and year in Korea. Data are shown for all adults. See the Table 2 for actual values of risk factor attributable deaths and 95% UIs. Note that the number of death attributables to individual risks cannot be added because of multi-causality and mediated effects. HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; WG, whole grains; SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

REFERENCES

1. Lee KS, Park JH. Burden of disease in Korea during 2000-10. *Journal of public health* 2014;**36**(2):225-34 doi: 10.1093/pubmed/fdt056published Online First: Epub Date]|.

2. Goodpaster BH, Krishnaswami S, Harris TB, et al. Obesity, regional body fat distribution, and the metabolic syndrome in older men and women. *Archives of internal medicine* 2005;**165**(7):777-83 doi: DOI 10.1001/archinte.165.7.777published Online First: Epub Date]|.

3. Statistics Korea. Causes of Death Statistics in 2014: Statistics Korea, 2015.

4. Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**(9859):2224-60 doi: 10.1016/S0140-6736(12)61766-8published Online First: Epub Date]|.

5. Musaiger AO, Al-Hazzaa HM. Prevalence and risk factors associated with nutrition-related noncommunicable diseases in the Eastern Mediterranean region. *International journal of general medicine* 2012;**5**:199-217 doi: 10.2147/IJGM.S29663published Online First: Epub Date]|.

6. Popkin BM. The nutrition transition: an overview of world patterns of change. *Nutrition reviews* 2004;**62**(7 Pt 2):S140-3

7. Murray CJ, Ezzati M, Lopez AD, et al. Comparative quantification of health risks conceptual framework and methodological issues. *Population health metrics* 2003;**1**(1):1

8. Begg SJ, Vos T, Barker B, et al. Burden of disease and injury in Australia in the new millennium: measuring health loss from diseases, injuries and risk factors. *The Medical journal of Australia* 2008;**188**(1):36-40

9. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS medicine* 2009;**6**(4):e1000058 doi: 10.1371/journal.pmed.1000058published Online First: Epub Date]|.

10. Farzadfar F, Danaei G, Namdaritabar H, et al. National and subnational mortality effects of metabolic risk factors and smoking in Iran: a comparative risk assessment. *Population health metrics* 2011;**9**(1):55 doi: 10.1186/1478-7954-9-55published Online First: Epub Date]|.

11. Afshin A, Micha R, Khatibzadeh S, et al. The impact of dietary habits and metabolic risk factors on cardiovascular and diabetes mortality in countries of the Middle East and North Africa in 2010: a comparative risk assessment analysis. *BMJ open* 2015;**5**(5):e006385 doi: 10.1136/bmjopen-2014-006385published Online First: Epub Date]|.

12. Yang G, Wang Y, Zeng Y, et al. Rapid health transition in China, 1990-2010: findings from the Global Burden of Disease Study 2010. *Lancet* 2013;**381**(9882):1987-2015 doi: 10.1016/S0140-6736(13)61097-1published Online First: Epub Date]|.

13. Lee SK, Sobal J. Socio-economic, dietary, activity, nutrition and body weight transitions in South Korea. *Public health nutrition* 2003;**6**(7):665-74

14. Singh GM, Danaei G, Farzadfar F, et al. The age-specific quantitative effects of metabolic risk factors on cardiovascular diseases and diabetes: a pooled analysis. *PloS one* 2013;**8**(7):e65174 doi: 10.1371/journal.pone.0065174published Online First: Epub Date]|.

15. Aune D, Norat T, Romundstad P, et al. Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. *European journal of epidemiology* 2013;**28**(11):845-58 doi: 10.1007/s10654-013-9852-5published Online First: Epub Date]|.

16. He FJ, Nowson CA, Lucas M, et al. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *Journal of human hypertension* 2007;**21**(9):717-28 doi: 10.1038/sj.jhh.1002212published Online First: Epub Date]|.

17. Mellen PB, Walsh TF, Herrington DM. Whole grain intake and cardiovascular disease: a meta-analysis. *Nutrition, metabolism, and cardiovascular diseases : NMCD* 2008;**18**(4):283-90 doi: 10.1016/j.numecd.2006.12.008published Online First: Epub Date]|.

18. Micha R, Kalantarian S, Wirojratana P, et al. Estimating the global and regional burden of suboptimal nutrition on chronic disease: methods and inputs to the analysis. *European journal of clinical nutrition* 2012;**66**(1):119-29 doi: 10.1038/ejcn.2011.147published Online First: Epub Date]|.

19. Micha R, Wallace SK, Mozaffarian D. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. *Circulation* 2010;**121**(21):2271-83 doi: 10.1161/CIRCULATIONAHA.109.924977published Online First: Epub Date]|.

20. Mozaffarian D, Fahimi S, Singh GM, et al. Global sodium consumption and death from cardiovascular causes. *The New England journal of medicine* 2014;**371**(7):624-34 doi: 10.1056/NEJMoa1304127published Online First: Epub Date]|.

21. Mozaffarian D, Hao T, Rimm EB, et al. Changes in diet and lifestyle and long-term weight gain in women and men. *The New England journal of medicine*

2011;**364**(25):2392-404 doi: 10.1056/NEJMoa1014296published Online First: Epub Date]|.

22. Pan A, Sun Q, Bernstein AM, et al. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *The American journal of clinical nutrition* 2011;**94**(4):1088-96 doi: 10.3945/ajcn.111.018978published Online First: Epub Date]|.

23. Poggio R, Gutierrez L, Matta MG, et al. Daily sodium consumption and CVD mortality in the general population: systematic review and meta-analysis of prospective studies. *Public health nutrition* 2015;**18**(4):695-704 doi: 10.1017/S1368980014000949published Online First: Epub Date]|.

24. Shulkin ML, Micha R, Rao M, et al. Abstract P279: Major Dietary Risk Factors for Cardiometabolic Disease: Current Evidence for Causal Effects and Effect Sizes From the Global Burden of Diseases (GBD) 2015 Study. *Circulation* 2016;**133**(Suppl 1):AP279-AP79

25. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *International journal of epidemiology* 2014;**43**(1):69-77 doi: 10.1093/ije/dyt228published Online First: Epub Date]|.

26. Rural Development Administration. *Consumer Friendly Food Composition Table for Adults*. Suwon, Korea: Rural Development Administration, 2009.

27. Willett W, Stampfer MJ. Total energy intake: implications for epidemiologic analyses. *American journal of epidemiology* 1986;**124**(1):17-27

28. Global Burden of Disease Risk Factors Collaborators., Forouzanfar MH, Alexander L, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study

2013. *Lancet* 2015;**386**(10010):2287-323 doi: 10.1016/S0140-6736(15)00128-2published Online First: Epub Date]|.

29. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;**384**(9945):766-81 doi: 10.1016/S0140-6736(14)60460-8published Online First: Epub Date]|.
30. Danaei G, Finucane MM, Lin JK, et al. National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5· 4 million participants. *The Lancet* 2011;**377**(9765):568-77
31. Evans A, Tolonen H, Hense H-W, et al. Trends in coronary risk factors in the WHO MONICA project. *International journal of epidemiology* 2001;**30**(suppl 1):S35
32. Ikeda N, Gakidou E, Hasegawa T, et al. Understanding the decline of mean systolic blood pressure in Japan: an analysis of pooled data from the National Nutrition Survey, 1986-2002. *Bulletin of the World Health Organization* 2008;**86**(12):978-88
33. Lewington S, Clarke R, Qizilbash N, et al. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;**360**(9349):1903-13
34. Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration., Lu Y, Hajifathalian K, et al. Metabolic mediators of the effects of body-mass index, overweight, and obesity on coronary heart disease and stroke: a pooled analysis of 97 prospective cohorts with 1.8 million participants. *Lancet* 2014;**383**(9921):970-83 doi: 10.1016/S0140-6736(13)61836-Xpublished Online First: Epub Date]|.

35. Lopez AD, Mathers CD, Ezzati M, et al. Measuring the Global Burden of Disease and Risk Factors, 1990-2001. In: Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJL, eds. Global Burden of Disease and Risk Factors. Washington (DC), 2006.

36. Murray CJ, Lopez AD. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. *Lancet* 1997;**349**(9063):1436-42 doi: 10.1016/S0140-6736(96)07495-8published Online First: Epub Date]|.

37. World Health Organizaion. *Global status report on noncommunicable diseases 2014*, 2014.

38. World Health Organization. *Global Health Risks: Mortality and burden of disease attributable to selected major risks*, 2009.

39. Hawkes C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Globalization and health* 2006;**2**:4 doi: 10.1186/1744-8603-2-4published Online First: Epub Date]|.

40. Kim S, Moon S, Popkin BM. The nutrition transition in South Korea. *The American journal of clinical nutrition* 2000;**71**(1):44-53

41. Law MR, Frost CD, Wald NJ. By how much does dietary salt reduction lower blood pressure? III--Analysis of data from trials of salt reduction. *Bmj* 1991;**302**(6780):819-24

42. Laverty AA, Bottle A, Majeed A, et al. Blood pressure monitoring and control by cardiovascular disease status in UK primary care: 10 year retrospective cohort study 1998-2007. *Journal of public health* 2011;**33**(2):302-9 doi: 10.1093/pubmed/fdq078published Online First: Epub Date]|.

43. Kim YC, Koo HS, Kim S, et al. Estimation of daily salt intake through a 24-hour urine collection in Pohang, Korea. *J Korean Med Sci* 2014;**29**:S87–S90

44. Afshin A, Micha R, Khatibzadeh S, et al. *The handbook of global health policy: Dietary policies to reduce noncommunicable diseases*: Wiley-Blackwell, 2014.

45. Goryakin Y, Suhrcke M. Economic development, urbanization, technological change and overweight: what do we learn from 244 Demographic and Health Surveys? *Economics and human biology* 2014;**14**:109-27 doi: 10.1016/j.ehb.2013.11.003published Online First: Epub Date]|.

46. Roy R, Kelly B, Rangan A, et al. Food Environment Interventions to Improve the Dietary Behavior of Young Adults in Tertiary Education Settings: A Systematic Literature Review. *Journal of the Academy of Nutrition and Dietetics* 2015;**115**(10):1647-81 e1 doi: 10.1016/j.jand.2015.06.380published Online First: Epub Date]|.

47. Larson N, Neumark-Sztainer D, Laska MN, et al. Young adults and eating away from home: associations with dietary intake patterns and weight status differ by choice of restaurant. *Journal of the American Dietetic Association* 2011;**111**(11):1696-703 doi: 10.1016/j.jada.2011.08.007published Online First: Epub Date]|.

48. Miedema MD, Petrone A, Shikany JM, et al. Association of Fruit and Vegetable Consumption During Early Adulthood With the Prevalence of Coronary Artery Calcium After 20 Years of Follow-Up: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Circulation* 2015;**132**(21):1990-8 doi: 10.1161/CIRCULATIONAHA.114.012562published Online First: Epub Date]|.

49. Lowe LP, Greenland P, Ruth KJ, et al. Impact of major cardiovascular disease risk factors, particularly in combination, on 22-year mortality in women and men. *Archives of internal medicine* 1998;**158**(18):2007-14

50. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *The American journal of clinical nutrition* 2002;**76**(6):1261-71

51. Kim DW, Song S, Lee JE, et al. Reproducibility and validity of an FFQ developed for the Korea National Health and Nutrition Examination Survey (KNHANES). *Public health nutrition* 2015;**18**(8):1369-77 doi: 10.1017/S1368980014001712published Online First: Epub Date]|.

52. Kabagambe EK, Baylin A, Allan DA, et al. Application of the method of triads to evaluate the performance of food frequency questionnaires and biomarkers as indicators of long-term dietary intake. *American journal of epidemiology* 2001;**154**(12):1126-35

53. Lee JS, Kim J. Vegetable intake in Korea: data from the Korean National Health and Nutrition Examination Survey 1998, 2001 and 2005. *The British journal of nutrition* 2010;**103**(10):1499-506 doi: 10.1017/S0007114509993527published Online First: Epub Date]|.

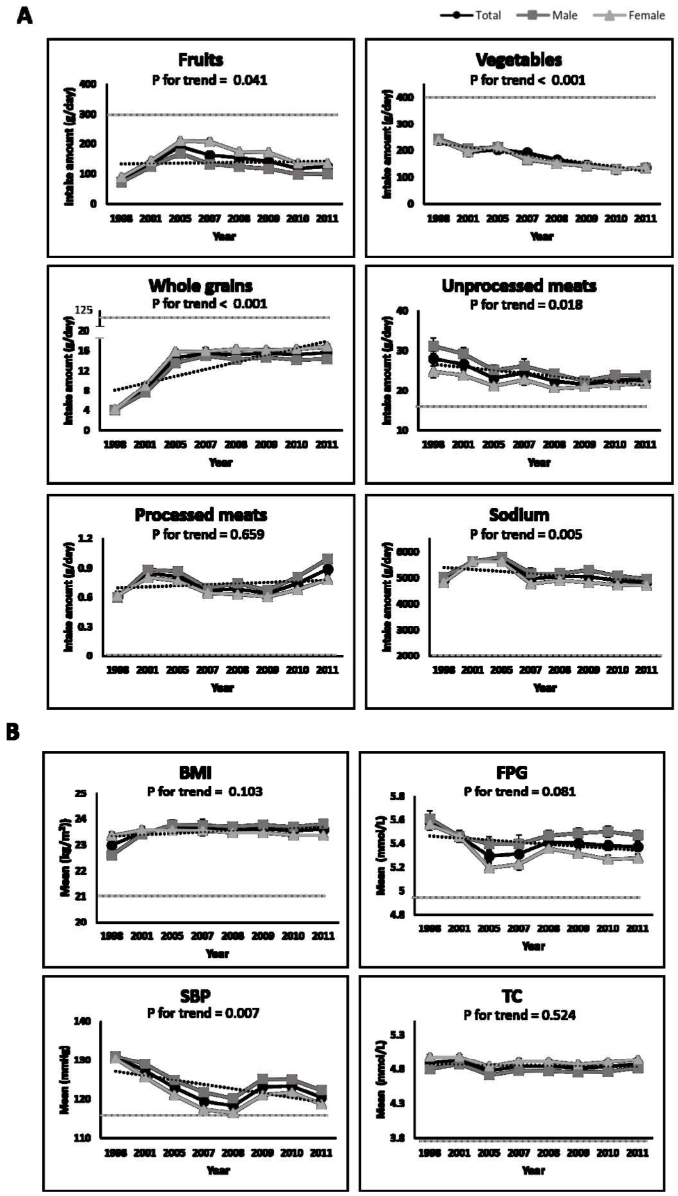


Figure 1. Trends in (A) diet and (B) metabolic risk factors in Korea from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests (p <0.05). SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

177x286mm (300 x 300 DPI)

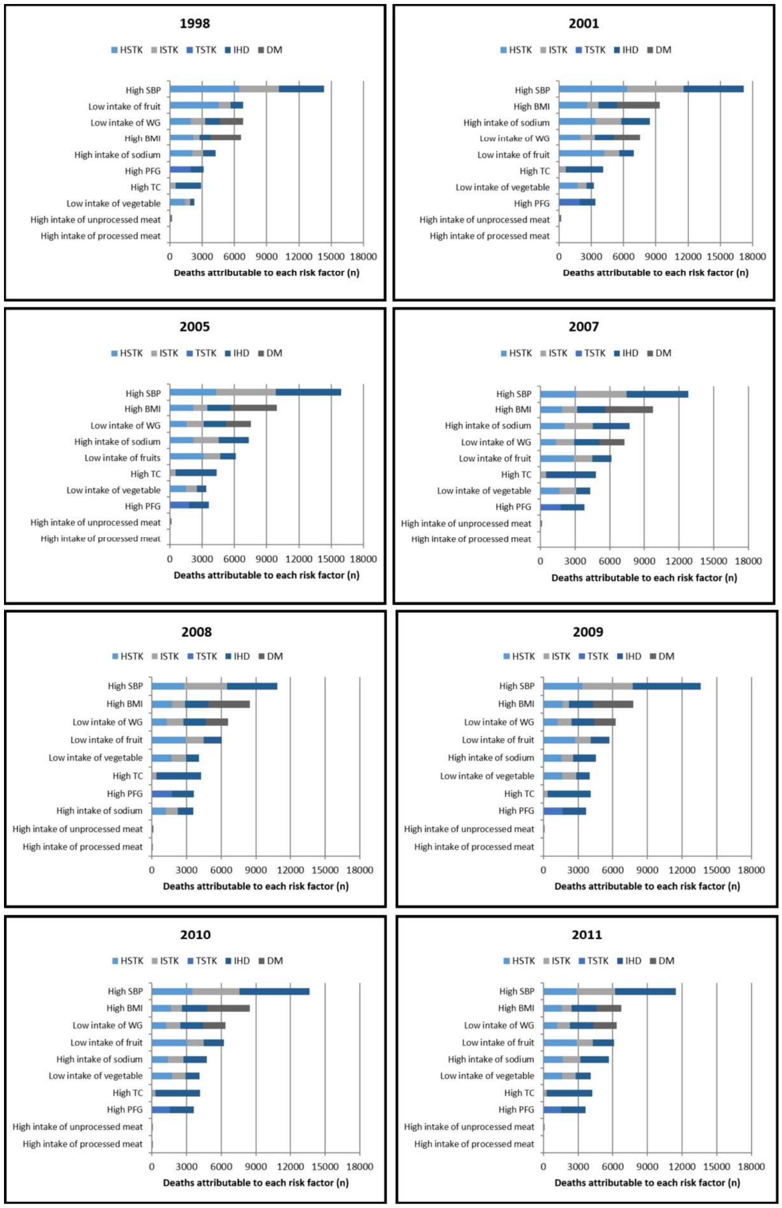


Figure 2. Mortality from cardiometabolic disease attributable to individual dietary and metabolic risk factors, by disease and year in Korea. Data are shown for all adults. See the Table 2 for actual values of risk factor attributable deaths and 95% UIs. Note that the number of death attributables to individual risks cannot be added because of multi-causality and mediated effects. HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; WG, whole grains; SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

152x235mm (300 x 300 DPI)

Supplementary Figure legend

Supplementary Figure 1. Transition of (A) dietary and (B) metabolic risk factors among Korean men from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests ($p < 0.05$). BMI, body mass index; PFG, plasma fasting glucose; SBP, systolic blood pressure; TC, total cholesterol**.**

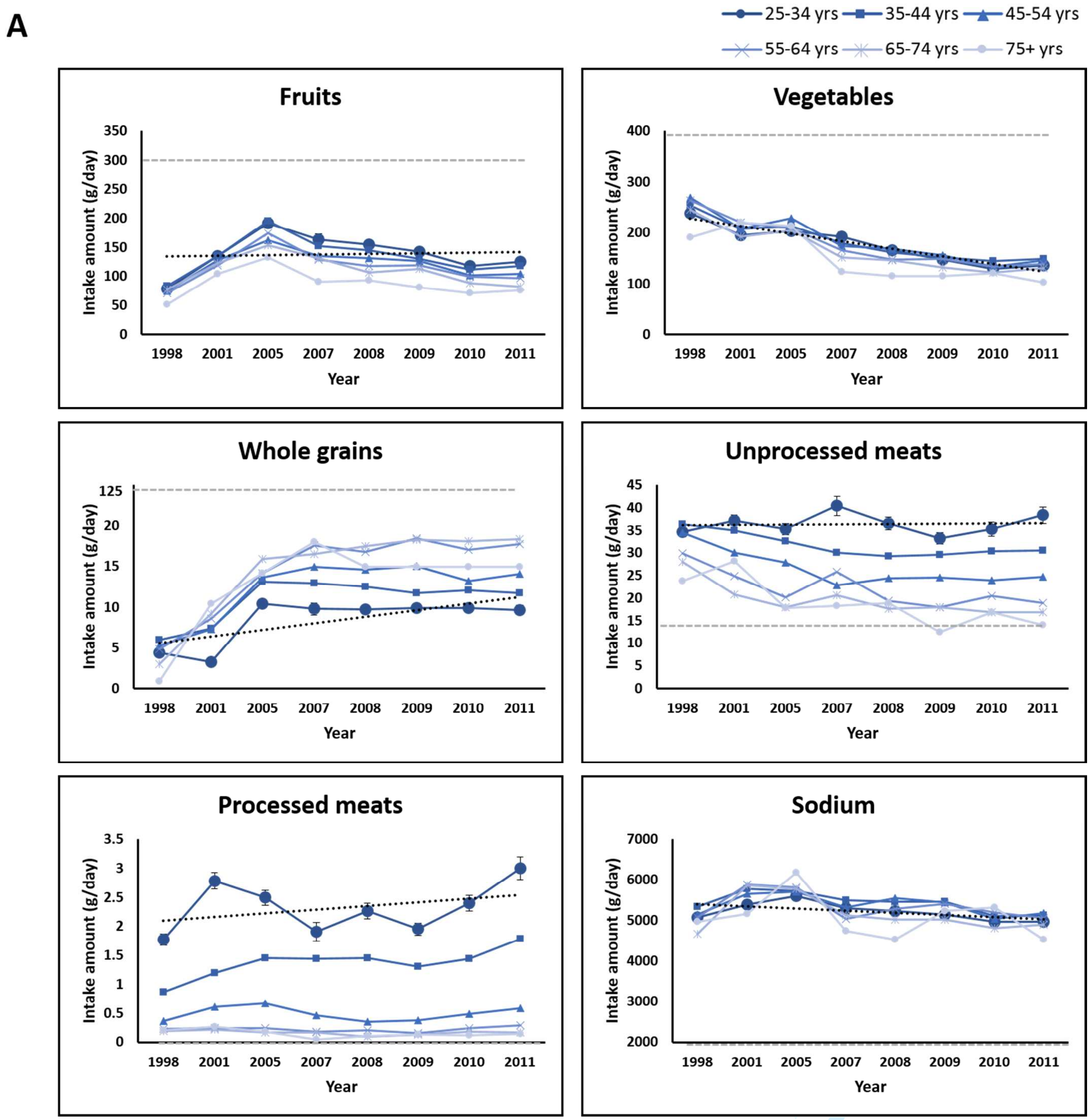
Supplementary Figure 2. Transition of (A) dietary and (B) metabolic risk factors among Korean women from 1998 to 2011. Each plots and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-value was derived from non-parametric trend test ($p < 0.05$). BMI, body mass index; PFG, plasma fasting glucose; SBP, systolic blood pressure; TC, total cholesterol**.**

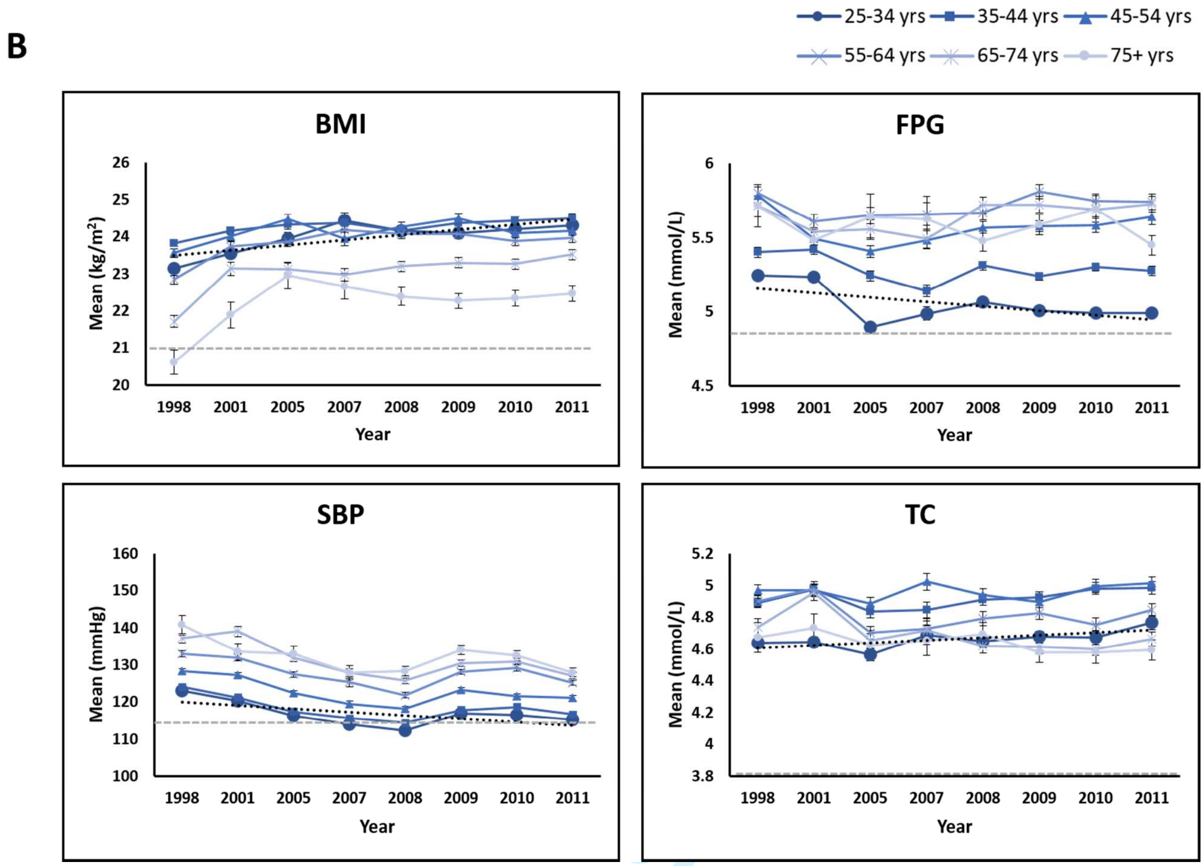
Supplementary Figure 3. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year in Korea. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. P-value was derived from non-parametric trend test ($p < 0.05$). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

Supplementary Figure 4. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year among Korean men. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. See the Supplementary Table S2 for relevant values of risk factor attributable deaths and 95% UIs. P-value was derived from non-parametric trend test ($p < 0.05$). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

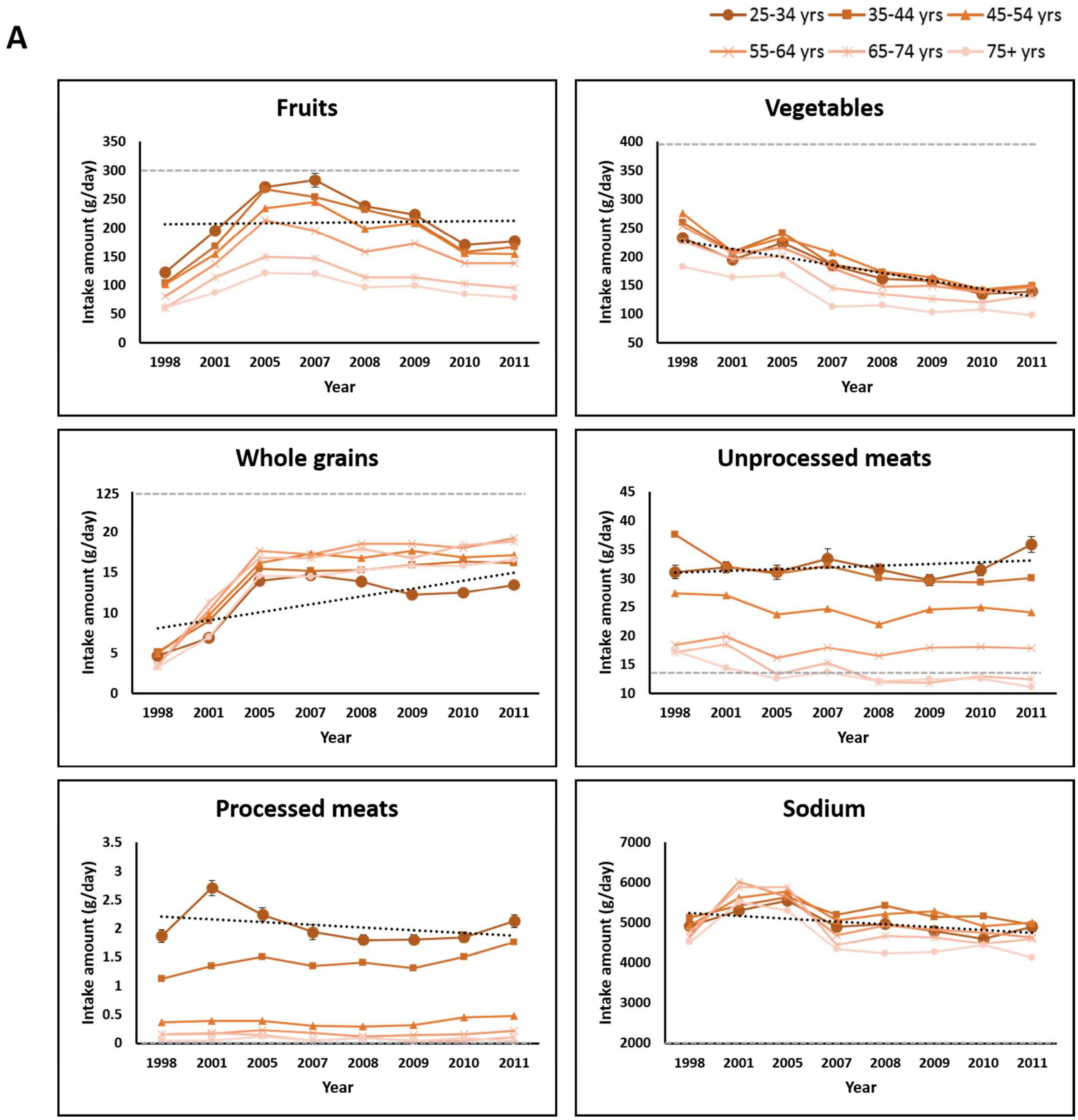
Supplementary Figure 5. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year among Korean women. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. See the Supplementary Table S2 for relevant values of risk factor attributable deaths and 95% UIs. P-value was derived from non-parametric trend test ($p < 0.05$). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

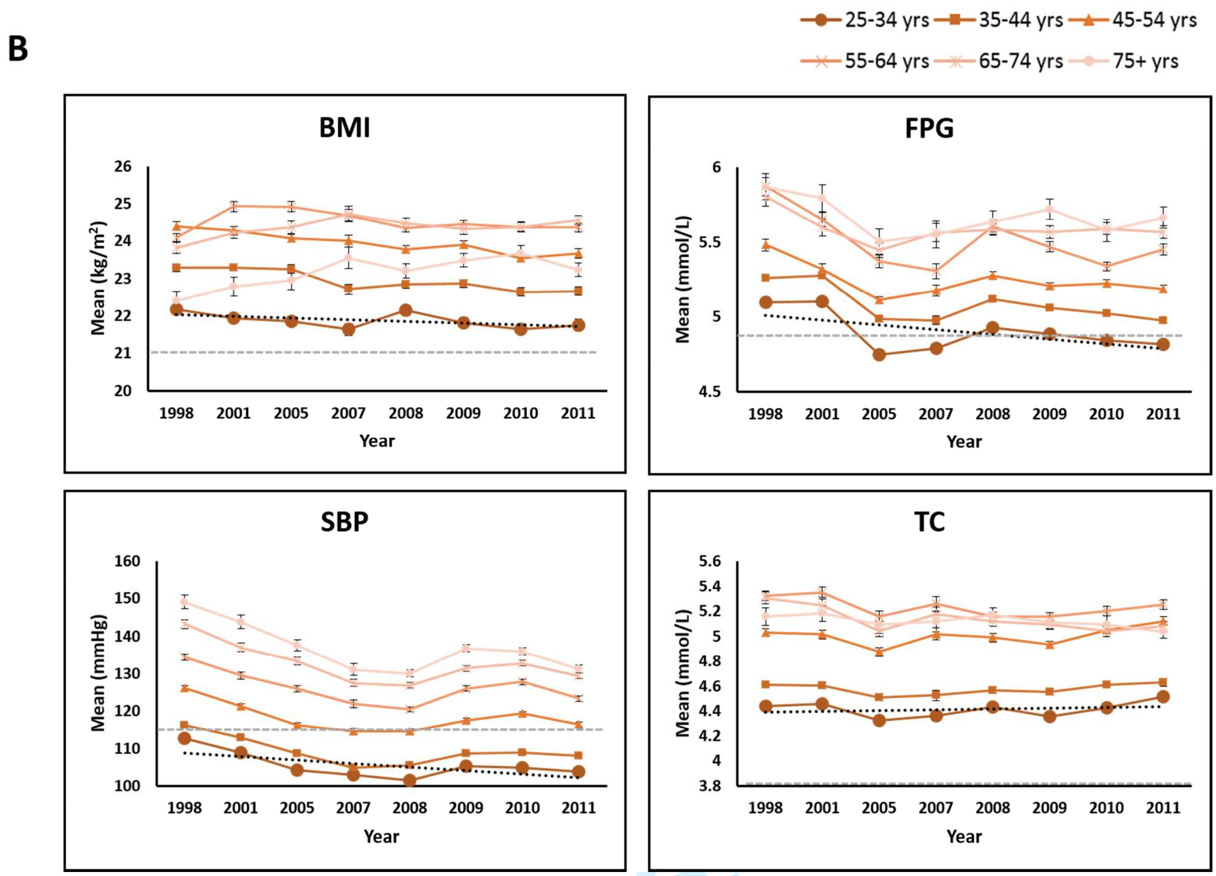
Supplementary Figure 1.



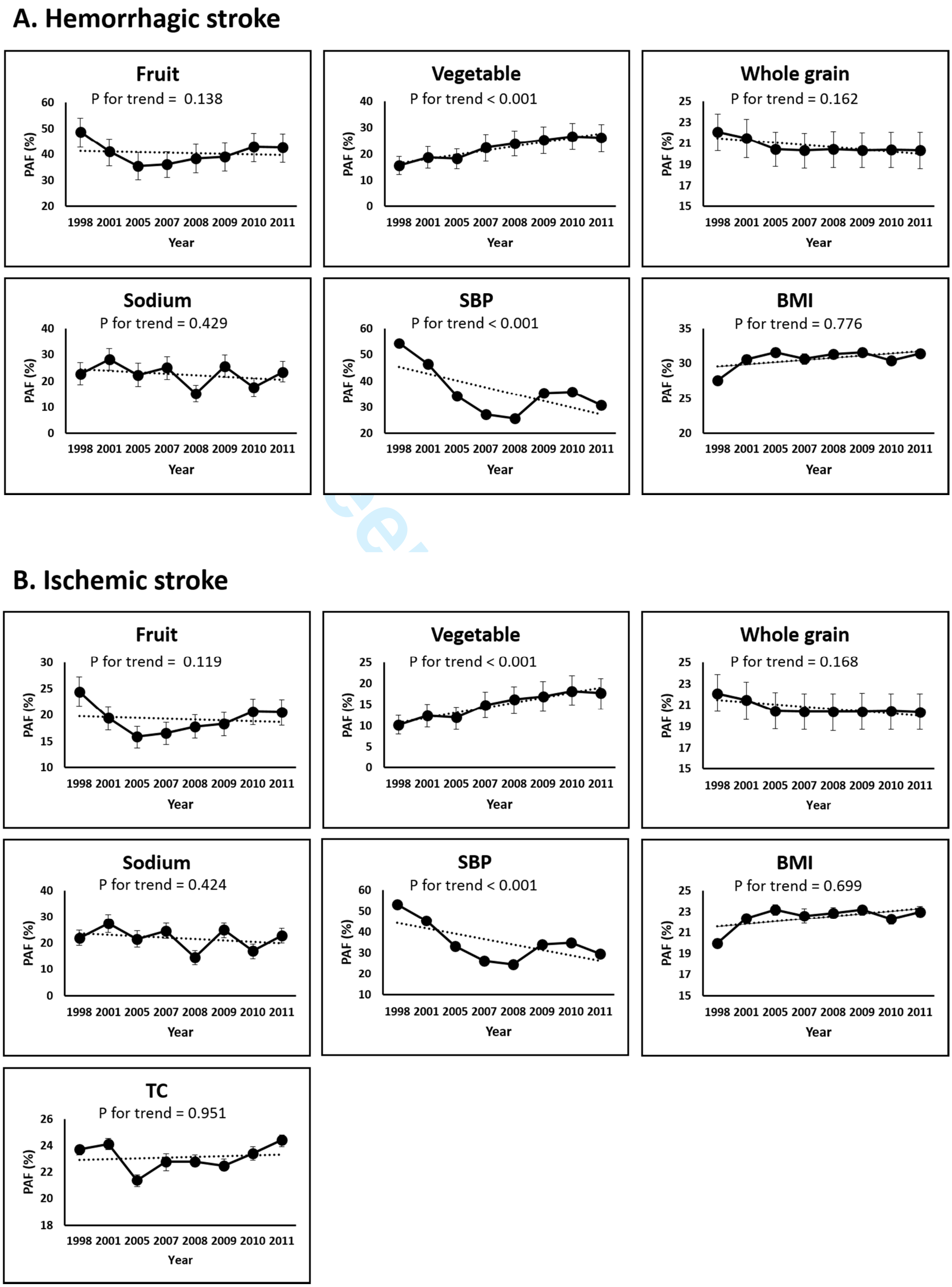

B
25-34 yrs
35-44 yrs
45-54 yrs
55-64 yrs
65-74 yrs
75+ yrs
BMI
Mean (kg/m²)
FPG
Mean (mmol/L)
SBP
Mean (mmHg)
TC
Mean (mmol/L)
1998
2001
2005
2007
2008
2009
2010
2011
Year

Supplementary Figure 2.

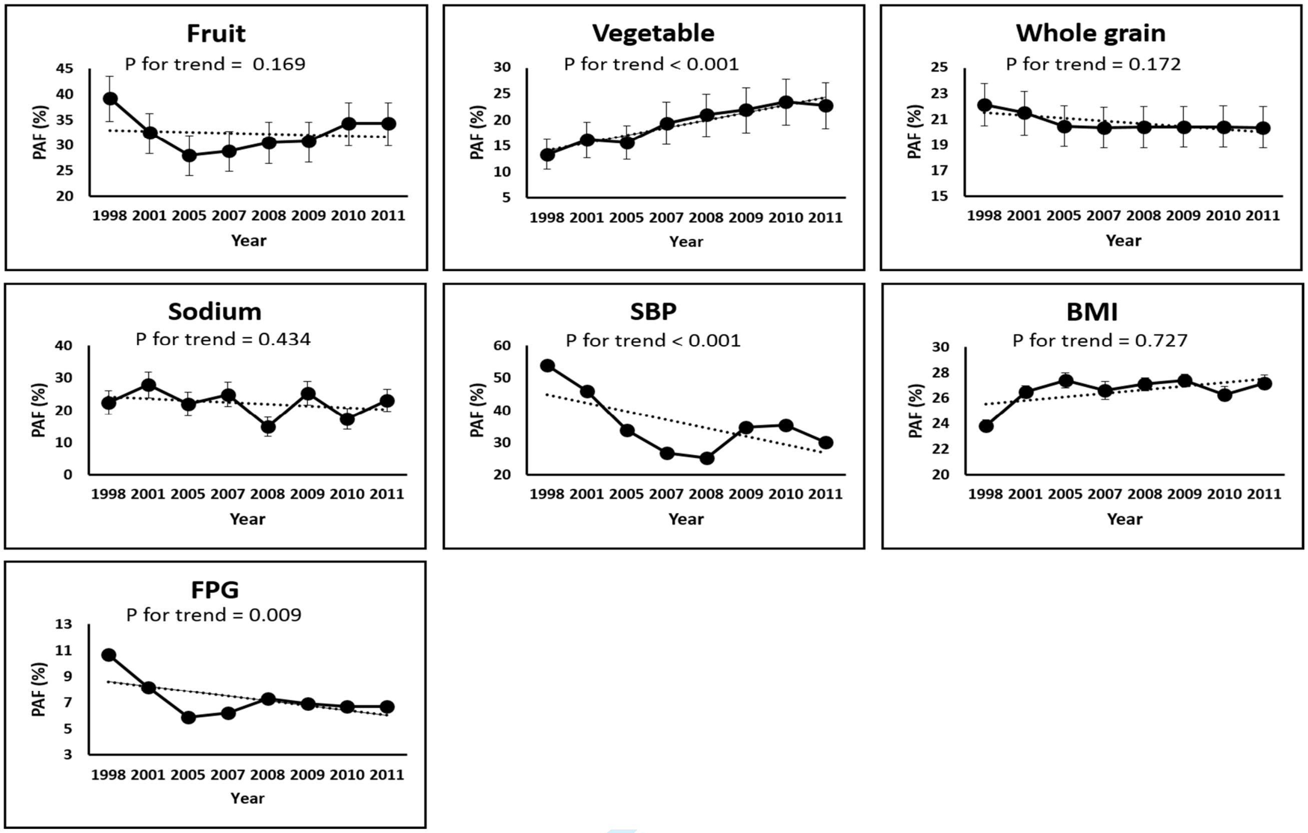



B
25-34 yrs
35-44 yrs
45-54 yrs
55-64 yrs
65-74 yrs
75+ yrs
BMI
Mean (kg/m²)
FPG
Mean (mmol/L)
SBP
Mean (mmHg)
TC
Mean (mmol/L)
Year
1998
2001
2005
2007
2008
2009
2010
2011

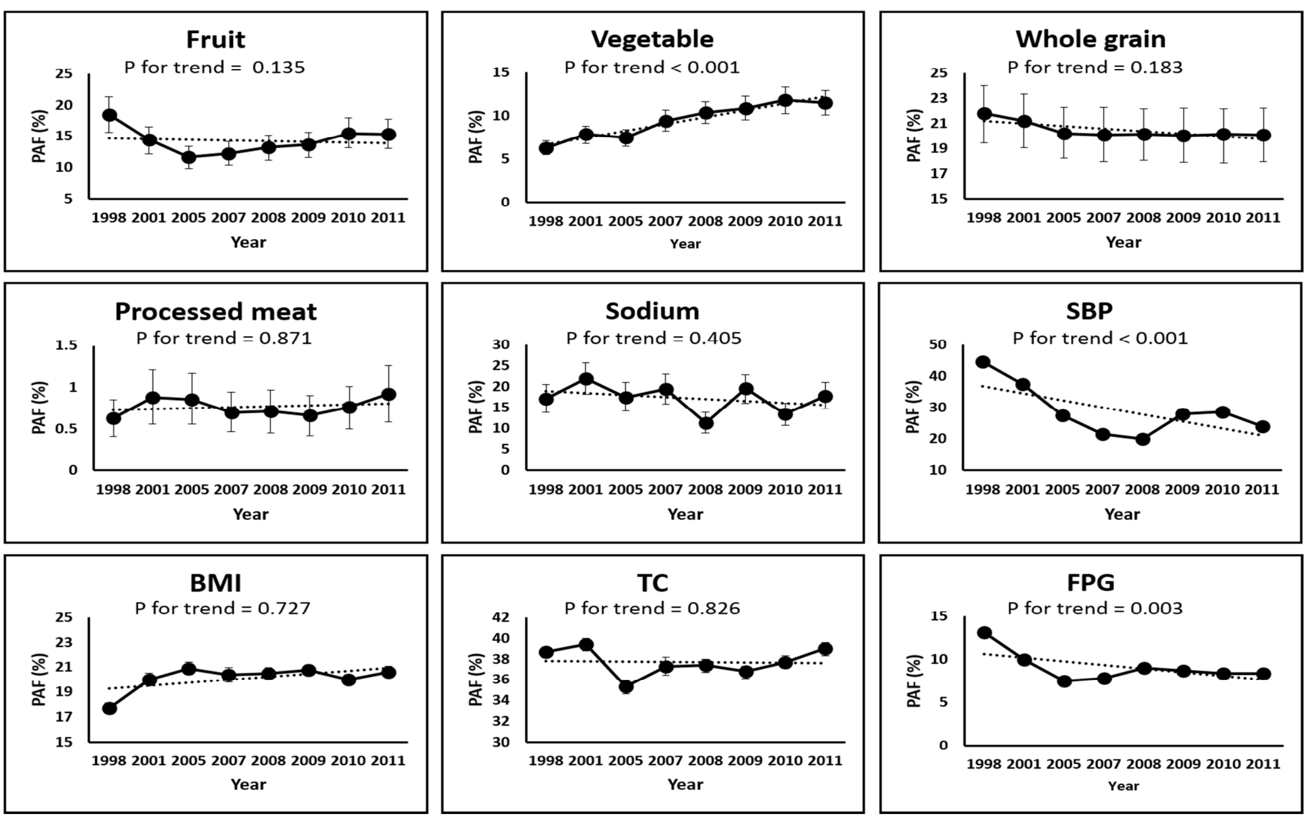
Supplementary Figure 3.



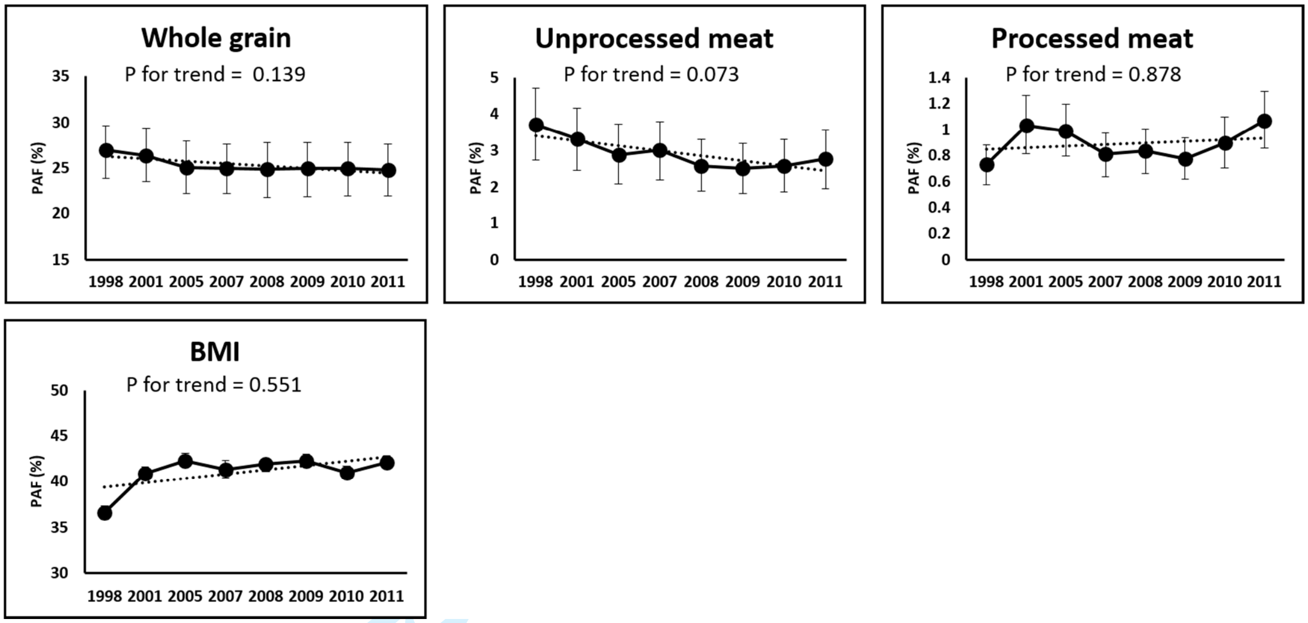
C. Total stroke



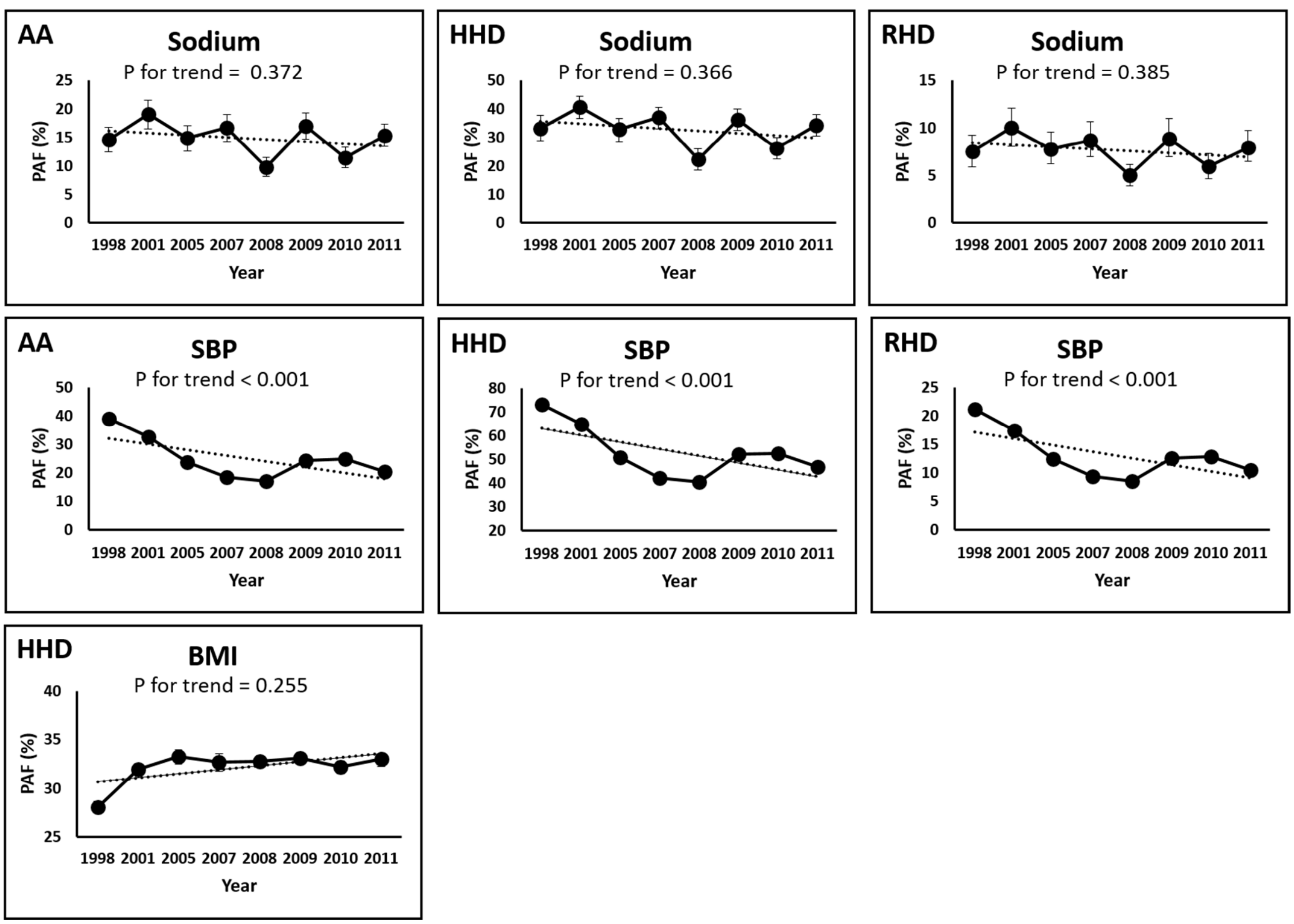
D. Ischemic Heart Disease



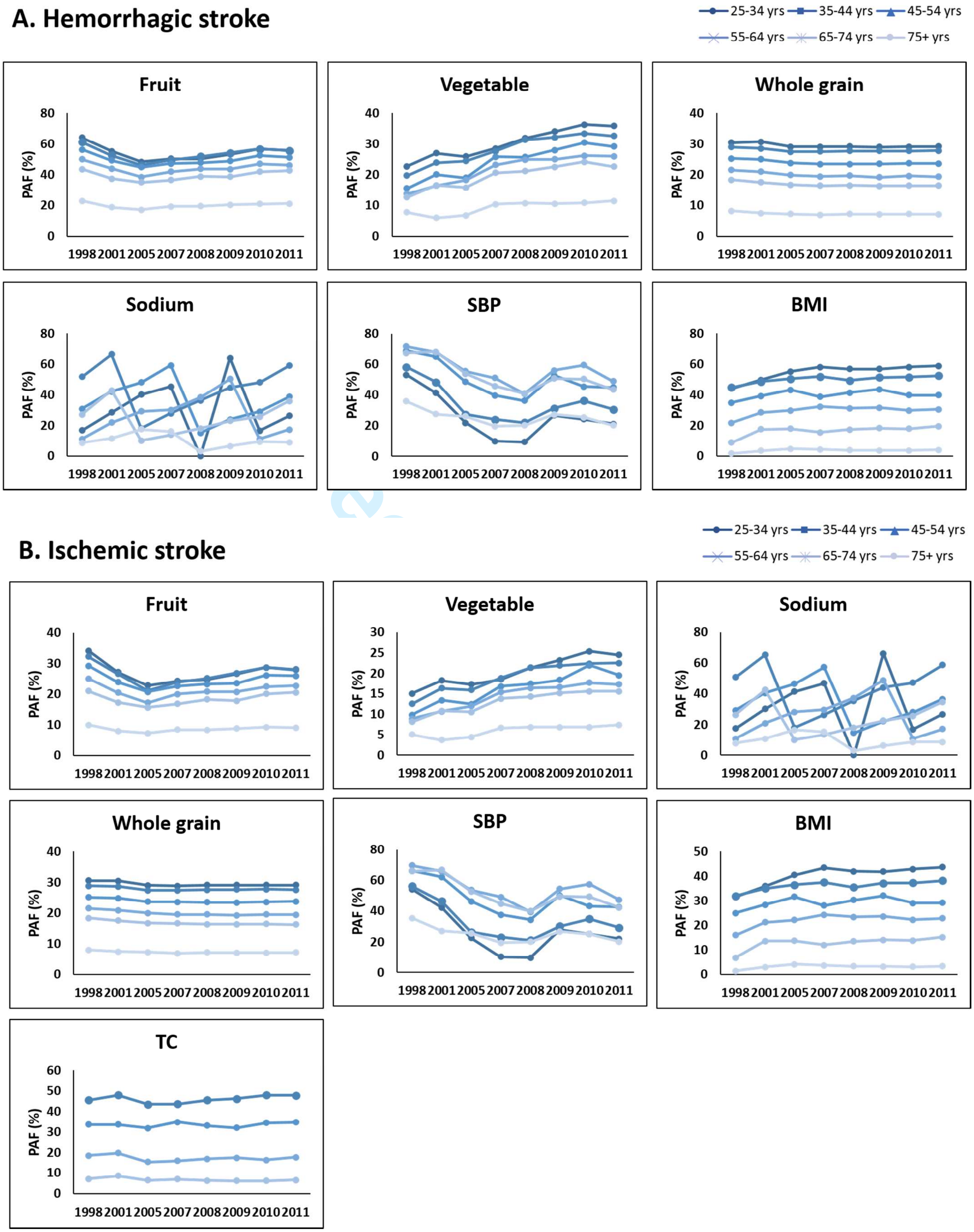
E. Diabetes



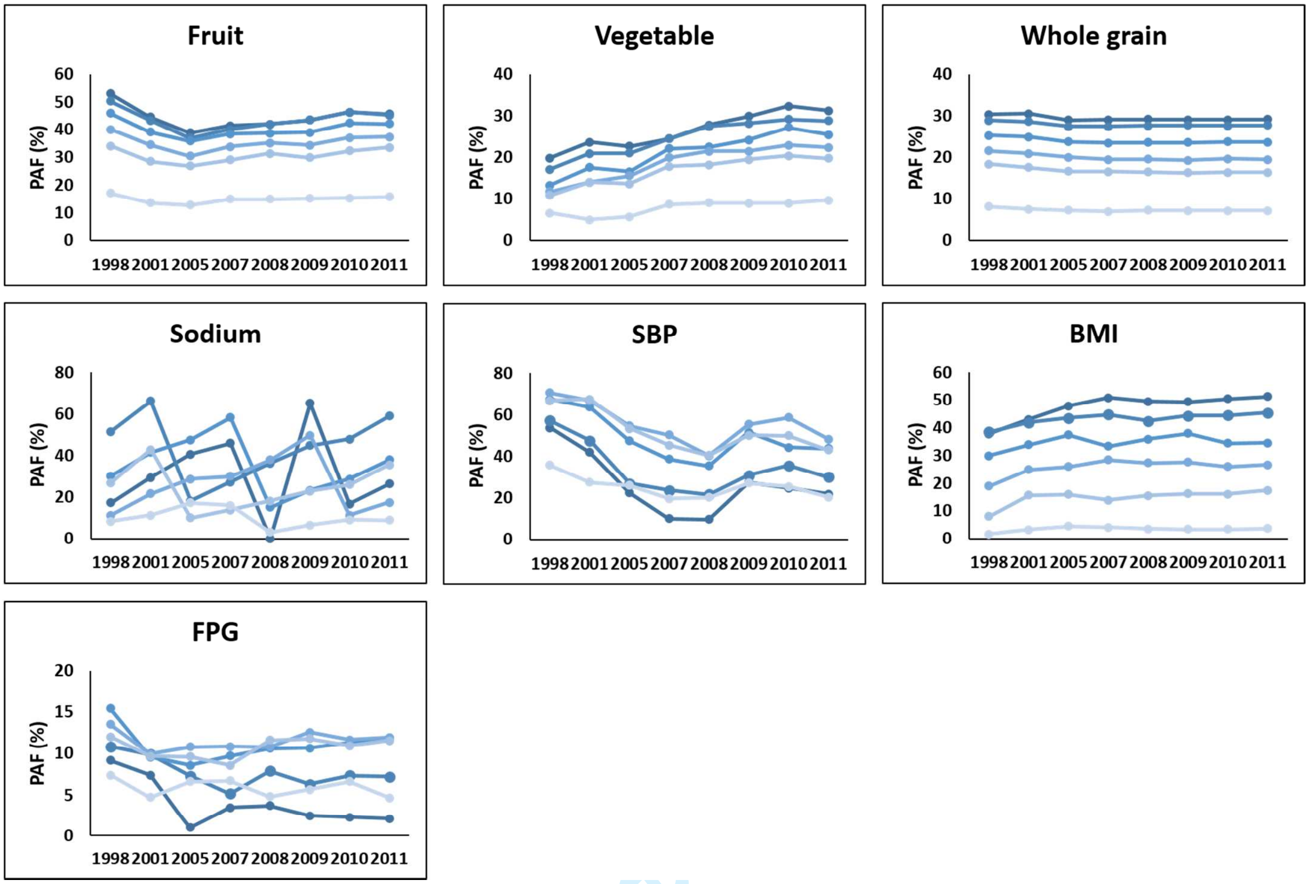
F. Other CVD



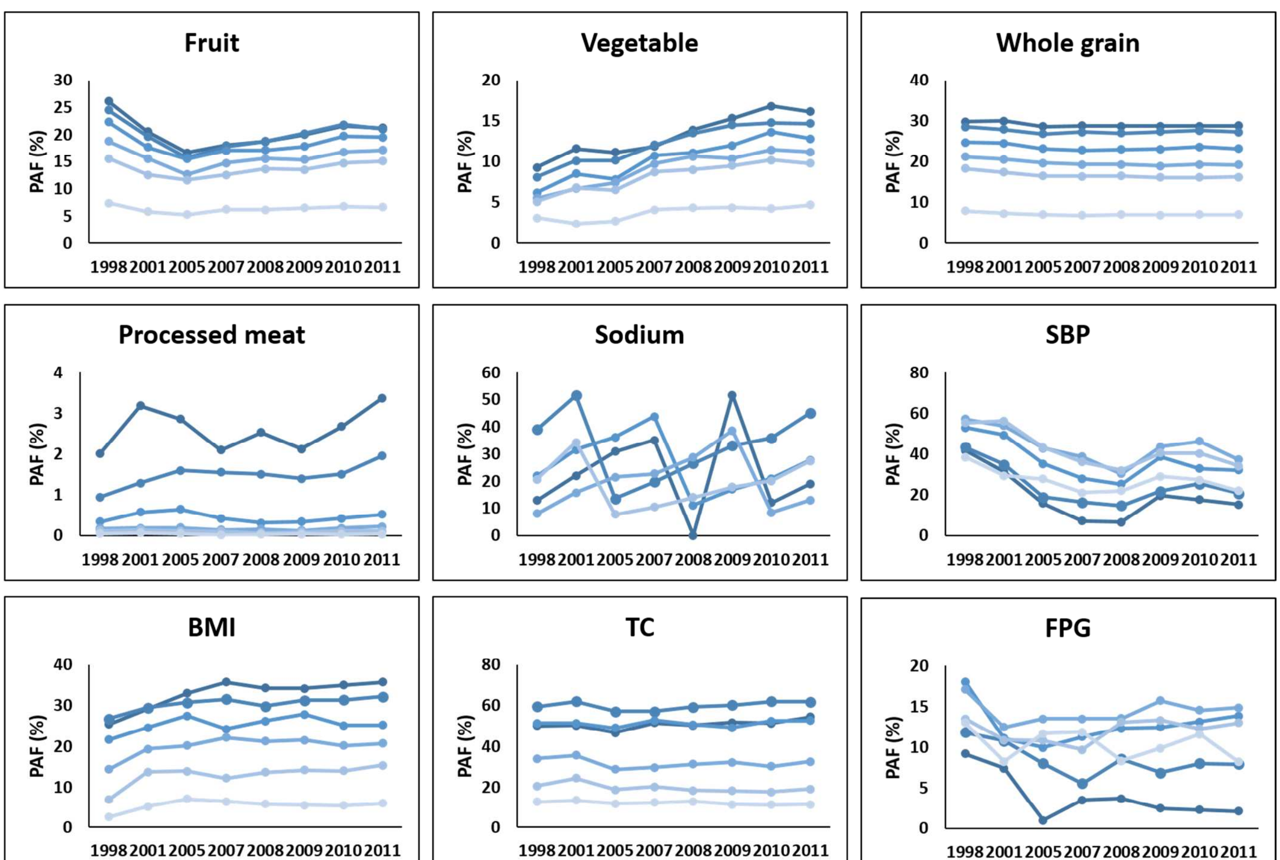
Supplementary Figure 4.



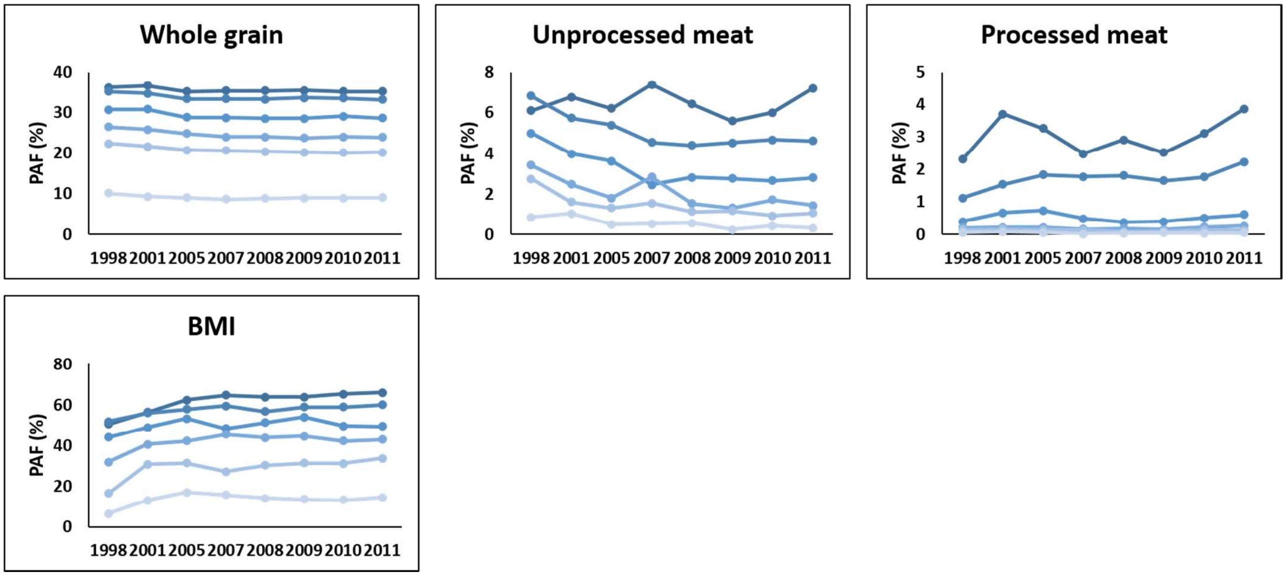
C. Total stroke



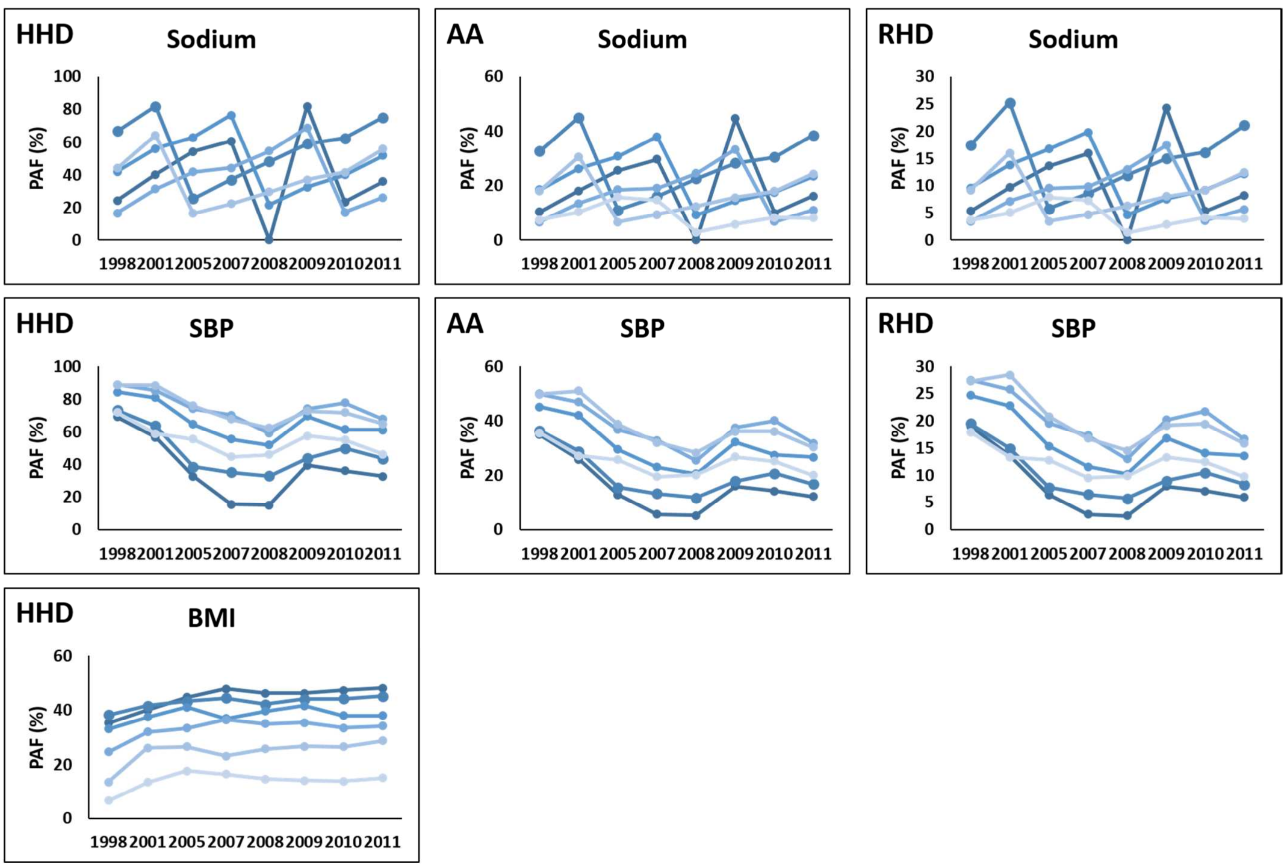
D. Ischemic Heart Disease



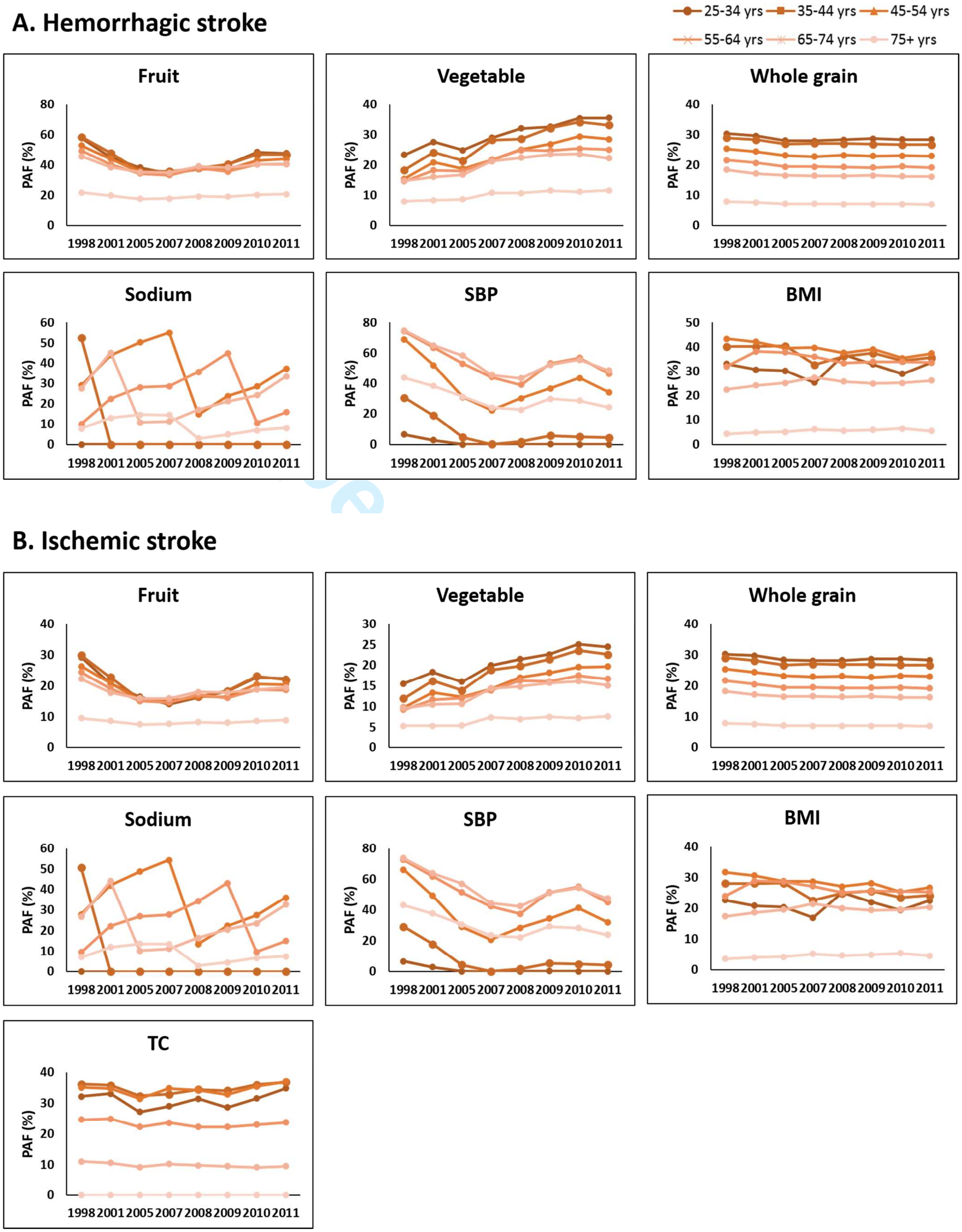
E. Diabetes



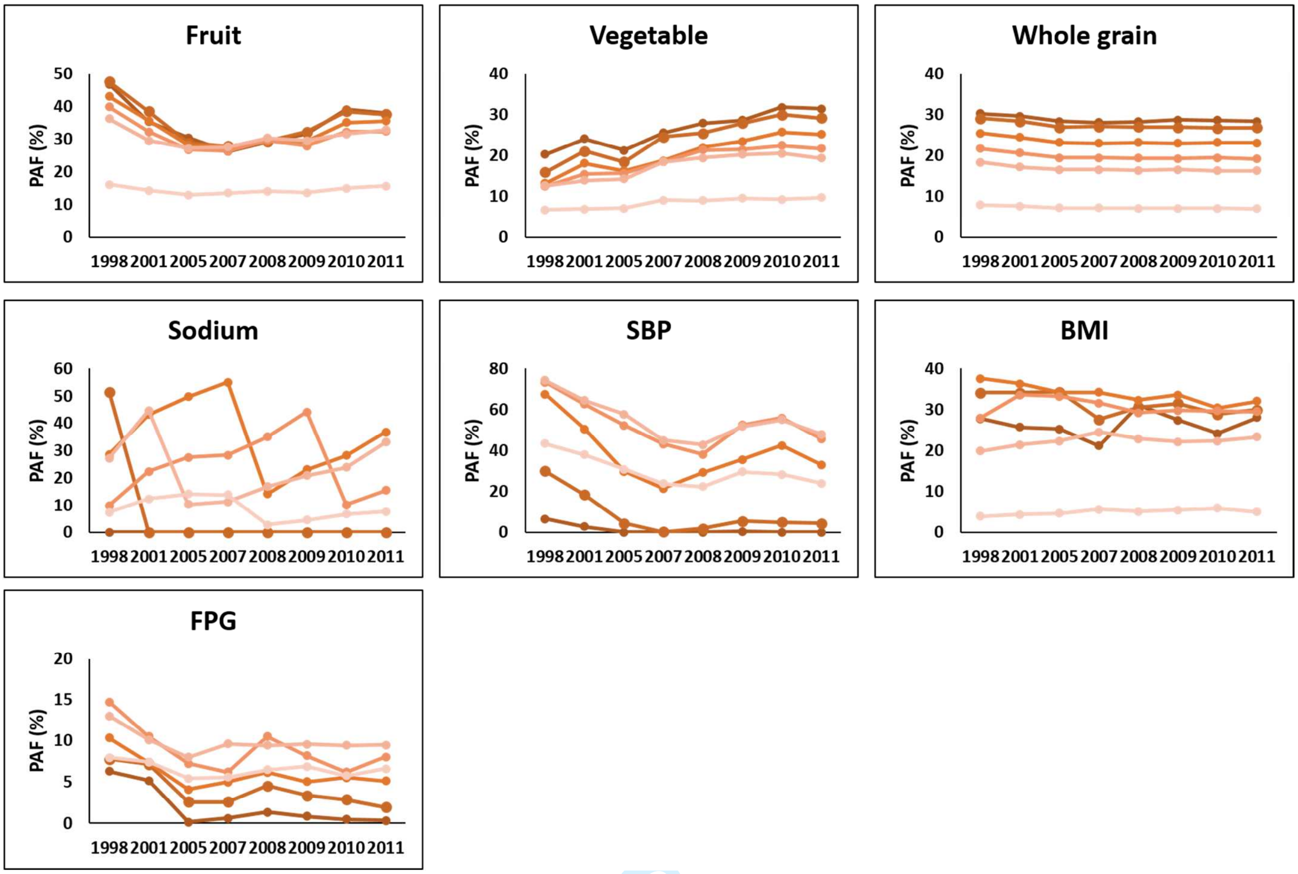
F. Other CVD



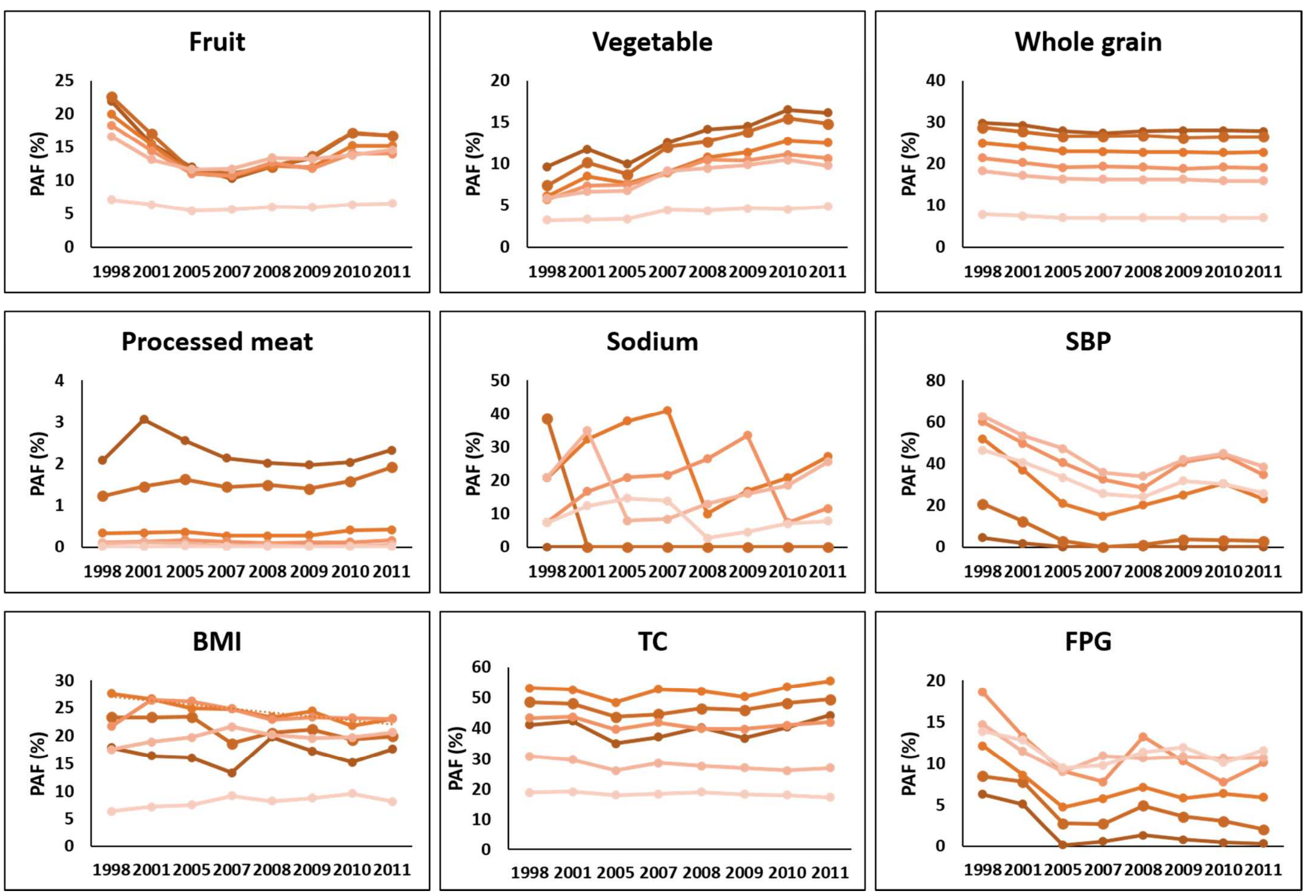
Supplementary Figure 5.



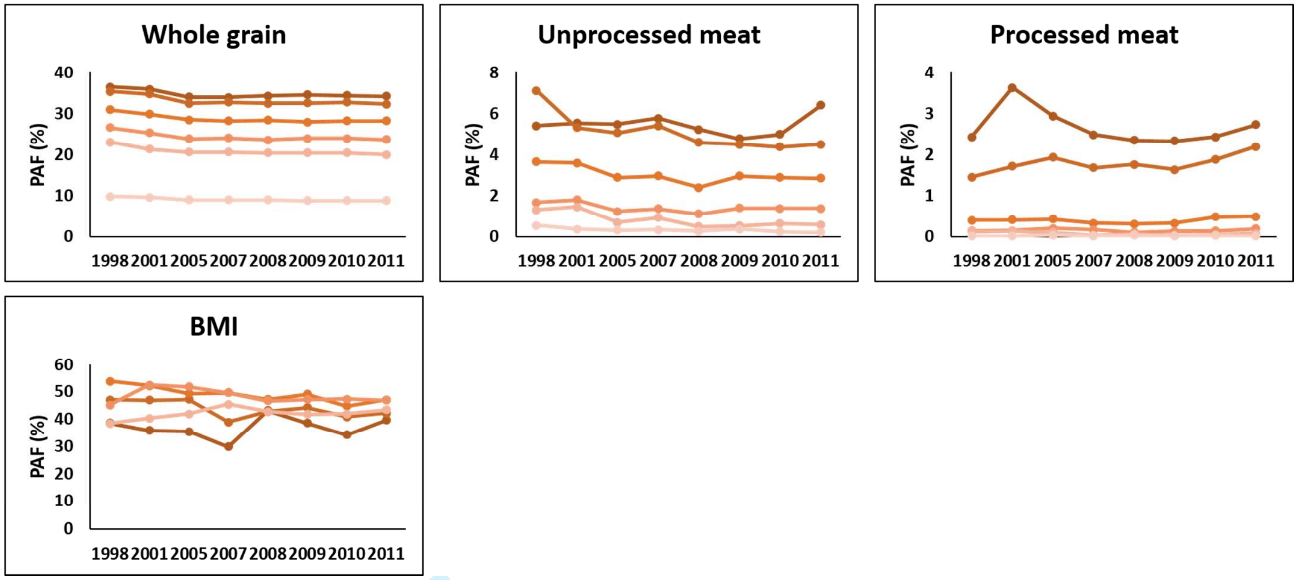
C. Total stroke



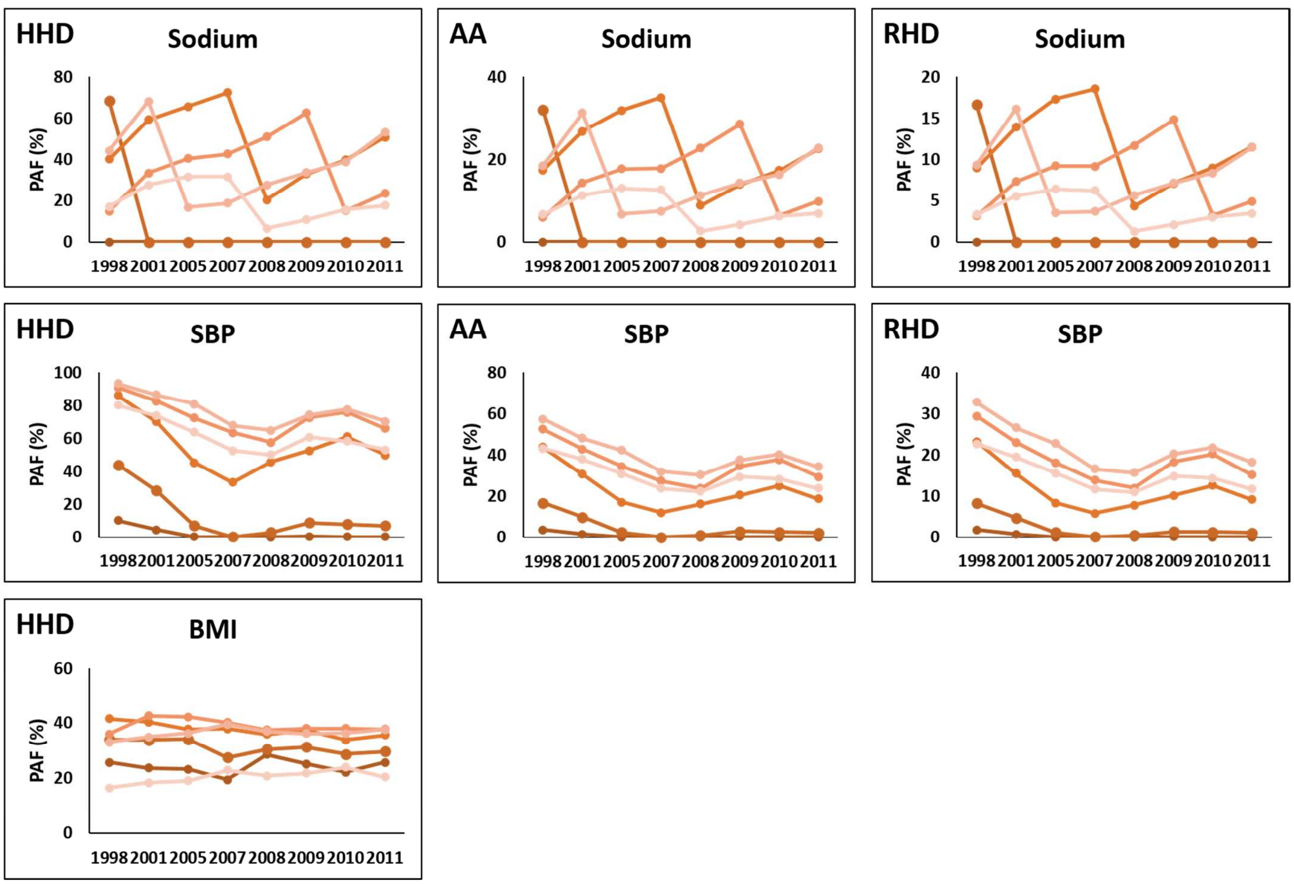
D. Ischemic Heart Disease



E. Diabetes



F. Other CVD



Supplementary Table 1. Total deaths due to cardiovascular disease, stroke, and diabetes in Korea (1998-2011).

Year	Age group (yrs)	Deaths number caused by specific diseases							
		IHD	ISTK	HSTK	TSTK	DM	HHD	AA	RHD
Total									
1998	All	8282	6744	10864	17608	10735	1148	379	83
2001		12954	11774	12347	24121	13385	3932	590	190
2005		17665	15448	10942	26390	14122	3430	861	333
2007		19554	15958	9727	25685	14125	4084	891	294
2008		17154	14602	9471	24073	12984	3244	921	294
2009		17554	13142	8903	22045	12510	2783	847	219
2010		18507	12872	9302	22174	13537	3006	904	257
2011		19323	12723	8996	21719	14250	3330	984	239
Men									
1998	25-34	116	21	150	171	47	1	5	2
	35-44	401	80	554	634	275	18	16	2
	45-54	668	174	870	1044	615	29	21	4
	55-64	1163	666	1413	2079	1521	81	54	6
	65-74	1115	1007	1137	2144	1423	129	50	7
	75+	1273	1303	1106	2409	1451	178	63	11
2001	25-34	117	18	114	132	52	2	2	5
	35-44	420	80	564	644	278	20	11	2
	45-54	803	229	1021	1250	685	40	21	6
	55-64	1292	761	1327	2088	1439	116	53	10
	65-74	1572	1360	1282	2642	1737	222	92	16
	75+	2384	2804	1362	4166	2129	823	140	19
2005	25-34	83	11	88	99	31	1	5	1
	35-44	397	51	480	531	242	11	30	9
	45-54	890	203	813	1016	790	35	40	13
	55-64	1270	666	951	1617	1361	74	60	27
	65-74	1978	1742	1087	2829	1980	142	110	34
	75+	3752	4013	1494	5507	2315	620	218	40
2007	25-34	77	15	76	91	25	1	6	0
	35-44	375	38	335	373	226	6	15	2
	45-54	902	195	791	986	725	29	36	15
	55-64	1347	527	770	1297	1033	66	52	14
	65-74	2097	1698	1011	2709	1952	168	134	17
	75+	4499	4229	1475	5704	2659	732	243	37
2008	25-34	58	6	64	70	24	1	10	1
	35-44	345	36	331	367	170	7	12	0
	45-54	915	176	768	944	606	37	37	8
	55-64	1125	451	718	1169	900	54	64	16
	65-74	2015	1449	988	2437	1814	126	141	22
	75+	3883	4101	1539	5640	2606	598	257	56
2009	25-34	63	6	52	58	25	2	5	3
	35-44	338	36	335	371	134	11	20	6
	45-54	905	147	700	847	590	30	33	5
	55-64	1173	398	637	1035	866	60	39	8
	65-74	1962	1251	890	2141	1631	107	112	11
	75+	4132	3855	1490	5345	2615	459	272	20
2010	25-34	54	6	62	68	23	3	7	2
	35-44	309	41	307	348	149	7	19	4
	45-54	875	138	689	827	583	30	31	11
	55-64	1151	359	661	1020	878	54	37	15
	65-74	1879	1114	883	1997	1675	105	128	19
	75+	4498	3733	1691	5424	2991	526	244	30

2011	25-34	43	8	53	61	17	2	5	0
	35-44	267	32	264	296	94	3	16	2
	45-54	847	99	685	784	570	25	41	10
	55-64	1155	334	647	981	923	46	43	16
	65-74	1856	960	768	1728	1787	108	121	16
	75+	4769	3749	1664	5413	3345	585	294	18
Women									
1998	25-34	23	14	71	85	32	0	0	4
	35-44	87	25	249	274	87	10	4	5
	45-54	153	90	500	590	177	18	8	7
	55-64	412	362	1077	1439	802	64	33	12
	65-74	891	893	1488	2381	1741	145	55	12
	75+	1980	2109	2249	4358	2564	475	70	11
2001	25-34	26	20	61	81	40	2	2	1
	35-44	73	29	234	263	88	8	6	9
	45-54	155	84	491	575	194	26	12	4
	55-64	500	355	937	1292	745	77	34	20
	65-74	1292	1241	1566	2807	2086	311	72	29
	75+	4320	4793	3388	8181	3912	2285	145	69
2005	25-34	10	8	35	43	31	0	3	0
	35-44	76	22	202	224	71	2	6	2
	45-54	191	80	429	509	211	10	15	16
	55-64	402	283	636	919	615	41	21	41
	65-74	1439	1334	1200	2534	1917	221	94	54
	75+	7177	7035	3527	10562	4558	2273	259	96
2007	25-34	13	6	50	56	17	0	3	0
	35-44	55	20	174	194	67	4	4	4
	45-54	178	70	385	455	194	19	13	13
	55-64	364	220	489	709	451	34	28	32
	65-74	1485	1180	1044	2224	1635	248	94	58
	75+	8162	7760	3127	10887	5141	2777	263	102
2008	25-34	3	9	33	42	20	1	2	1
	35-44	43	26	149	175	59	2	6	6
	45-54	148	76	396	472	167	3	7	8
	55-64	319	180	415	595	425	30	23	21
	65-74	1183	993	987	1980	1451	157	91	48
	75+	7117	7099	3083	10182	4742	2228	271	107
2009	25-34	5	10	44	54	23	1	5	1
	35-44	48	21	129	150	50	4	4	2
	45-54	144	51	390	441	145	8	4	10
	55-64	285	158	373	531	336	26	23	18
	65-74	1119	775	841	1616	1328	141	79	44
	75+	7380	6434	3022	9456	4767	1934	251	91
2010	25-34	6	7	32	39	14	2	3	1
	35-44	36	18	159	177	52	2	7	0
	45-54	131	51	415	466	136	6	7	6
	55-64	284	144	428	572	318	14	27	21
	65-74	1163	671	849	1520	1315	113	69	36
	75+	8121	6590	3126	9716	5403	2144	325	112
2011	25-34	9	8	26	34	17	1	2	0
	35-44	40	19	141	160	55	2	1	1
	45-54	107	53	359	412	147	5	6	3
	55-64	270	127	412	539	356	16	25	20
	65-74	1023	593	750	1343	1228	94	72	48
	75+	8937	6741	3227	9968	5711	2443	358	105

Supplementary Table 2. Number of cardiometabolic mortality attributable to each risk factor by sex from 1998 to 2011 with 95% uncertainty intervals

Risk factor	Disease	Percentage of death (95% UI)							
		Year							
		1998	2001	2005	2007	2008	2009	2010	2011
Men									
Low intake of fruits	HSTK	2378.4 (1913.7-2768.3)	2178.7 (1690.7-2576.4)	1630.8 (1265.2-1974.1)	1554.8 (1202.0-1855.8)	1566.9 (1233.0-1874.2)	1475.2 (1176.0-1762.5)	1604.7 (1274.7-1891.2)	1504.0 (1189.5-1795.7)
	ISTK	593.2 (462.6-715.8)	697.2 (549.6-863.1)	737.6 (555.4-922.3)	804.4 (606.6-997.3)	754.2 (572.4-937.8)	692.0 (527.2-846.5)	699.8 (521.5-876.3)	650.9 (472.6-814.3)
	TSTK	2971.6 (2498.6-3390.8)	2875.9 (2379.9-3299.5)	2368.4 (1964.4-2762.1)	2359.2 (1961.7-2707.0)	2321.1 (1950.9-2688.6)	2167.3 (1822.6-2499.7)	2304.5 (1938.8-2640.5)	2154.9 (1791.3-2489.6)
	IHD	762.8 (592.4-940.0)	787.4 (600.5-982.1)	804.1 (600.6-1003.7)	976.8 (754.4-1226.5)	923.1 (698.4-1144.3)	957.8 (729.6-1200.4)	1027.7 (778.8-1282.0)	1026.3 (771.3-1283.5)
Low intake of vegetables	HSTK	702.4 (459.3-943.9)	879.8 (589.2-1155.3)	740.1 (494.3-978.5)	857.7 (565.4-1124.7)	873.7 (587.5-1144.8)	837.2 (566.7-1082.6)	902.5 (620.4-1181.8)	835.7 (576.9-1092.0)
	ISTK	237.9 (147.5-330.0)	379.5 (224.7-521.6)	477.3 (280.8-678.1)	642.4 (386.3-919.1)	601.7 (343.8-851)	558.8 (328.1-785.3)	535.9 (316.4-756.1)	514.6 (282.1-732.8)
	TSTK	940.3 (695.0-1189.0)	1259.3 (953.3-1577.5)	1217.5 (890.7-1534.1)	1500.1 (1107.4-1858.6)	1475.4 (1102.2-1827.7)	1396.0 (1044.4-1739.0)	1438.4 (1104.2-1774.9)	1350.3 (995.2-1687.7)
	IHD	245.8 (197.6-299.7)	375.3 (296.9-448.5)	445.1 (350.7-543.9)	652.4 (518.2-796.8)	626.9 (506.0-758.6)	657.3 (526.2-788.7)	688.9 (535.1-839.5)	690.0 (538.1-830.1)
Low intake of whole grains	HSTK	1028.7 (901.6-1161.9)	1055.0 (919.6-1186.9)	829.4 (726.4-932.5)	718.1 (625.5-803.6)	704.7 (616.8-786.6)	646.8 (560.8-727.9)	661.7 (578.4-742.6)	620.2 (543.6-696.2)
	ISTK	505.7 (430.4-578.9)	691.3 (588.1-795.4)	781.0 (656.9-898.4)	739.9 (618.4-861.3)	673.2 (559.1-790.9)	601.1 (490.1-710.1)	565.0 (468.9-657.6)	524.9 (434.6-620.9)
	TSTK	1534.4 (1384.7-1682.4)	1746.3 (1584.8-1914.7)	1610.3 (1441.4-1764.5)	1458.0 (1313.2-1606.3)	1377.9 (1232.1-1524)	1247.9 (1117.8-1388.2)	1226.7 (1104.4-1355.6)	1145.1 (1032.4-1266.7)
	IHD	866.4 (728.6-1001.7)	1064.2 (902.6-1224)	1178.8 (989.6-1373.7)	1242.5 (1019-1441.9)	1143.3 (957.8-1328.2)	1148.0 (952.6-1344.0)	1151.4 (955.2-1344.4)	1143.9 (939.4-1322)
	DM	1171.6 (951.8-1380.3)	1273.2 (1040.1-1490.7)	1278.1 (1035.2-1525.5)	1177.1 (954.4-1387.2)	1056.6 (859.9-1268.9)	993.3 (802.5-1173.7)	1043.0 (822.6-1239.1)	1086.5 (855.9-1305.4)
High intake of processed meats	IHD	12.3 (8.0-17.2)	19.9 (12.7-27.4)	20.7 (13.4-28.4)	15.7 (9.1-22.5)	13.6 (8.1-19.1)	13.5 (8.6-18.7)	15.4 (9.3-21.7)	17.3 (10.8-23.6)
	DM	12.6 (9.7-15.6)	18.4 (14.6-22.7)	18.1 (13.8-22.3)	12.5 (9.4-15.5)	9.9 (7.7-12)	9.0 (7.0-11.0)	11.5 (9.0-14.0)	12.3 (9.7-15.1)
High intake of unprocessed meats	DM	155.7 (97.1-220.2)	132.2 (85.1-181.9)	105.7 (66.8-143.7)	103.4 (60.9-142.6)	75.2 (49.4-101.2)	60.4 (37.3-83.6)	67.2 (41.7-92)	63.8 (40.7-86.2)
High intake of sodium	HSTK	1146.2 (868.5-1425.3)	1835.8 (1477-2200.4)	1166.4 (854.0-1493.5)	1209.4 (906.0-1507.7)	741.5 (531.7-953.4)	976.5 (769.9-1205.6)	820.1 (612.2-1033.9)	975.2 (770.3-1201.9)
	ISTK	535.2 (407.1-679.8)	1189.3 (955.6-1421.3)	1134.8 (798.7-1495.4)	1157.9 (843.9-1495.7)	589.6 (417.1-772.1)	769.4 (591.9-961.6)	705.0 (534.8-887.2)	767.9 (598.9-947.6)

	TSTK	1681.5 (1376.4-2002)	3025.0 (2570.9-3458.9)	2301.2 (1844.1-2770.3)	2367.3 (1923.3-2835.4)	1331.1 (1061.3-1610.9)	1745.9 (1463.7-2043.6)	1525.1 (1250.2-1796.3)	1743.1 (1462.4-2023.0)
	AA	27.1 (21.1-33.3)	60.7 (48.3-73.5)	69.9 (54.3-87.7)	76.2 (59.5-94.6)	46.8 (35.4-58.4)	59.5 (45.8-72.0)	57.9 (46.0-70.3)	75.2 (61.0-91.1)
	HHD	128.7 (100.0-156.7)	430.2 (342.2-514.5)	312.7 (233.9-390.2)	356.9 (253.7-461.7)	122.2 (72.7-173.1)	167.3 (124.7-209.9)	178.5 (134.4-224.2)	207.8 (164.7-253.7)
	RHD	2.1 (1.5-2.7)	6.1 (4.5-7.7)	9.8 (6.9-13.2)	8.0 (5.6-10.9)	4.6 (3.1-6.2)	4.9 (3.7-6.1)	5.3 (3.9-6.9)	5.3 (3.9-6.7)
	IHD	749.9 (556.9-943.7)	1508.7 (1192.3-1825.0)	1495.3 (1068.0-2014.3)	1758.9 (1281.0-2336.5)	923.3 (677.8-1183.4)	1369.7 (1052.7-1700.6)	1190.7 (888.8-1533.8)	1455.5 (1121.6-1795.9)
High fasting plasma glucose	TSTK	963.4 (908.7-1018.6)	853.4 (792.4-914.7)	939.0 (842.8-1048.7)	874.8 (767.3-975.8)	812.1 (754-869.4)	800.8 (748.0-855.4)	816.0 (745.1-884.2)	685.5 (634.4-740.5)
	IHD	695.0 (651.4-740.2)	674.4 (618.9-729.0)	948.3 (835.4-1068.2)	1047.1 (915.6-1182.4)	887.6 (825.1-949.3)	995.0 (931.7-1066.7)	1064.0 (975.4-1157.9)	947.2 (875.3-1018.5)
High total cholesterol	ISTK	298.7 (286.8-309.0)	388.8 (374.8-403.4)	305.7 (291.7-320.9)	292.7 (275.7-309.9)	243.8 (232.1-255.1)	212.8 (203.1-222.0)	195.8 (187.4-203.6)	175.3 (167.5-182.6)
	IHD	1427.5 (1381.1-1473.9)	1895.6 (1833.1-1956.6)	1884.0 (1771.1-1989.1)	2111 (1986.1-2240.2)	1922.0 (1837.9-2001.9)	1887.9 (1812.6-1971.8)	1871.4 (1777.6-1963.2)	1917.2 (1822.2-2005.3)
High systolic blood pressure	HSTK	3173.6 (3098.2-3253.1)	3128.9 (3031.5-3222.9)	2048.8 (1961.0-2138.5)	1551.9 (1449.4-1645.5)	1368.4 (1297.5-1436.1)	1703.1 (1645.0-1753.3)	1708.8 (1640.8-1771.4)	1389.1 (1326.2-1447.5)
	ISTK	1762.9 (1692.2-1831.6)	2356.6 (2225.2-2494.5)	2414.8 (2224.9-2598.2)	1925.2 (1735.8-2116.7)	1645.4 (1531.9-1773.0)	1954.1 (1848.0-2058.7)	1766.6 (1658.6-1872.1)	1372.0 (1276.2-1465.5)
	TSTK	4936.5 (4838.9-5036.4)	5485.5 (5328.1-5647.4)	4463.7 (4250.9-4663.7)	3477.1 (3259.2-3685.4)	3013.8 (2885.6-3169.0)	3657.1 (3543.0-3771.0)	3475.4 (3335.9-3601.7)	2761.1 (2648.6-2875.4)
	IHD	2346.7 (2267.2-2429.5)	2859.5 (2724.1-2992.4)	2840.4 (2641.3-3030.3)	2544.0 (2328.9-2762.5)	2118.9 (1972.5-2260.0)	2938.0 (2794.8-3081.4)	2895.1 (2750-3038.6)	2444.9 (2287.4-2598.1)
	HHD	352.7 (343-361.6)	826.3 (768.6-875.7)	534.7 (493.5-575.2)	505.6 (451.4-558.1)	406.7 (377.7-436.0)	413.4 (394.7-430.3)	429.6 (405.9-454.4)	389.5 (363.3-415.8)
	RHD	7.3.0 (6.9-7.7)	12 .0 (11.3-12.7)	20.2 (19-21.6)	10.7 (9.7-11.7)	11.6 (10.7-12.6)	8.0 (7.6-8.4)	12.8 (12.2-13.4)	8.5 (8.1-9.0)
	AA	91.4 (87.8-95.0)	122.3 (114.9-129.1)	137.8 (127.7-148.2)	117.7 (107.2-129.0)	117.3 (108.6-125.8)	143.1 (136.2-151.0)	135.9 (128.8-143.4)	123.5 (115.1-131.8)
High body mass index	HSTK	1046.6 (1010.4-1084.1)	1384.1 (1336.9-1432.2)	1191.2 (1151.6-1230.3)	995.1 (947.7-1040.2)	974.8 (945.4-1004.4)	926.8 (901.4-952.7)	886.0 (858.7-914.0)	857.1 (832.0-885.3)
	ISTK	269.7 (253.7-286.0)	528.8 (496.2-563.4)	638.4 (586.5-695.2)	563.5 (510.8-616.1)	504.7 (469.9-536.1)	455.6 (428.0-483.4)	407.5 (379.0-436.1)	392.7 (368.1-419.3)
	TSTK	1316.3 (1276.1-1356.7)	1912.9 (1857.7-1968.4)	1829.6 (1762.2-1898.3)	1558.7 (1488.6-1626)	1479.5 (1433.3-1523.4)	1382.3 (1346.1-1420.8)	1293.5 (1254.1-1332.3)	1249.8 (1215.2-1285.1)
	IHD	558.3 (533.9-582.6)	945.8 (894.6-992.8)	1192.8 (1115.5-1271.4)	1211.4 (1124.3-1304.0)	1101.9 (1047.0-1155.9)	1141.6 (1092.8-1190.7)	1078.3 (1025.5-1133.3)	1126.1 (1072.1-1186.4)
	DM	1248.4 (1186.8-1319.9)	1914.7 (1817.8-2018.0)	2168.9 (2056.5-2286.2)	1918.0 (1805.6-2044.2)	1733.8 (1655.1-1814.9)	1667.6 (1598.3-1736.9)	1681.5 (1603.0-1761.6)	1831.6 (1746.0-1918.7)
	HHD	66.5 (61.8-72.1)	230.2 (202.2-259.1)	192.4 (164.4-216.4)	197.5 (169.5-227.9)	157.7 (140.3-175.1)	133.6 (122.3-144.2)	135.1 (122.3-148.6)	147.2 (132.9-161.9)
Women									
Low intake of fruits	HSTK	2155.9 (1680.4-2564.2)	2014.8 (1514.4-2493.5)	1506.5 (1083.4-1921.5)	1297.8 (950.2-1644.9)	1355.1 (981.5-1689.9)	1250.7 (913.6-1587.8)	1425.9 (1048.8-1787.7)	1379.6 (996.2-1758)

	ISTK	524.7 (397.7-640.3)	730.6 (524.4-923.8)	806.7 (567.3-1062.3)	835.9 (566.8-1127.5)	819.3 (544.0-1080.1)	698.1 (484.4-934.9)	740.8 (476.9-998.5)	758.4 (484.1-1009.6)
	TSTK	2680.6 (2174.8-3113.9)	2745.4 (2212.6-3267.7)	2313.2 (1789.3-2797.8)	2133.7 (1701.4-2595.8)	2174.4 (1736.6-2608.4)	1948.9 (1544.2-2390.2)	2166.7 (1697.7-2609.2)	2138.0 (1662.9-2581.7)
	IHD	419.4 (316.4-524.5)	557.5 (384.0-727.1)	636.7 (397.0-870.0)	699.4 (438.3-972.1)	653.9 (412.7-889.6)	646.3 (397.1-891.6)	746.9 (468.4-1051.5)	794.0 (458.1-1116.1)
Low intake of vegetables	HSTK	700.4 (454.1-945.6)	883.9 (552.2-1216.3)	756.3 (455.3-1039.3)	813.1 (486.9-1136.7)	809.5 (512.6-1113.4)	801.1 (488.6-1090.5)	848.6 (528.2-1150.6)	804.3 (479.1-1116.4)
	ISTK	245.4 (135.8-355.1)	448.0 (243.5-674.5)	572.4 (287.0-874.0)	787.0 (349.3-1204.9)	693.4 (313.1-1065)	645.6 (307.4-974.7)	623.1 (263.4-961.4)	643.7 (244.6-1038.6)
	TSTK	945.7 (687.7-1216.2)	1332.0 (951.3-1717.6)	1328.6 (898.9-1763.3)	1600.1 (1036.3-2114.6)	1502.9 (1027.3-1980.8)	1446.7 (986.4-1900.2)	1471.7 (970.1-1938.5)	1448.0 (934.5-1989.2)
	IHD	158.7 (120.0-197.3)	290.4 (215.9-369.3)	392.5 (273.3-507.5)	558.9 (406.9-724.6)	480.1 (339.4-615.6)	507.0 (354.7-670.4)	546.7 (381.4-718.3)	583.6 (385.5-766.4)
Low intake of whole grains	HSTK	907.5 (790.1-1024.4)	927.8 (799.5-1046.4)	739.9 (626.8-845.6)	642.6 (549.4-737.0)	603.5 (509.6-690.4)	562.9 (481.8-648.6)	591.6 (505.5-681.0)	555.6 (475.7-639.9)
	ISTK	443.6 (368.2-513.9)	689.1 (563.4-809.4)	808.7 (641.5-986.5)	818.8 (635.2-997.5)	733.6 (572.7-897.9)	640.5 (496.4-790.2)	623.5 (473.9-771.9)	614.2 (464.1-767.1)
	TSTK	1351.1 (1213.5-1482.6)	1616.9 (1430.7-1790.4)	1548.6 (1339.7-1745.7)	1461.4 (1257.6-1661.5)	1337.1 (1159.0-1533.5)	1203.5 (1042.7-1370.5)	1215.1 (1043.1-1379.3)	1169.8 (996.4-1342.7)
	IHD	475.2 (387.1-563.4)	713.9 (575.5-857.7)	885.7 (655.9-1101.0)	945.8 (706.8-1187.6)	797.0 (583.1-991.9)	799.1 (589-999.8)	844.5 (629.2-1066.8)	878.9 (642.7-1113.6)
	DM	965.0 (747.0-1186.6)	1116.0 (852.1-1354.3)	1047.3 (784.6-1294.6)	990.1 (746.0-1230.2)	898.3 (673.7-1118.2)	839.8 (639.1-1032.3)	884.0 (634.2-1102.4)	899.0 (666.5-1139.3)
High intake of processed meats	IHD	3.7 (2.3-5.1)	3.7 (2.3-5.1)	5 (3.2-6.9)	6.3 (3.8-9.3)	3.5 (2.2-5.1)	3.7 (2-5.4)	2.5 (1.5-3.5)	3.8 (1.9-6)
	DM	6.3 (4.8-8.0)	6.3 (4.8-8.0)	8.3 (6.4-10.4)	8.2 (6.4-10.1)	4.2 (3.2-5.3)	4.7 (3.6-5.8)	3.2 (2.5-4)	4.4 (3.3-5.7)
High intake of unprocessed meats	DM	64.7 (40.0-90.2)	72.5 (43.2-104.9)	46.4 (29.6-63.4)	48.9 (30.4-68)	32.3 (19.8-45.9)	36.6 (21.8-53.2)	33 (19.4-46.4)	31.8 (20.3-43.9)
High intake of sodium	HSTK	961.1 (725.9-1215.7)	1568.2 (1193.0-1971.2)	1029.2 (687.1-1434.6)	913.7 (608.6-1263.0)	460.8 (310.5-629.2)	582.5 (425.9-768.1)	582.3 (404.0-783.7)	705.2 (521.1-904.5)
	ISTK	460.4 (349.9-574.5)	1228.6 (932.8-1527.7)	1205.3 (818.3-1614.2)	1266.2 (847.7-1752.3)	430.9 (224.1-694.6)	524.0 (352.2-721.7)	621.3 (422.4-854.2)	728.4 (522.3-945.4)
	TSTK	1421.5 (1149.4-1719.5)	2796.8 (2333.1-3297.4)	2234.4 (1696.3-2860.3)	2179.9 (1677.2-2772.6)	891.7 (643.1-1194.6)	1106.5 (866.8-1355.1)	1203.6 (947.4-1482.5)	1433.6 (1153.2-1717.8)
	AA	19.5 (15.1-24.3)	46.9 (36.8-57.7)	48.6 (35.1-63.5)	49.6 (35.9-64.5)	23.2 (14.6-32.2)	29.0 (21.1-37.7)	34.7 (24.6-45)	45.1 (34.1-57.0)
	HHD	169.1 (130.4-211.3)	883.9 (673.4-1080.7)	778.1 (539.9-1026.3)	954.3 (625.7-1255.6)	207.0 (60.7-383.7)	274 (158.4-399.1)	382.9 (247.3-520.1)	486.8 (347.6-642.6)
	RHD	3.3 (2.4-4.3)	10.5 (7.2-14.1)	14.6 (9.7-20.3)	13.8 (9.2-19.0)	6.9 (4.6-9.6)	8.4 (6.2-10.9)	7.6 (5.0-10.5)	10.5 (6.9-14.1)
	IHD	428.1 (314.9-553.9)	1119.4 (795.4-1454.6)	1320.6 (758.3-1951.0)	1406.7 (807.7-2131.7)	449.8 (230.8-718.6)	639.1 (407.9-933.3)	841.0 (542.3-1219.7)	1027.3 (662.4-1471.5)
High fasting plasma glucose	TSTK	957.0 (903.4-1012.7)	1089.9 (994.9-1186.5)	865 (773.3-974.8)	887.6 (775.3-999.2)	944.6 (865.0-1026.8)	871.6 (791.3-955.5)	765.8 (689.1-854.8)	851.6 (770.3-929.4)
	IHD	510.0 (472.3-550.0)	789.7 (705.9-873.6)	859.4 (742.8-978.9)	1000.5 (852.8-1156.1)	990.6 (893.7-1086.9)	1042.6 (939.7-1151.3)	975.5 (855.8-1104.2)	1180.7 (1058.1-1313.5)

High total cholesterol	ISTK	233.1 (226.5-239.7)	266.7 (257.8-275.6)	220.9 (212.6-229.9)	205.7 (195.9-215.2)	175.5 (169.8-181.1)	136.2 (131.9-140.6)	121.7 (117.5-125.8)	116.1 (112.5-119.8)
	IHD	961.5 (922.8-996.2)	1558.1 (1490.6-1628.9)	1965.6 (1837.8-2096.1)	2203.3 (2042.8-2361.7)	1911.7 (1810.8-2011.9)	1863.2 (1763.1-1962.9)	1984.1 (1833.3-2124.1)	2023.6 (1915.1-2129.7)
High systolic blood pressure	HSTK	3323.8 (3248.8-3396.6)	3214.1 (3097.5-3330.7)	2281.4 (2165.9-2393.4)	1528.7 (1417.4-1644.9)	1410.3 (1340.4-1479.9)	1691.0 (1626.7-1754.5)	1797.7 (1723.4-1867.5)	1464.8 (1392.6-1537.6)
	ISTK	1896.7 (1816.9-1959.8)	2864 (2709.7-3011.9)	3088.1 (2874.0-3305.5)	2461.2 (2201.3-2715.2)	2087.3 (1933.5-2229.0)	2382.8 (2249.1-2500.0)	2320.3 (2187.9-2460.7)	1959.6 (1818.0-2104.1)
	TSTK	5220.5 (5119.1-5319.8)	6078.1 (5896.7-6263.3)	5369.5 (5124.4-5596.3)	3989.9 (3686.1-4264.7)	3497.6 (3328.0-3661.3)	4073.9 (3924.7-4213.1)	4118.0 (3966.4-4277.1)	3424.4 (3258.2-3591)
	IHD	1825.3 (1757.8-1892.1)	2764.5 (2630.6-2907.3)	3278.7 (3038.5-3496.5)	2771.0 (2467.3-3089.2)	2245.3 (2090.1-2396.7)	2967.2 (2813.1-3128.3)	3157.1 (2993.5-3344.9)	2825.8 (2634.1-3011.8)
	HHD	593.2 (579.2-605.4)	2037.5 (1965.6-2106.6)	1660.9 (1561.9-1747.4)	1653.4 (1512.9-1797.2)	1235.0 (1156.0-1307.3)	1302.5 (1249.9-1353.0)	1352.0 (1289.8-1417.3)	1374.0 (1286.2-1456.7)
	RHD	12.1 (11.7-12.5)	26.8 (25.4-28.4)	36.0 (34.1-38.0)	26.7 (24.5-28.9)	22.4 (21.1-23.8)	26.8 (25.5-28.0)	28.8 (27.4-30.3)	24.4 (23.1-25.8)
	AA	83.3 (80.7-85.7)	108.5 (103.2-112.9)	129.4 (121.2-137.6)	101.5 (92.3-110.6)	94.6 (89.0-100.4)	112.5 (107.1-117.6)	131.7 (124.9-138.4)	118.7 (111.3-126.5)
High body mass index	HSTK	1114.6 (1075.8-1154.3)	1215.6 (1173.7-1261.8)	980.1 (937.6-1017.6)	875.2 (832.0-918.4)	775.6 (751.0-802.3)	728.5 (704.1-752.5)	769.7 (740.3-801.1)	702.1 (676.6-727.6)
	ISTK	355.9 (336.4-375.0)	566.8 (526.2-605.2)	672.6 (616.7-729.7)	743.4 (668.5-815.5)	604.6 (566.1-645.9)	534.4 (497.9-570.2)	545.9 (501.2-590.5)	484.9 (448.8-522.3)
	TSTK	1470.5 (1430.2-1511.3)	1782.4 (1721.0-1837.3)	1652.7 (1582.8-1724.9)	1618.5 (1527.1-1698.4)	1380.2 (1333.9-1429.9)	1262.9 (1219.5-1304.0)	1315.6 (1259.9-1372.4)	1187.1 (1142.4-1230.1)
	IHD	438.9 (413.8-464.3)	749.0 (693.9-801.3)	995.4 (901.2-1092.9)	1215.8 (1092.0-1337.0)	940.8 (874.7-1011.2)	980.7 (910.3-1051.3)	1111.9 (1015.1-1212.5)	1034.3 (952.0-1121.1)
	DM	1574.2 (1496-1656.2)	2062.7 (1955.3-2173.4)	2096.3 (1966.6-2246.1)	2211.4 (2043.2-2375.4)	1857.8 (1755.4-1964.4)	1801.7 (1704.4-1904.4)	2015.8 (1881.8-2147.3)	1896.0 (1785.2-2007.3)
	HHD	159.0 (146.1-173.3)	570.9 (509.5-638.0)	532.7 (470.3-599.9)	749.2 (656.9-840.9)	531.0 (484.4-582.2)	484.1 (441.7-523.7)	560.4 (508.9-612.8)	537.7 (485.1-588.5)

The values were expressed as death number for each risk factors (95% Uncertainty Intervals). HSTK, hemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; AA, aortic aneurysm and dissection; HHD, hypertensive heart disease; RHD, rheumatic heart disease.

BMJ Open

Estimating change in cardiovascular disease and diabetes burdens due to dietary and metabolic transition in Korea 1998-2011: A comparative risk assessment analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-013283.R1
Article Type:	Research
Date Submitted by the Author:	29-Sep-2016
Complete List of Authors:	Cho, Yoonsu; Korea University, Department of Public Health Sciences Cudhea, Frederick; Tufts University Friedman School of Nutrition Science and Policy, Friedman School of Nutrition Science & Policy Park, Ju-Hyun; Dongguk University, Department of Statistics Lee, Jong-Tae; Korea University, Department of Public Health Sciences Mozaffarian, Dariush; Friedman School of Nutrition Science and Policy, Tufts University, Friedman School of Nutrition Science & Policy Singh, Gitanjali; Tufts University Friedman School of Nutrition Science and Policy, Friedman School of Nutrition Science & Policy Shin, Min-Jeong; Korea University, Department of Public Health Sciences
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Global health, Nutrition and metabolism
Keywords:	burden of disease, dietary risk, metabolic risk, cardiometabolic disease, cardiovascular disease

Estimating change in cardiovascular disease and diabetes burdens due to dietary and metabolic transition in Korea 1998-2011: A comparative risk assessment analysis

Yoonsu Cho[1], Frederick Cudhea[2], Ju-Hyun Park[3], Jong-Tae Lee[1], Dariush Mozaffarian[2], Gitanjali Singh[2,]*, Min-Jeong Shin[1,]*

[1]Department of Public Health Sciences, BK21PLUS Program in Embodiment: Health-Society Interaction, Graduate School, Korea University, Seoul 136-701, Republic of Korea, [2]Friedman School of Nutrition Science & Policy, Tufts University, Boston, Massachusetts, USA, [3]Department of Statistics, Dongguk University, Seoul, Republic of Korea

*Correspondence and request for reprints: Singh G and Shin MJ jointly directed this study. **Gitanjali Singh**, Friedman School of Nutrition Science and Policy, Tufts University, 150 Harrison Avenue, Boston, MA 02111, USA; Tel: +1-617-636-3737; E-mail: Gitanjali.Singh@Tufts.edu; **Min-Jeong Shin**, Department of Public Health Sciences, Graduate School, Korea University, Seoul 136-701; Tel: +82-2-3290-5643; Fax: +82-2-940-2849; E-mail: mjshin@korea.ac.kr

Keywords: burden of disease, dietary risk, metabolic risk, cardiometabolic disease, cardiovascular disease

Word count: 5032

ABSTRACT

OBJECTIVES: Over the past 10 years, the burden of chronic diseases in Korea has increased. However, there are currently no quantitative estimates of how changes in diet and metabolic risks have contributed to these shifting burdens. This study aims to evaluate the contributions of dietary and metabolic risk factors to death from cardiometabolic diseases (CMDs) such as cardiovascular conditions, strokes, and diabetes in Korea, and to estimate how these contributions have changed over the past 10 years. **DESIGN AND METHODS:** We used data on the 6 dietary and 4 metabolic risk factors by sex, age, and year from the Korea National Health and Nutrition Examination Survey. The relative risks for the effects of the risk factors on the CMD mortality were obtained from meta-analyses. The population-attributable fraction attributable to the risk factors was calculated by using comparative risk assessment approach across sex and age strata (males and females, age groups 25-34, 35-44, 45-54, 55-64, 65-74, and 75+) from 1998 to 2011. **RESULTS:** The results showed that a suboptimal diet and high blood pressure were the main risk factors of CMD mortality in Korea. High blood pressure accounted for 127095.7 (UIs: 121907.0, 132217.5) deaths from CMD. Among the individual dietary risk factors, a high intake of sodium (42387.0 deaths; UIs: 42387.0, 65093.6) and a low intake of fruits (50243.8 deaths; UI: 40981.4, 59178.2) and whole grains (54248.2 deaths; UIs: 47020.0, 61343.0) were responsible for the highest number of CMD deaths in Korea. **CONCLUSIONS:** Providing relative importance of risk factors in Korea, the results implicate that metabolic and dietary risk factors were major contributor to CMD mortality.

Main strengths and limitations of study

- This is the first investigation to analyse data from national individual-based surveys to evaluate the diet consumption and its transition over past decades in Korea.
- This study estimates the impacts of dietary and metabolic risks on CMDs in Korea using the best available and most up-to-date aetiological effect size of risk factor-disease relationships, as well as multiple years of data from the nationally-representative Korean National Health and Nutrition Survey.
- This study identifies national priorities for improving diet and reducing cardiometabolic risk to improve CMD health in Korea.
- This analysis was based on a limited number of dietary factors that were assessed in KNHANES.

INTRODUCTION

Along with rapid socio-economic changes, cardiometabolic diseases (CMDs) including cardiovascular disease (CVD) and diabetes mellitus (DM) have been the leading cause of global death, killing 38 million people.[1] Corresponding to global trend, the burden of CMDs has dramatically increased in Korea.[2 ,3] According to data from the Korea National Statistics, more than 45% of deaths in Korea are caused by non-communicable diseases such as CVD and DM.[4]

The increased prevalence of suboptimal lifestyles and metabolic risk factors are important modifiable risk factors of CMDs.[5-7] Previous global burden of disease (GBD) study reported that the global and regional burdens of chronic diseases were attributable to multiple risk factors and advocated the systematic assessment of multiple dietary risk factors for CMD, called comparative risk assessment (CRA).[8] There have been previous efforts to estimate the comparable contributions of selected dietary and metabolic risk factors based on national estimates from various regions, using CRA approach.[9-12] However, most of the current estimates of dietary risk factors have focused on Western countries, making it hard to represent the population-specific effects. So far, there is only one study on burden of disease with Chinese population among the Asian countries. The burden of disease study in China emphasised the necessity of nation-specific estimates for chronic diseases to reflect region specific changes in health and surveillance system.[13]

Similarly, the burden of disease in Korea shows unique characteristics, based on the nation's distinctive epidemiological and sociocultural contexts.[2] Korea has experienced rapid socio-cultural changes, including rapid economic growth, and constant westernization, which has been accompanied by ageing society, a decline of physical activity, an increase of energy intake, and an increase of body weight.[2 ,14] In addition, Korea has a unique diet characterized by a higher level of refined carbohydrates and pickled vegetables than Western countries and other Asian countries.[15] To address these nation-specific gaps, it is necessary to characterize and estimate the effects of dietary risk factors on the mortality from chronic disease in Korea population. Yet, with the absence of systematic and comparable methods to estimate the nationally representative burden of disease attributable to risk factors, it is hard to obtain an accurate estimation of the effects of dietary and metabolic risk factors on CMDs in Korea. The quantitative estimates of the changes in the burdens of CMDs caused by dietary and metabolic transitions could provide a better understanding of the ways changes in diet have contributed to these shifting burdens.

The aim of the current study was to evaluate the contributions of dietary and metabolic risk factors to chronic diseases such as CVD, stroke, and DM in Korea. We also aimed to estimate the trends these contributions have changed over the past 10 years.

METHODS

We conducted a population-level comparative risk assessment analysis (CRA) of 6 dietary and 4 metabolic risk factors in order to estimate the number of deaths from chronic diseases in Korea. Detailed information on CRA is available elsewhere.[8] Briefly, using CRA, we estimated the number of deaths that would have been prevented within the period of analysis if the current distribution of each risk factor exposure had been changed to a hypothetical alternative distribution.

Selection of risk factors

Dietary and metabolic risk factors in this analysis were selected based on the following criteria, as described previously:[10 ,16] 1) the risk factors presented probable or convincing evidence of effects on cardiovascular diseases, strokes, or DMs and 2) data from the nationally representative health and nutrition survey in Korea was available. The dietary risk factors included low intakes of fruit, vegetables, and whole grains, and high intakes of processed meats, unprocessed meats (red meats), and sodium (Table 1). The metabolic risk factors included high levels of fasting plasma glucose (FPG), total cholesterol (TC), systolic blood pressure (SBP), and body mass index (BMI).

Table 1. Data sources for age, sex, and year-specific estimates of dietary intakes, metabolic risk factor exposure levels, optimal risk factor distributions, the etiologic effects of risk factors on disease, and disease-specific mortality.

Dietary risks	Definition	Data source (Available year)	TMRED[4]	Unit for RRs	Related disease outcomes
Low intake of fruits[1]	Average daily consumption of fruits (fresh, frozen, cooked, canned, or dried, excluding salted or pickled fruits)	KNHANES (1998-2011)	300 ± 30 g/day	per 1 serving (100g)/day	IHD, ISTK, HSTK
Low intake of vegetables[2]	Average daily consumption of vegetables (fresh, cooked, canned, or dried vegetables)	KNHANES (1998-2011)	400 ± 40 g/day	per 1 serving (100g)/day	IHD, ISTK, HSTK
Low intake of whole grains	Average daily consumption of whole grains such as barley, and cereal	KNHANES (1998-2011)	125 ± 12.5 g/day	per 1 serving (50 g)/day	IHD, ISTK, HSTK, DM
High intake of processed meats	Average daily consumption of meats processed by smoking, curing, salting or addition of chemical preservatives (ham, and sausage)	KNHANES (1998-2011)	0 ± 0 g/day	per 1 serving (50g)/day	IHD, DM
High intake of unprocessed meat	Average daily consumption of red meats (beef, and pork, excluding poultry, fish and eggs).	KNHANES (1998-2011)	14.3 ± 1.43 g/day	per 1 serving (100g)/day	DM
High intake of sodium	Average daily intake of sodium from all sources	KNHANES (1998-2011)	2000 ± 200 mg/day	per 100 mmol/d (2.3 g/d)	Blood pressure mediated effect (CVD)
Metabolic risks	**Definition**	**Data source (Available year)**	**TMRED**		**Related disease outcomes**
High fasting plasma glucose	Serum fasting plasma glucose, measured in mmol/L	KNHANES (1998-2011)	4.9 ± 0.3 mmol/L	1 mmol/L	IHD, stroke
High total cholesterol	Serum total cholesterol, measured in mmol/L	KNHANES (1998-2011)	3.8 ± 0.6 mmol/L	1 mmol/L	IHD, ISTK
High systolic blood pressure	Systolic blood pressure, measured in mmHg	KNHANES (1998-2011)	115 ± 6 mmHg	10 mmHg	IHD, HSTK, ISTK, other CVD
High body mass index	Body-mass index, measured in kg/m^2	KNHANES (1998-2011)	21 ± 1 kg/m^2	5 kg/m^2	IHD, ISTK, DM, other CVD
Relative risks by age and sex[3]	**Description**	**Data source**			
Effect of fruits on IHD, ISTK, and HSTK	Published meta-analyses of 9, 10, and 7 cohorts studies, respectively [17]	Data were from US and European cohorts including 241,190 participants and 5,603 cases of IHD, 329,204 participants and 5,517 cases of ISTK, and 175,035 participants and 1,535 case of HSTK, respectively			

Effect of vegetables on IHD, ISTK, and HSTK	Published meta-analyses of 9, 9, and 7 cohorts studies, respectively [17]	Data were from US and European cohorts including 229,937 participants and 6,288 cases of IHD, 309,135 participants and 5,376 cases of ISTK, and 175,035 participants and 1,535 case of HSTK, respectively
Effect of whole grains on CVD, IHD, and DM	Published meta-analyses of 7, 6, and 10 cohorts studies, respectively [18 ,19]	Data were from US, European, and Asian cohorts including 285,217 participants and 7,005 cases of CVD, 284,682 participants and 4,837 cases of IHD, and 385,686 participants and 19,829 case of DM, respectively
Effect of processed meats on IHD, and DM	Published meta-analyses of 6, and 9 cohorts studies, respectively [20 ,21]	Data were from US, European, and Asian cohorts including 614,062 participants and 21,308 cases of IHD, and 372,391 participants and 26,234 cases of DM, respectively
Effect of unprocessed meats on DM	Published meta-analyses of 10 cohorts studies [21]	Data were from US, European, and Asian cohorts including 447,333 participants and 28,206 cases of DM
Effect of sodium on CVD	Published meta-analyses of 11 cohorts studies [22]	Data were from US, European, and Asian cohorts including 299,785 participants and 9,346 cases of CVD
Linear effects of sodium on blood pressure	Published original analyses of 103 randomized clinical trial studies [22 ,23]	Data were from US, European, and Asian randomized clinical trial including 6,970 participants
Effect of metabolic risk on CVD, and DM	Published meta-analyses of 123 cohorts studies [16]	Data were from US, European, and Asian cohorts including 1.42 million participants
Cause-specific total mortality by year, age, and sex	**Description**	
Data on causes of death	Vital-registration systems	Data were obtained from the national statistics in Korea (KOSIS).

KNHANES, Korea National Health and Nutrition Examination Survey; TMRED, Theoretical minimum risk exposure level; RR, relative risk; IHD, ischemic heart disease; ISTK, ischemic stroke; HSTK , haemorrhagic stroke; DM, diabetes; CVD, cardiovascular disease.

[1] Fruit intake in 2001-2011 included intake of fruit juice because KNHANES did not separate fruit juice from fresh fruits within relevant years.

[2] Vegetables did not include Korean cabbage since most of Korean cabbage is salted/pickled, and the etiologic effects do not included salted/pickled vegetables. .

[3] Relative risks for diet-disease relationships and units for each relative risk were obtained from ongoing meta-analyses of published literature.[24]

[4] TMREDs for each risk factor were obtained from published literature.[16 ,25]

Data sources

The exposure distribution for each risk factor was obtained from the Korea National Health and Nutrition Examination Survey (KNHANES). The relative risk for each risk factor and disease was collected from published systematic reviews and meta-analyses of epidemiological studies,[16-24 ,26 ,27] and the number of deaths by specific cause was taken from the Korea Statistics (KOSIS).

Dietary risk factors The dietary risk factors were obtained from KNHANES, a nationwide cross-sectional survey conducted by the Ministry of Health and Welfare annually since 1998. The details of KNHANES are available elsewhere,[28] Briefly, KNHANES is composed of three sections: a health interview, a health examination, and a nutrition survey. A nationally representative sample was chosen among the Korean population using household records provided by the Population and Housing Census in Korea. Twenty households from each survey section were selected using a stratified, multistage probability cluster sampling method that considered each participant's geographical area, age, and sex. We used five rounds of KHHANES (1998-2011) to estimate the transitional effect over the years. Sixty-three items of the food frequency questionnaire (FFQ) data from the KNHANES were used to assess the intake amount of each dietary factor. The FFQ evaluated how often the subjects had consumed each particular food over the prior 12 months on a 10-point scale (9 = 3 times per day, 8 = twice per day, 7 = once per day, 6 = 4–6 times per week, 5 = 2–3 times per week, 4 = once per week, 3 = 2–3 times per month, 2 = once per month, 1 = 6–11 times per year, and 0 = almost never). The ten-point scale units were converted into the daily consumed amount by multiplying the serving size according to the Korea Rural Development Administration (KRDA) guideline,[29] The mean and standard deviation (SD) of the intake of each dietary factor by sex, age, and year were estimated using the residual method after adjusting for the total energy intake.[30] To obtain national distribution of dietary risks, we limited to those who had no missing data in the nutrition survey among the participants in the KNHANES. Participants with implausible data and an upper or lower 3SD to the mean value were also excluded. Based on established evidence, subjects who consume rice less than 1 time per day on a regular basis were excluded as having implausible diets, perhaps due to recording or data entry error, given that rice is a staple food in Korea and almost never consumed less than once a day.[31 ,32] After exclusion, the total sample size in KNHANES 1998-2011 ranged from 41,810 for fruit intake to 42,524 for whole grain intake (Supplementary Table S1).

Metabolic risk factors The levels of the metabolic risk factors were also obtained from the KNHANES. The anthropometric measurements were obtained by trained experts who followed standardized protocols.[28] The body weights and heights of the subjects were measured to the nearest 0.1 kg and 0.1 cm, respectively. The BMI was calculated as the weight (kg) / height squared (m^2). The systolic blood pressure (SBP) was measured 3 times with a mercury sphyngmomanometer (Baumanometer, New York, NY, USA) applied to the right arm in the sitting position. The average of SBP was calculated using three measurements. To assess the serum levels of the biochemical markers, blood samples were collected from an antecubital vein after 10-12 hours of fasting. The levels of FPG (mmol/L) and TC (mmol/L) were measured using a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan). To obtain national distribution of dietary risks, we limited to those who had no missing data in the nutrition survey among the participants in the KNHANES. Participants with implausible data and an upper or lower 3SD to the mean value were also excluded. To obtain distribution of each risk factor, we used about 45,000 of subject (ranged from 44387 for glucose and 46,297 for BMI) who met the described criteria (Supplementary Table S1).

Etiological effects of risk factors on disease-specific mortality Each risk factor and disease was paired based on convincing evidence (Table 1).[5 ,25] To calculate population attributable fraction (PAF) and uncertainty, we obtained the relative risk (RR) of cardiovascular disease, stroke, and diabetes mortality (or incidence) per unit of exposure from the most recent published systematic reviews, meta-analyses of randomized controlled trials, and observational studies, in conjunction with population exposure data from KNHANES, and TMRED values from the GBD study.[16 ,24] For risk factors-disease pairs which no recent published papers, we conducted de novo meta-analysis following previous study.[16] The aetiological effect of risk factors had adjusted for potential confounders such as age, sex, education, socioeconomic status, physical activity, smoking, and alcohol use. The details were provided elsewhere.[12]

Theoretical minimum-risk distributions To measure the mortality effects for all populations' levels of exposure according to dietary risk factors in order to allow for comparison, we used an optimal level (Table 1). This is known as theoretical minimum-risk exposure distribution (TMRED), which is based on epidemiological studies or the levels observed in low-exposure populations. TMRED were obtained from previous literature.[16 ,25] The TMRED for risk factors with protective effects was defined as the intake levels at which they had beneficial effects (e.g., a high intake of fruit, vegetables, and whole grains). The standard level of the optimal intake for protective factors was based on the levels observed in populations with a high intake. For dietary risk factors and metabolic risk factors with harmful effects (e.g., a high intake of processed or unprocessed meats, and sodium, and high levels of FPG, SBP, BMI, and TC), the optimal level was obtained from the exposure levels associated with the lowest level of harm. For those risk factors for which zero exposure led to minimum risk, and has been observed in some population subgroup around the world (e.g., processed meats), the TMREDs were zero.

Disease-specific deaths The number of disease-specific deaths by sex, age, and year was obtained from the KOSIS, which provides official statistics for Korea. The KOSIS provided data on the mortality from 235 causes between 1998 and 2011. The causes of mortality from the KOSIS were coded following the International Classification of Disease. In the present study, we used the mortality data for deaths attributable to diabetes mellitus (DM, E10-E14), ischemic heart disease (IHD, I20-I25), ischemic stroke (I63, I67), haemorrhagic stroke (I60-I62), aortic aneurysm and dissection (AA, I71), hypertensive heart disease (HHD, I11), and rheumatic heart disease (RHD, I00-I09). The number of cause-specific deaths over the years was aggregated by age and sex group.

Statistical analyses

Estimation of temporal difference across year To see any overall temporal pattern of each risk factor and PAF across 1998-2011, a non-parametric trend test was conducted at a significance level of 0.05. A conventional parametric approach to a trend test is one based on a linear regression model. However, as results of an exploratory data analysis, it was observed that empirical distributions of a given risk factor dramatically vary across years, so that it was likely that the assumptions underlying a linear regression model did not hold. The non-parametric trend test of Cuzick [33] was considered as an alternative approach, which is an extended version of the Wilcoxon rank-sum test to compare mean values among groups of interest. All analyses were conducted using Stata 12.0 and R v.3.2.2.

Estimation of deaths attributable to risk factors We calculated PAF for each continuous risk factor with the following equation:

$$\mathrm{PAF} = \frac{\int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}(x)\,\mathrm{d}x - \int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}'(x)\mathrm{d}x}{\int_{x=0}^{\mathrm{m}} \mathrm{RR}(x)\mathrm{P}(x)\,\mathrm{d}x}$$

where x was the level of exposure and m was the maximum exposure level. $\mathrm{P}(x)$ represented the actual distribution of the exposure in the population, while $\mathrm{P'}(x)$ was the optimal level of exposure distribution. $\mathrm{RR}(x)$ was the RR of the mortality at exposure level x.

The PAF estimates the proportional reduction in disease-specific deaths that would occur if the risk factor exposure was at the optimal level. We calculated the number of deaths from IHD, ischemic stroke, haemorrhagic stroke, DM, and CVD attributable to causally-related risk factors by multiplying their PAF by the total-specific mortality. We conducted all analyses separately by sex, age group (25-34, 35-44, 45-54, 55-64, 65-74, and 75+ yrs), and year (1998, 2001, 2005, 2007, 2008, 2009, 2010, 2011). We restricted the analyses to ≥25 yrs as the data on the risk factors and the mortality data were limited.

Estimation of uncertainty and sensitivity analysis We calculated the uncertainty of the attributable mortality as caused by the sampling variability. To quantify the uncertainty for the attributable deaths, we applied a second order Monte Carlo simulation to each risk factor. Briefly, this simulation approach combines the uncertainties of the exposure distributions and the RRs in each age-sex group. We generated 1000 draws from the exposure distribution for each age-sex group as characterized by its mean and standard error (which was assumed to be normal). Independently from the exposure, we drew 1000 times the log-normal distribution of the RR for each risk factor on the disease outcomes. Those draws were used to generate 1,000 mortality estimates for each age-sex group, and they reported 95% of the uncertainty intervals

(UIs) based on the resulting distributions of the 1,000 estimated attributable deaths. Sensitivity analysis was performed to the choice of the optimal level of each risk factor.

RESULTS

Distribution of dietary and metabolic risk factors by sex, age, and year

Across the time period of analysis (1998-2011), all dietary risk factors in Korea showed non-optimal levels. The national intakes of protective dietary factors (fruits, vegetables, and whole grains) were lower than the TMRED, while the intakes of harmful dietary factors (processed meats, unprocessed meats, and sodium) were higher than the TMRED. As shown in Figure 1, the intakes of fruits and whole grains increased by 60% from 78.1 ± 2.9 g/day in 1998 to 125.3 ± 5.4 g/day in 2011 and 120% from 4.4 ± 0.3 g/day in 1998 to 9.64 ± 0.6 g/day in 2011, respectively, while among protective dietary factors, the intakes of vegetables decreased by 43% (238.2 ± 6.0 g/day to 136.5 ± 4.7 g/day). Among harmful dietary factors, the consumption of processed meats and red meats increased by 69% (1.8 ± 0.1 g/day to 3.0 ± 0.2 g/day) and 11% (34.7 ± 1.2 g/day to 38.4 ±1.8 g/day), respectively, while the consumption of sodium decreased by 2% (4929.2 ± 163.8 g/day to 4830.2 ± 118.2 mg/day). Between 1998 and 2011, the intake patterns for all dietary risk factors were similar between men and women, except for fruits and whole grains (Figure 1). The consumption of fruits and whole grains was consistently higher in women than in men over the years, whereas the consumption of other dietary risk factors was lower in women than in men over the years (Figure 1).

Between 1998 and 2011, levels of metabolic risk factors in Korea on average were higher than optimal distribution. The distribution of metabolic risk factors in the total population varied little by year. Among metabolic risk factors, BMI and TC increased by 5% (23.0 ± 0.1 kg/m2 to 23.6 ± 0.1 kg/m2) and 3% (4.89 ± 0.04 mmol/L to 4.88 ± 0.04 mmol/L), whereas FPG and SBP have decreased by 5% (5.6 ± 0.1 mmol/L to 5.4 ± 0.0 mmol/L) and 6% (130.7 ± 1.0 mmHg to 120.5 ± 0.7 mmHg), respectively (Figure 1). Between 1998 and 2011, the levels of BMI, FPG, SBP, and TC increased with age in women, whereas the BMI and TC showed a decreasing trend in elderly men (Supplementary Figure S1 and S2). Younger women showed more favourable levels of all metabolic risk factors than men. For example, women aged 25-34 yrs showed optimal SBP levels across the years (ranged from 101.5 ± 0.4 mmHg to 112.6 ± 0.3 mmHg). Similarly, younger men had more favourable levels of metabolic risk factors than older men.

CVD, stroke, and DM mortality by age, sex, and year

Over the analysis period (1998-2011), CVD, stroke, and DM were responsible for 259,203 men's deaths and 316,479 women's deaths (total: 575,682 deaths) in Korea (Supplementary Table S2). Deaths from chronic diseases showed a dramatic increase between 1998 and 2007, followed by a slight decrease after 2008. Deaths from CMD increased over the analysis period, except for haemorrhagic stroke. Elderly women showed a higher mortality from diseases than men across the years.

CVD, stroke, and DM mortality attributable to dietary risk factors by year

Between 1998 and 2011, low intakes of fruits and whole grains and high intakes of sodium were the leading dietary risk factors of chronic disease mortality in Korea (Figure 2). The ranking of the dietary risk factors varied over the years. Low fruit intake was the leading dietary risk factor of CMD mortality in 1998 accounting for 6834.5 CMD deaths (UIs: 5794.3, 7756.6), and its effects showed a decreasing trend over the years. After 1998, low whole grains intake became the leading dietary risk factor of CMD mortality, which is responsible for 54248.2 deaths (UIs: 40981.4, 59178.2) during study period. A high intake of sodium was responsible for the highest number of CMD deaths from 2001 to 2007 [9888.3 death (UIs: 8165.0, 11341.1) and 9171.6 death (UIs: 6866.2, 11212.8), respectively]. The risk of a high intake of sodium showed a slightly decreasing pattern. Although it was not ranked as the highest dietary factor, the risk of a low intake of vegetables also showed an increasing pattern over the years [2290.5 deaths (UIs: 1725.7, 2868.2) to 4072.0 deaths (UIs: 2926.7, 5143.8); Table 2]. The high intakes of meats had almost no effects on Koreans over the years.

Table 2. Number of cardiometabolic mortality attributable to each risk factor from 1998 to 2011 with 95% uncertainty intervals

Risk factor	Disease	Percentage of death (95% UI)							
		Year							
		1998	2001	2005	2007	2008	2009	2010	2011
Low intake of fruits	HSTK	4534.2 (3866.1-5090.0)	4534.2 (3866.1-5090.0)	4193.5 (3516.3-4827.5)	3137.3 (2579.3-3678.7)	2852.6 (2378.1-3316.1)	2922.0 (2413.5-3382.6)	2726.0 (2251.4-3175.2)	3030.6 (2513.3-3519.5)
	ISTK	1118.0 (944.2-1283.1)	1118 .0 (944.2-1283.1)	1427.8 (1177.4-1655.9)	1544.3 (1228.8-1857.6)	1640.4 (1320.2-1998.1)	1573.5 (1262.2-1876.3)	1390.2 (1107.6-1655.1)	1440.6 (1123.9-1753.8)
	TSTK	5652.2 (4977.4-6259.1)	5621.3 (4899.3-6298.8)	4681.6 (4049.5-5331.2)	4492.9 (3934.0-5087.0)	4495.5 (3892.6-5072.8)	4116.2 (3548.6-4673.1)	4471.2 (3858.4-5035.8)	4292.9 (3705.6-4872.1)
	IHD	1182.3 (984.0-1383.5)	1182.3 (984.0-1383.5)	1344.9 (1100.6-1581.6)	1440.7 (1133.5-1753.5)	1676.1 (1317.5-2038.2)	1577.0 (1245.1-1904.0)	1604.1 (1269.7-1963.4)	1774.6 (1373.1-2188.6)
Low intake of vegetables	HSTK	1402.7 (1038.4-1776.1)	1763.7 (1306.3-2187.8)	1496.4 (1105.3-1871.9)	1670.8 (1244.9-2082.8)	1683.2 (1268-2076.9)	1638.3 (1226.8-2042.3)	1751.1 (1347.6-2163.3)	1640.0 (1207.7-2033.8)
	ISTK	483.3 (343.4-622.6)	827.6 (589.0-1088.2)	1049.7 (704.2-1424.8)	1429.4 (947.2-1953.6)	1295.2 (855.5-1726.1)	1204.4 (772.6-1619.1)	1159 .0 (704.1-1601.2)	1158.3 (683.8-1611.9)
	TSTK	1886.0 (1501.6-2260.8)	2591.2 (2062.2-3080.7)	2546.1 (2009.4-3093.5)	3100.2 (2436.7-3763.6)	2978.3 (2399.7-3572.8)	2842.7 (2255.6-3429.5)	2910.1 (2310.3-3462.7)	2798.4 (2153.0-3424.0)
	IHD	404.5 (343.9-469.6)	665.7 (560.0-781.0)	837.7 (683.2-983.4)	1211.4 (1004.7-1433.1)	1107.1 (924.0-1289.6)	1164.3 (957.9-1372.9)	1235.5 (1008.3-1463.6)	1273.6 (1035.2-1498.2)
Low intake of whole grains	HSTK	1936.3 (1755.8-2107.3)	1982.9 (1804.4-2172.5)	1569.3 (1416.3-1720.8)	1360.7 (1232.4-1491.8)	1308.2 (1179.5-1438.3)	1209.7 (1091.9-1324.7)	1253.2 (1134.9-1374.9)	1175.8 (1053.4-1281.4)
	ISTK	949.3 (844.3-1048.0)	1380.4 (1221.0-1530.5)	1589.7 (1377.9-1798.5)	1558.7 (1341.8-1777.6)	1406.8 (1219.4-1605.6)	1241.7 (1056.4-1409.3)	1188.5 (1010.5-1369.9)	1139.1 (962.7-1318.4)
	TSTK	2885.5 (2692.6-3093.6)	3363.2 (3125.9-3597.8)	3158.9 (2890.3-3419.9)	2919.4 (2663.8-3163.5)	2715.0 (2491.2-2953.8)	2451.4 (2239.1-2661.4)	2441.7 (2230.9-2653.2)	2314.9 (2111.7-2521.9)
	IHD	1341.6 (1182.7-1499.2)	1778.1 (1563.6-1987.0)	2064.5 (1789.8-2337.5)	2188.3 (1856.8-2504.1)	1940.3 (1664.9-2209.5)	1947.2 (1671.9-2225.6)	1995.9 (1694.7-2276.4)	2022.8 (1713.4-2314.7)
	DM	2136.6 (1829.1-2440.7)	2389.2 (2060.6-2744.4)	2325.4 (1980.0-2650.3)	2167.2 (1827.2-2497.9)	1954.9 (1648.5-2243.2)	1833.2 (1554.4-2096.9)	1927.1 (1623.4-2229.7)	1985.6 (1656.4-2316.4)
High intake of processed meats	IHD	16.0 (11.2-21.0)	24.9 (17.5-32.8)	27.0 (19.3-35.4)	19.2 (12.5-26.0)	17.3 (11.6-23.1)	16.0 (10.9-21.4)	19.2 (13.3-25.5)	20.5 (13.8-27.0)
	DM	18.9 (15.6-22.3)	26.6 (22.3-31.3)	26.2 (21.3-31.0)	16.7 (13.5-19.9)	14.6 (11.9-17.1)	12.2 (10.1-14.5)	15.9 (13.2-18.8)	16.8 (14.1-19.7)
High intake of unprocessed meats	DM	220.4 (155.4-288.7)	204.7 (151.1-262.8)	152.2 (109.3-193.2)	152.3 (107.1-195.5)	107.5 (78.5-135.3)	97.0 (70.7-124.5)	100.2 (72.8-128.0)	95.6 (70.0-122.3)
High intake of sodium	HSTK	2107.4 (1749.1-2489.5)	3404.0 (2859.9-3919.9)	2195.6 (1745.3-2693.1)	2123.1 (1665.1-2540.5)	1202.3 (934.8-1455.4)	1559.0 (1288.0-1846.6)	1402.4 (1137.8-1686.9)	1680.4 (1415.6-1989.4)
	ISTK	995.6 (813.4-1175.2)	2417.9 (2052.0-2796.0)	2340.1 (1856.2-2905.3)	2424.1 (1858.8-2971.0)	1020.5 (740.2-1322.1)	1293.4 (1033.1-1550.8)	1326.4 (1059-1610.4)	1496.3 (1237.6-1765.6)
	TSTK	3103.0 (2694.1-3527.4)	5821.9 (5151.3-6465.9)	4535.7 (3821.5-5307.4)	4547.1 (3842.1-5269.3)	2222.8 (1819-2609.8)	2852.4 (2456.7-3220.3)	2728.7 (2350.3-3099.8)	3176.7 (2786.9-3543.7)
	AA	46.6 (39.0-54.5)	107.6 (91.6-123.6)	118.5 (97.7-142.5)	125.8 (102.8-151.5)	70 .0 (55.6-85.7)	88.5 (73.6-102.6)	92.6 (77.3-107.9)	120.3 (102.0-139.4)

	HHD	297.8 (250.7-347.7)	1314.1 (1084.2-1527.8)	1090.8 (843.1-1348.2)	1311.2 (972.1-1630.9)	329.2 (177.7-510.9)	441.3 (324.1-576.2)	561.4 (420.3-705.3)	694.6 (543.0-854.6)
	RHD	5.4 (4.3-6.7)	16.6 (12.7-20.6)	24.4 (18.4-30.3)	21.9 (16.6-27.6)	11.5 (8.7-14.5)	13.3 (10.7-16.2)	12.9 (9.9-16.4)	15.7 (12.0-19.7)
	IHD	1178.0 (959.5-1393.1)	2628.1 (2156.2-3076.8)	2815.9 (2078.3-3666.0)	3165.6 (2353.5-4042.8)	1373.1 (1034.8-1764.1)	2008.8 (1587.9-2427.5)	2031.6 (1555.1-2537.2)	2482.8 (1960.8-3059.3)
High fasting plasma glucose	TSTK	1920.4 (1843.1-2000.5)	1943.4 (1831.8-2057.5)	1804 (1663.9-1951.2)	1762.5 (1588.3-1909.2)	1756.7 (1656.7-1856.1)	1672.4 (1574.4-1774)	1581.8 (1477.7-1689.5)	1537.1 (1442.8-1630.2)
	IHD	1205 (1149.2-1263.5)	1464.1 (1373.1-1560.0)	1807.6 (1642.3-1970.2)	2047.5 (1843.3-2250.6)	1878.2 (1758-1999.4)	2037.6 (1921.1-2162.6)	2039.5 (1895.2-2190.6)	2127.9 (1984.1-2269.2)
High total cholesterol	ISTK	531.8 (519.2-544.6)	655.5 (639.3-672.7)	526.6 (508.8-544.1)	498.4 (479.8-517.7)	419.3 (406.6-432)	349.1 (338.6-359.7)	317.5 (308.2-326.2)	291.4 (282.9-299.4)
	IHD	2389.0 (2330.7-2446.8)	3453.6 (3364.9-3548.1)	3849.6 (3678.7-4018.6)	4314.4 (4114.2-4518)	3833.7 (3698-3961.9)	3751.0 (3613.3-3878.4)	3855.5 (3684.9-4025.3)	3940.9 (3791.2-4079.0)
High systolic blood pressure	HSTK	6343.0 (6190.5-6501.5)	4330.3 (4182.0-4475.8)	3080.6 (2936.6-3226.0)	2778.7 (2680.3-2878.4)	3394.1 (3312.1-3475.2)	3506.6 (3412.9-3598.8)	2853.9 (2761.7-2942.2)	6343.0 (6190.5-6501.5)
	ISTK	5220.6 (5013.2-5427.0)	5502.9 (5225.7-5784.5)	4386.4 (4079.3-4696.4)	3732.7 (3540-3914.1)	4336.9 (4174.6-4498.9)	4086.9 (3912.0-4271.9)	3331.6 (3151.5-3509.0)	5220.6 (5013.2-5427.0)
	TSTK	10157.0 (10007.8-10304.7)	11563.6 (11308.3-11804.9)	9833.1 (9522.9-10150.6)	7467.0 (7124.7-7806.8)	6511.4 (6300.0-6731.9)	7731.0 (7547.5-7922.6)	7593.4 (7393.5-7805.2)	6185.6 (5981.5-6387.9)
	IHD	5624 (5416.7-5819.3)	6119.1 (5815.5-6416.9)	5315.0 (4942.8-5672.4)	4364.2 (4145.9-4576.7)	5905.2 (5702.1-6103.6)	6052.2 (5823.7-6290.0)	5270.7 (5012.7-5509.4)	5624.0 (5416.7-5819.3)
	HHD	945.9 (926.1-962.5)	945.9 (926.1-962.5)	2863.8 (2766.8-2955.7)	2195.7 (2092.6-2291.4)	2158.9 (1997.8-2315.8)	1641.7 (1558.8-1724.9)	1716.0 (1661.9-1768.0)	1781.6 (1715.5-1849.9)
	RHD	19.3 (18.8-19.9)	38.8 (37.2-40.5)	56.3 (53.7-58.6)	37.4 (34.8-39.8)	34.0 (32.4-35.7)	34.8 (33.5-36.0)	41.6 (40.1-43.2)	32.9 (31.4-34.3)
	AA	174.7 (170.1-179.0)	230.7 (222.2-238.6)	267.2 (254.1-281.3)	219.3 (205.6-233.4)	211.9 (201.8-222.2)	255.6 (246.9-265.3)	267.5 (257.4-277.7)	242.2 (231.1-253.9)
High body mass index	HSTK	2161.2 (2108.7-2218.3)	2599.7 (2537.3-2659.4)	2171.3 (2112.5-2224.9)	1870.3 (1807.3-1934.1)	1750.4 (1712.0-1791.9)	1655.3 (1619.0-1691.9)	1655.7 (1618.1-1697.0)	1559.2 (1522.2-1599.1)
	ISTK	625.6 (600.9-649.8)	1095.7 (1042.1-1147.9)	1311.0 (1233.4-1393.1)	1306.9 (1219.5-1393.2)	1109.3 (1055.7-1161.0)	989.9 (943.1-1035.1)	953.5 (899.3-1006.4)	877.6 (832.3-920.9)
	TSTK	2786.8 (2730.9-2848.2)	3695.3 (3614.9-3773.7)	3482.3 (3390.5-3577.8)	3177.2 (3070.6-3283.4)	2859.7 (2794.1-2924.7)	2645.2 (2586.6-2702.3)	2609.1 (2542.0-2676.5)	2436.9 (2376.1-2491.7)
	IHD	997.1 (961.7-1033.6)	997.1 (961.7-1033.6)	1694.8 (1627.9-1766.5)	2188.2 (2067.7-2305.8)	2427.3 (2274.5-2574.8)	2042.7 (1956.6-2125.4)	2122.3 (2033.2-2209.7)	2190.2 (2079.9-2303.0)
	DM	2822.6 (2716.9-2924.3)	3977.4 (3841.1-4121.2)	4265.1 (4096.8-4455.6)	4129.4 (3921.8-4346.4)	3591.6 (3461.0-3722.6)	3469.3 (3350.8-3608.0)	3697.3 (3535.0-3861.1)	3727.6 (3589.1-3877.1)
	HHD	225.5 (211.6-240.1)	801.1 (730.4-873.5)	725.1 (656.6-797.2)	946.7 (849.4-1041.0)	688.8 (638.8-744.2)	617.7 (573.6-660.0)	695.4 (643.4-748.9)	684.9 (632.6-739.4)

The values were expressed as population attributable death number for each risk factors (95% Uncertainty Intervals). HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; AA, aortic aneurysm and dissection; HHD, hypertensive heart disease; RHD, rheumatic heart disease.

CVD, stroke, and DM mortality attributable to metabolic risk factors by year

With regard to metabolic risk factors, high levels of SBP stood out as the leading metabolic risk of CMD mortality over the years, responsible for 127095.7 CMD deaths (UIs: 121907.0, 132217.5; Figure 2). Although high SBP appeared as the leading risk factor over the years, the contribution of the blood pressure decreased over the decade of the analysis period, from 15468.8 deaths (UIs: 15124.3, 15812.6) in 1998 to 13494.8 deaths (UIs: 12863.8, 14099.6) in 2011 (Table 2). A non-optimal BMI was responsible for the second-most number of deaths over the analysis years. High levels of TC and PFG had smaller effects than the SBP and BMI over the analysis period (Supplementary Figure S3).

CVD, stroke, and DM mortality attributable to dietary and metabolic risk factors by age and sex

The number of CMD deaths caused by dietary and metabolic risk factors increased with age, in line with the increase in the number of CMD deaths in the older age groups. However, the attributable fraction of these risk factors decreased with the age (Supplementary Figure S4 and S5), particularly for dietary risk factors. Older age groups showed higher attributable fractions of metabolic risks such as SBP and FPG, while in participants aged 25-44 yrs, the highest proportion of CMD deaths was attributable to dietary risk factors and several metabolic risk factors, including the BMI and TC. In the younger population, the SBP and FPG showed no or little effect on CMD deaths, as younger men and women had optimal metabolic levels (Supplementary Figure S4 and S5). The proportion of CMD deaths caused by low intakes of fruits and whole grains and high intake of sodium were greater among men than women, while no noticeable difference was observed in the deaths caused by other dietary risk factors (Supplementary Table S3). The deaths from CMD caused by metabolic risk factors were consistently greater among men than women (Supplementary Table S3).

Sensitivity analysis

The results of the sensitivity analyses in Supplementary Figure S6. The results showed that change of optimal levels for SBP (from 115 to 110 mm Hg), fasting plasma glucose (from 5.3 to 4.9 mmol/L) and total cholesterol (from 4.0 to 3.8 mmol/L) increased the mortality attributable to each risk factor by 20-40% in 2010 and 2011. The change of optimal levels for BMI from 23 to 21 kg/m^2 results more than two times increase of attributable mortality in both years.

DISCUSSION

The present study evaluated and quantified the contribution of 6 dietary risk factors and 4 metabolic risk factors attributable to CVD, stroke, and DM mortality in Korea by age and sex from 1998 to 2011 using comparable methods. This study demonstrates the trends in risk factors and burden of disease from those risk factors. While confirming the importance of high blood pressure to CMD mortality, the results also showed that a suboptimal diet had been the leading factor of CMD mortality in Korea since 1998. This was consistent with an earlier GBD study reporting that suboptimal diet is the leading risk factor for chronic disease in most regions of the world.[5 ,25]

With trends of increased prevalence of metabolic risk factors in Korea, this study demonstrates the effect of convincing metabolic risks on CMD mortality in Korean population over past decade. In accordance with previous GBD study, high SBP is the leading risk factor with high BMI as the leading risk across the year.[25 ,34] Although decreased trend in burden of high SBP, approximately 50% of stroke and 45% of IHD deaths were attributable to high blood pressure in Koreans, corresponding to previous GBD study.[35] The result on SBP is consistent with global or national trends of blood pressure, including modest decreased levels of SBP over the decade of analysis period (1998-2011).[35-37] On the contrary to blood pressure, the risk of high BMI increased overtime in Korean. The burden of high BMI increased globally, accompanying with adverse obesity related changes in metabolic condition.[3] Nearly 45% of diabetes burden and 20% of IHD burden are attributable to obese in Korean.

Metabolic risk is a physiological indicators, which is related to shorten life expectancy through increasing possibility of developing CVDs.[10 ,11] Furthermore, attributable burden of metabolic risks have considered as mediator of other risks including changes in the diet, and decreasing levels of physical activity.[38 ,39] The results from metabolic risks suggest that the need for adoption and implementation of effective interventions to reduce the burden of metabolic risk factors.

Following metabolic risks, we found that among individual dietary risk factors, a high intake of sodium and low intakes of fruits and whole grains were responsible for the highest CMD mortality in Korea. Suboptimal dietary patterns are linked to a substantial burden of morbidity, mortality, and medical costs.[40] According to a previous study, dietary or strongly diet-related risk factors are expected to cause nearly 75% of all deaths and 60% of all disability-adjusted life years by 2020.[5 ,41] The most noticeable feature of dietary risks in Korea was that the intakes of fruits, vegetables, and whole grains were much lower than the levels recommended by the TMRED and World Health Organisation (WHO) guideline.[1 ,42] The intake of sodium was also much higher than the guideline. The causes of this problem might be nation-specific and multifaceted. Despite increase of whole grain intake through the study period, the risk of low intake of whole grain has been increased and has become leading dietary risk factor of CMD from 1998. The low intake of whole grains and high intake of sodium in Korea are partly due to the country's unique dietary habits, including the regular consumption of seasoned soup, salt fermented food, and refined rice. Furthermore, our results present increased risk of low intake of vegetables and fruit between 1998 and 2011. The reduced intakes of fruits and vegetables over time could reflect changes in lifestyle and factors linked to the economic transition in Korea, such as increased food prices.[43] Along with adoption of Westernised lifestyle, the increased fast food consumption and westernised diet have also aggravated dietary problems. Moreover, the increased participation of women in the workforce has contributed to reducing the time available to prepare healthy food.[31] These findings highlight the need for interventions to improve the accessibility and affordability of healthy foods to reduce CMD risks in Korea.

Our study clearly showed that the mortality burden of dietary risks in Korea had slightly increased since 1998, especially in the younger population. Between 1998 and 2011, burden of CMDs mortality attributable to sodium and SBP has decreased trend whereas mortality burdens from vegetables, whole grains, and BMI has increased trend. The shifting trends in the burden of CMDs in the Korean population may be due to socioeconomic changes such as rapid economic development and urbanisation. Korea is one of the world's fastest-growing countries, witnessing rapid industrial changes. Those remarkable sociocultural changes have been found to contribute to an unhealthy lifestyle, including dietary risks from the increased availability, affordability, and consumption of unhealthy food.[31 ,44] Additionally, changes in epidemiological trends, including decreased levels of metabolic risks and cardiovascular death rates in Korea, have also been attributed to changes in the magnitude of the burden of CMD risks.[31] The findings from the current study highlight the importance of the epidemiological transition to estimate the population's health.

In addition, we quantified the contribution of dietary risk factors (e.g., sodium) to the burden of CMD deaths as mediated by metabolic risks (e.g., SBP). For example, although high blood pressure has remained the leading risk factor in Korea, it is closely related to the consumption of sodium.[22] The sodium intake in Korea is more than double the WHO dietary recommendation, which in turn increases the risk of hypertensive disease.[37 ,45] The WHO issued a global call for salt management to reduce the prevalence of hypertensive-related diseases in cost-effective ways. In line with the WHO recommendation, the Korean government has been running a low salt campaign since 2005 [46] to achieve an overall reduction in the Korean population's salt intake. As the results have shown, the reduction in dietary salt has been successfully reducing the national sodium intake since 2005, and this has brought about a decrease in CVD deaths. This result implies the possibility that dietary risk factors may affect the CMD through their effects on changes in metabolic risk factors, while disease-specific deaths are caused by multiple risk factors acting simultaneously. Moreover, the results support the theory that a suboptimal diet is affected by the relative influence of the individual level, the community level, and the national level.[47]

We also focused on understanding the comparative importance of the risk factors by age-sex specific groups to observe the trends in the disease burden over time. The results showed that the younger population was prone to more harmful dietary risks causing CMD deaths.[48] According to a previous study of the Western population,[49] young adults in Korea tend to have a higher intake of animal products and sugar-sweetened drinks. Due to their metabolic status, people aged under 50 are more easily influenced by their dietary intake than the elderly. A longitudinal cohort study demonstrated that higher intakes of fruits and vegetables in young adulthood were responsible for lower odds of prevalent CVDs.[50] Additionally, high levels of exposure to dietary and metabolic risks were responsible for a large number of CMD deaths, particularly in men. A previous study reported that this gender difference was not only attributable to biological differences,[51] but also to differences in socioeconomic status and lifestyle, including health awareness and diet quality.[51 ,52] The results suggest that political initiatives to prevent CMD mortality should be taken based on an understanding of the age-sex specific effects.

Our analysis had several strengths. To our knowledge, this was the first investigation to analyse data from national individual-based surveys to evaluate the diet consumption and its transition over time in Korea. The results provide most detailed result, focusing on the nation-specific impacts of dietary and metabolic risk factors on CMDs to identify national priorities for management and prevention of CMDs. Additionally, we obtained and used the most up-to-date aetiological effect sizes of the diet–disease relationships. We used RRs from meta-analyses of observational studies adjusted for potential confounders such as age, sex, education, socioeconomic status, physical activity, smoking, and alcohol use. We also accounted for uncertainty in the current risk factor levels, the effects of the risk factors on the CMD mortality, and the current cause-specific mortality by age, sex, and time, propagating this uncertainty into the final results.

Potential limitations should also be considered when interpreting our findings. The dietary amount data were imputed based on the FFQ rather than investigated actual amount. Therefore, there is a possibility of over-estimate or under-estimate of intake amount, comparing to actual intake amount. However, FFQ in the KNHANES has substantial reproducibility and validity, [53] measuring long term dietary pattern for specific target population.[54] Second, we could not divide fruits into fresh fruit and fruit juice or vegetables into pickled vegetables and fresh vegetables, as the KNHANES did not investigate those items separately. To account for this, in the vegetable category, we excluded Korean cabbage, i.e. kimchi, which is the major source of pickled vegetables in the Korean diet. However, there is a possibility that the vegetable intake was underestimated as the daily intakes of kimchi in Korea represent 40-50% of the daily total vegetable intake of Koreans.[55] Third, the latest exposure data were excluded from the main results as the KNHANES had adopted different methods in recent years. Fourth, although we used the confounder-adjusted RR, the possibility of residual confounding cannot be excluded. Sixth, the analysis of risk factors has focused on selected risk factors including dietary and metabolic risks. The further study with behavioural risk factors including alcohol use and smoking is required in current population. Additionally, although high sugar intake has appeared to increase risk of CMDs, the risk of sugar intake was excluded current analysis since the KNHANES did not investigate consumption amount of sugar or sugar sweetened beverage in detail. Seventh, we used generalised RRs from multiple ethnics including U.S., European, and Asian population, rather than use Korean-specific RRs. However, using RRs that have been found to be generalizable across populations strengthens the analysis and makes it possible to compare the burdens estimated for Korea with those from other countries.

In summary, we found that both metabolic and dietary risk factors were major contributors to CMD mortality in Korea, and we investigated their relative importance over the years. Our findings highlight the need for the adoption, implementation, and evaluation of dietary recommendations reflecting shifting trends for the prevention of CMDs in Korea. Moreover, the findings provide robust and comparable levels quantifying the effects of major metabolic risk factors on CMDs. The results of the current study can contribute to the development of evidence-based national government policies to manage and improve the major risk factors of CMDs in Korea.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology [NRF-2015R1A2A1A15054758 to MJS]. MJS and GS conceived the study and MJS acquired the data. YC, FC and GS developed the statistical analysis plan. YC and JHP analysed the data. YC, GS and MJS prepared the first draft of manuscript. YC, JTL, DM, GS, MJS contributed to the writing of the manuscript. All authors reviewed and agreed on the manuscript.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

DATA SHARING STATEMENT

No additional data are available.

Figure legend

Figure 1. Trends in (A) diet and (B) metabolic risk factors in Korea from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests ($p < 0.05$). SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose**.**

Figure 2. Mortality from cardiometabolic disease attributable to individual dietary and metabolic risk factors, by disease and year in Korea. Data are shown for all adults. See the Table 2 for actual values of risk factor attributable deaths and 95% UIs. Note that the number of death attributable to individual risks cannot be added because of multi-causality and mediated effects. HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; WG, whole grains; SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

REFERENCES

1. World Health Organizaion. *Global status report on noncommunicable diseases 2014*, 2014.

2. Lee KS, Park JH. Burden of disease in Korea during 2000-10. *J Public Health (Oxf)* 2014;36:225-34.

3. Goodpaster BH, Krishnaswami S, Harris TB, et al. Obesity, regional body fat distribution, and the metabolic syndrome in older men and women. *Archives of Internal Medicine* 2005;165:777-83.

4. Statistics Korea. Causes of Death Statistics in 2014: Statistics Korea, 2015.

5. Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2224-60.

6. Musaiger AO, Al-Hazzaa HM. Prevalence and risk factors associated with nutrition-related noncommunicable diseases in the Eastern Mediterranean region. *Int J Gen Med* 2012;5:199-217.

7. Popkin BM. The nutrition transition: an overview of world patterns of change. *Nutr Rev* 2004;62:S140-3.

8. Murray CJ, Ezzati M, Lopez AD, et al. Comparative quantification of health risks conceptual framework and methodological issues. *Popul Health Metr* 2003;1:1.

9. Begg SJ, Vos T, Barker B, et al. Burden of disease and injury in Australia in the new millennium: measuring health loss from diseases, injuries and risk factors. *Med J Aust* 2008;188:36-40.

10. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med* 2009;6:e1000058.

11. Farzadfar F, Danaei G, Namdaritabar H, et al. National and subnational mortality effects of metabolic risk factors and smoking in Iran: a comparative risk assessment. *Popul Health Metr* 2011;9:55.

12. Afshin A, Micha R, Khatibzadeh S, et al. The impact of dietary habits and metabolic risk factors on cardiovascular and diabetes mortality in countries of the Middle East and North Africa in 2010: a comparative risk assessment analysis. *BMJ Open* 2015;5:e006385.

13. Yang G, Wang Y, Zeng Y, et al. Rapid health transition in China, 1990-2010: findings from the Global Burden of Disease Study 2010. *Lancet* 2013;381:1987-2015.

14. Lee SK, Sobal J. Socio-economic, dietary, activity, nutrition and body weight transitions in South Korea. *Public Health Nutr* 2003;6:665-74.

15. Song Y, Joung H. A traditional Korean dietary pattern and metabolic syndrome abnormalities. *Nutr Metab Cardiovasc Dis* 2012;22:456-62.

16. Singh GM, Danaei G, Farzadfar F, et al. The age-specific quantitative effects of metabolic risk factors on cardiovascular diseases and diabetes: a pooled analysis. *PLoS One* 2013;8:e65174.

17. He FJ, Nowson CA, Lucas M, et al. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens* 2007;21:717-28.

18. Aune D, Norat T, Romundstad P, et al. Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. *Eur J Epidemiol* 2013;28:845-58.

19. Mellen PB, Walsh TF, Herrington DM. Whole grain intake and cardiovascular disease: a meta-analysis. *Nutr Metab Cardiovasc Dis* 2008;18:283-90.

20. Micha R, Wallace SK, Mozaffarian D. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. *Circulation* 2010;121:2271-83.

21. Pan A, Sun Q, Bernstein AM, et al. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *Am J Clin Nutr* 2011;94:1088-96.

22. Poggio R, Gutierrez L, Matta MG, et al. Daily sodium consumption and CVD mortality in the general population: systematic review and meta-analysis of prospective studies. *Public Health Nutr* 2015;18:695-704.

23. Mozaffarian D, Hao T, Rimm EB, et al. Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med* 2011;364:2392-404.

24. Shulkin ML, Micha R, Rao M, et al. Abstract P279: Major Dietary Risk Factors for Cardiometabolic Disease: Current Evidence for Causal Effects and Effect Sizes From the Global Burden of Diseases (GBD) 2015 Study. *Circulation* 2016;133:AP279-AP79.

25. Global Burden of Disease Risk Factors Collaborators., Forouzanfar MH, Alexander L, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015;386:2287-323.

26. Micha R, Kalantarian S, Wirojratana P, et al. Estimating the global and regional burden of suboptimal nutrition on chronic disease: methods and inputs to the analysis. *Eur J Clin Nutr* 2012;66:119-29.

27. Mozaffarian D, Fahimi S, Singh GM, et al. Global sodium consumption and death from cardiovascular causes. *N Engl J Med* 2014;371:624-34.

28. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol* 2014;43:69-77.

29. Rural Development Administration. *Consumer Friendly Food Composition Table for Adults*. Suwon, Korea: Rural Development Administration, 2009.

30. Willett W, Stampfer MJ. Total energy intake: implications for epidemiologic analyses. *Am J Epidemiol* 1986;124:17-27.

31. Kim S, Moon S, Popkin BM. The nutrition transition in South Korea. *Am J Clin Nutr* 2000;71:44-53.

32. Chung HK, Park JY, Cho Y, et al. Contribution of dietary patterns to blood heavy metal concentrations in Korean adults: findings from the Fifth Korea National Health and Nutrition Examination Survey 2010. *Food Chem Toxicol* 2013;62:645-52.

33. Cuzick J. A Wilcoxon-type test for trend. *Stat Med* 1985;4:87-90.

34. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:766-81.

35. Danaei G, Finucane MM, Lin JK, et al. National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5· 4 million participants. *The Lancet* 2011;377:568-77.

36. Evans A, Tolonen H, Hense H-W, et al. Trends in coronary risk factors in the WHO MONICA project. *International journal of epidemiology* 2001;30:S35.

37. Ikeda N, Gakidou E, Hasegawa T, et al. Understanding the decline of mean systolic blood pressure in Japan: an analysis of pooled data from the National Nutrition Survey, 1986-2002. *Bull World Health Organ* 2008;86:978-88.

38. Lewington S, Clarke R, Qizilbash N, et al. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;360:1903-13.

39. Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration., Lu Y, Hajifathalian K, et al. Metabolic mediators of the effects of body-mass index, overweight, and obesity on coronary heart disease and stroke: a pooled analysis of 97 prospective cohorts with 1.8 million participants. *Lancet* 2014;383:970-83.

40. Lopez AD, Mathers CD, Ezzati M, et al. Measuring the Global Burden of Disease and Risk Factors, 1990-2001. In: Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJL, eds. Global Burden of Disease and Risk Factors. Washington (DC), 2006.

41. Murray CJ, Lopez AD. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. *Lancet* 1997;349:1436-42.

42. World Health Organization. *Global Health Risks: Mortality and burden of disease attributable to selected major risks*, 2009.

43. Hawkes C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Global Health* 2006;2:4.

44. Goryakin Y, Suhrcke M. Economic development, urbanization, technological change and overweight: what do we learn from 244 Demographic and Health Surveys? *Econ Hum Biol* 2014;14:109-27.

45. Laverty AA, Bottle A, Majeed A, et al. Blood pressure monitoring and control by cardiovascular disease status in UK primary care: 10 year retrospective cohort study 1998-2007. *J Public Health (Oxf)* 2011;33:302-9.

46. Kim YC, Koo HS, Kim S, et al. Estimation of daily salt intake through a 24-hour urine collection in Pohang, Korea. *J Korean Med Sci* 2014;29:S87–S90.

47. Afshin A, Micha R, Khatibzadeh S, et al. *The handbook of global health policy: Dietary policies to reduce noncommunicable diseases*: Wiley-Blackwell, 2014.

48. Roy R, Kelly B, Rangan A, et al. Food Environment Interventions to Improve the Dietary Behavior of Young Adults in Tertiary Education Settings: A Systematic Literature Review. *J Acad Nutr Diet* 2015;115:1647-81 e1.

49. Larson N, Neumark-Sztainer D, Laska MN, et al. Young adults and eating away from home: associations with dietary intake patterns and weight status differ by choice of restaurant. *J Am Diet Assoc* 2011;111:1696-703.

50. Miedema MD, Petrone A, Shikany JM, et al. Association of Fruit and Vegetable Consumption During Early Adulthood With the Prevalence of Coronary Artery Calcium After 20 Years of Follow-Up: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Circulation* 2015;132:1990-8.

51. Lowe LP, Greenland P, Ruth KJ, et al. Impact of major cardiovascular disease risk factors, particularly in combination, on 22-year mortality in women and men. *Arch Intern Med* 1998;158:2007-14.

52. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr* 2002;76:1261-71.

53. Kim DW, Song S, Lee JE, et al. Reproducibility and validity of an FFQ developed for the Korea National Health and Nutrition Examination Survey (KNHANES). *Public Health Nutr* 2015;18:1369-77.

54. Kabagambe EK, Baylin A, Allan DA, et al. Application of the method of triads to evaluate the performance of food frequency questionnaires and biomarkers as indicators of long-term dietary intake. *Am J Epidemiol* 2001;154:1126-35.

55. Lee JS, Kim J. Vegetable intake in Korea: data from the Korean National Health and Nutrition Examination Survey 1998, 2001 and 2005. *Br J Nutr* 2010;103:1499-506.

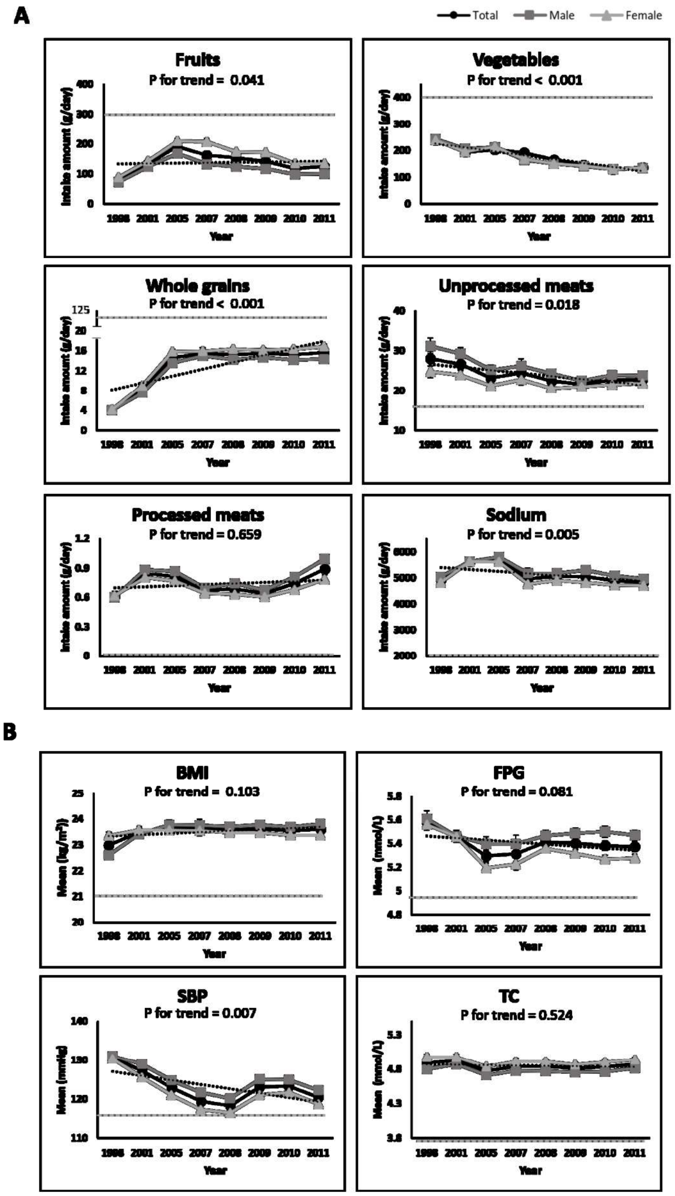


Figure 1. Trends in (A) diet and (B) metabolic risk factors in Korea from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests (p <0.05). SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

177x286mm (300 x 300 DPI)

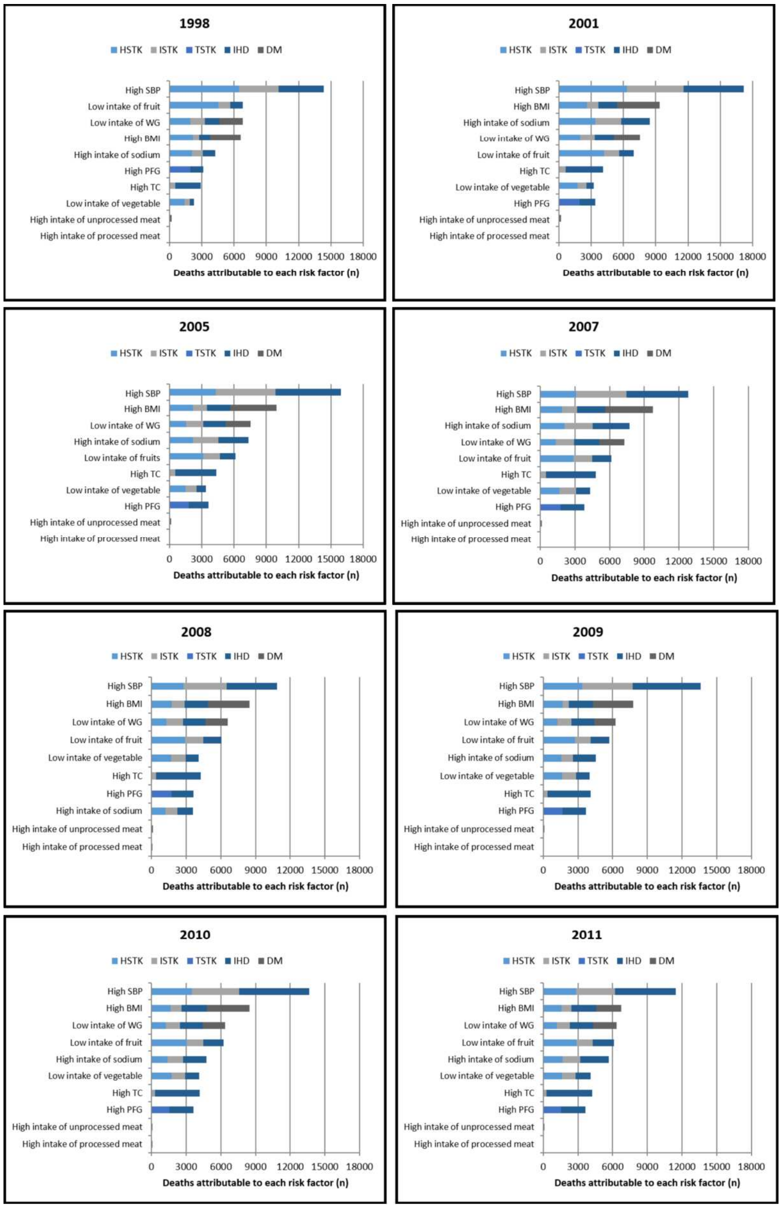


Figure 2. Mortality from cardiometabolic disease attributable to individual dietary and metabolic risk factors, by disease and year in Korea. Data are shown for all adults. See the Table 2 for actual values of risk factor attributable deaths and 95% UIs. Note that the number of death attributables to individual risks cannot be added because of multi-causality and mediated effects. HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; WG, whole grains; SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

152x235mm (300 x 300 DPI)

Supplementary Figure legend

Supplementary Figure 1. Transition of (A) dietary and (B) metabolic risk factors among Korean men from 1998 to 2011. Each plot and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-values were derived from non-parametric trend tests (p <0.05). BMI, body mass index; PFG, plasma fasting glucose; SBP, systolic blood pressure; TC, total cholesterol**.**

Supplementary Figure 2. Transition of (A) dietary and (B) metabolic risk factors among Korean women from 1998 to 2011. Each plots and error bars indicates mean of intake and standard error, respectively. A squared dashed line indicates optimal level for each risk factor. A dotted line indicates trend of risk distribution across year. P-value was derived from non-parametric trend test (p <0.05). BMI, body mass index; PFG, plasma fasting glucose; SBP, systolic blood pressure; TC, total cholesterol**.**

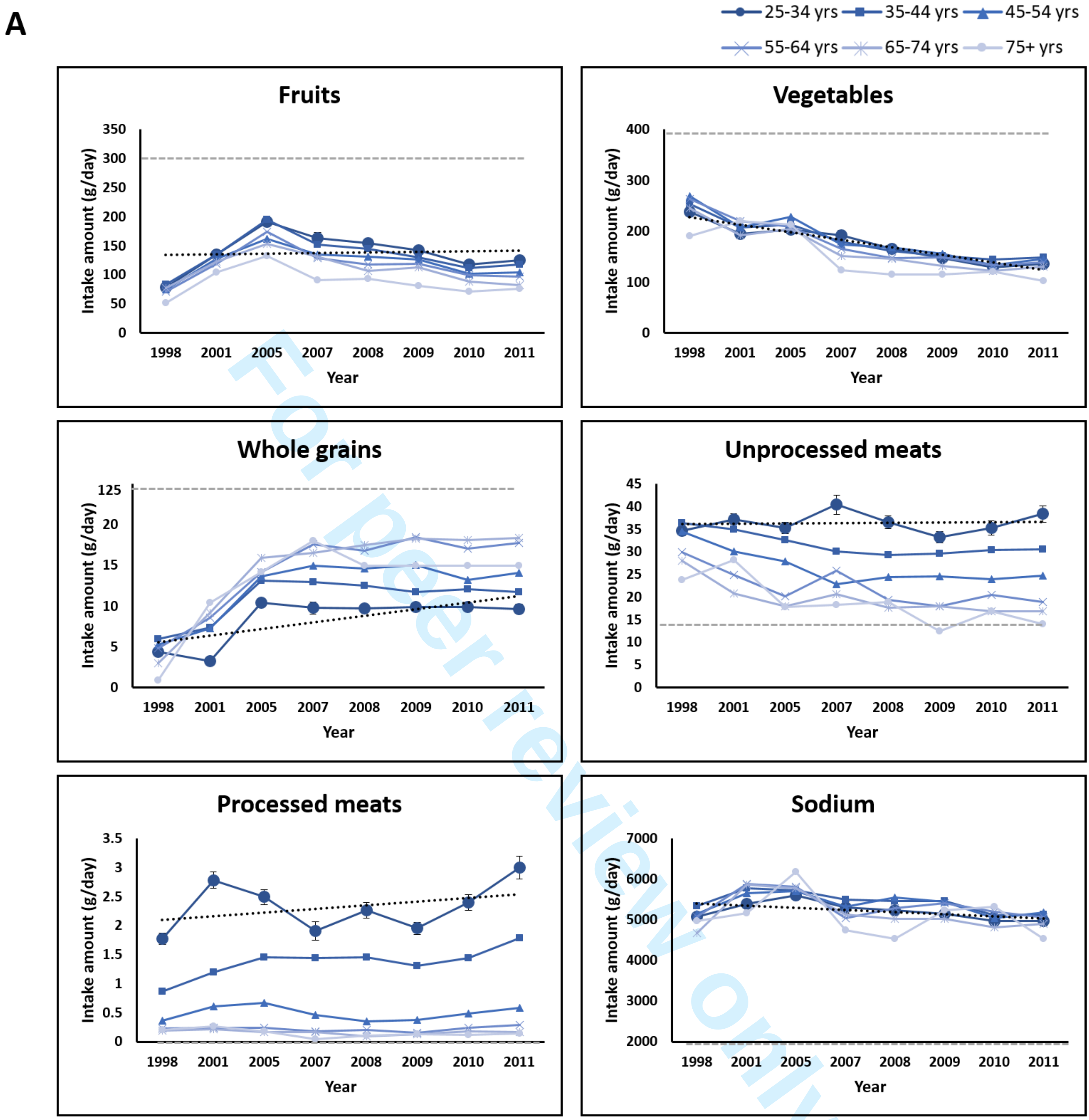
Supplementary Figure 3. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year in Korea. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. P-value was derived from non-parametric trend test (p <0.05). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

Supplementary Figure 4. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year among Korean men. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. See the Supplementary Table S2 for relevant values of risk factor attributable deaths and 95% UIs. P-value was derived from non-parametric trend test (p <0.05). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

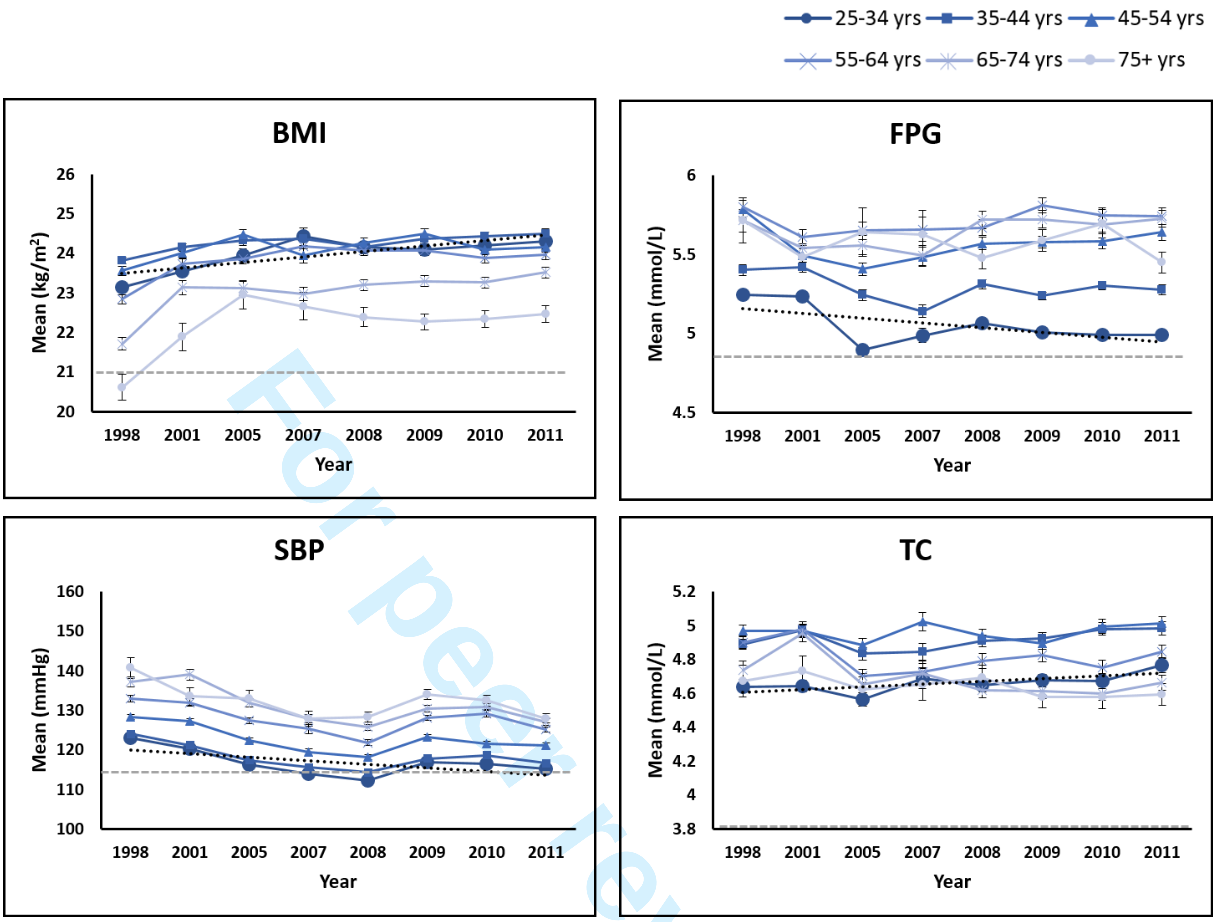
Supplementary Figure 5. Proportional mortality from cardiometabolic factors attributable to diet and metabolic risk factors by disease and year among Korean women. Each plots and error bars indicates mean of population attributable fraction of individual risk factors and standard error, respectively. See the Supplementary Table S2 for relevant values of risk factor attributable deaths and 95% UIs. P-value was derived from non-parametric trend test (p <0.05). AA, aortic aneurysm and dissection; BMI, body mass index; DM, diabetes; HHD, hypertensive heart disease; HSTK, hemorrhagic stroke; IHD, ischemic heart disease; ISTK, ischemic stroke; PFG, plasma fasting glucose; RHD, rheumatic heart disease; SBP, systolic blood pressure; TC, total cholesterol; TSTK, total strokes.

Supplementary Figure 6. Cardiometabolic deaths attributable to metabolic risk factors in Korea in different sensitivity analysis (2010-2011). Data are shown for all adults. See the Table 2 for actual values of risk factor attributable deaths and 95% UIs. Note that the number of death attributables to individual risks cannot be added because of multi-causality and mediated effects. HSTK, haemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; WG, whole grains; SBP, systolic blood pressure; BMI, body mass index; TC, total cholesterol; PFG, plasma fasting glucose.

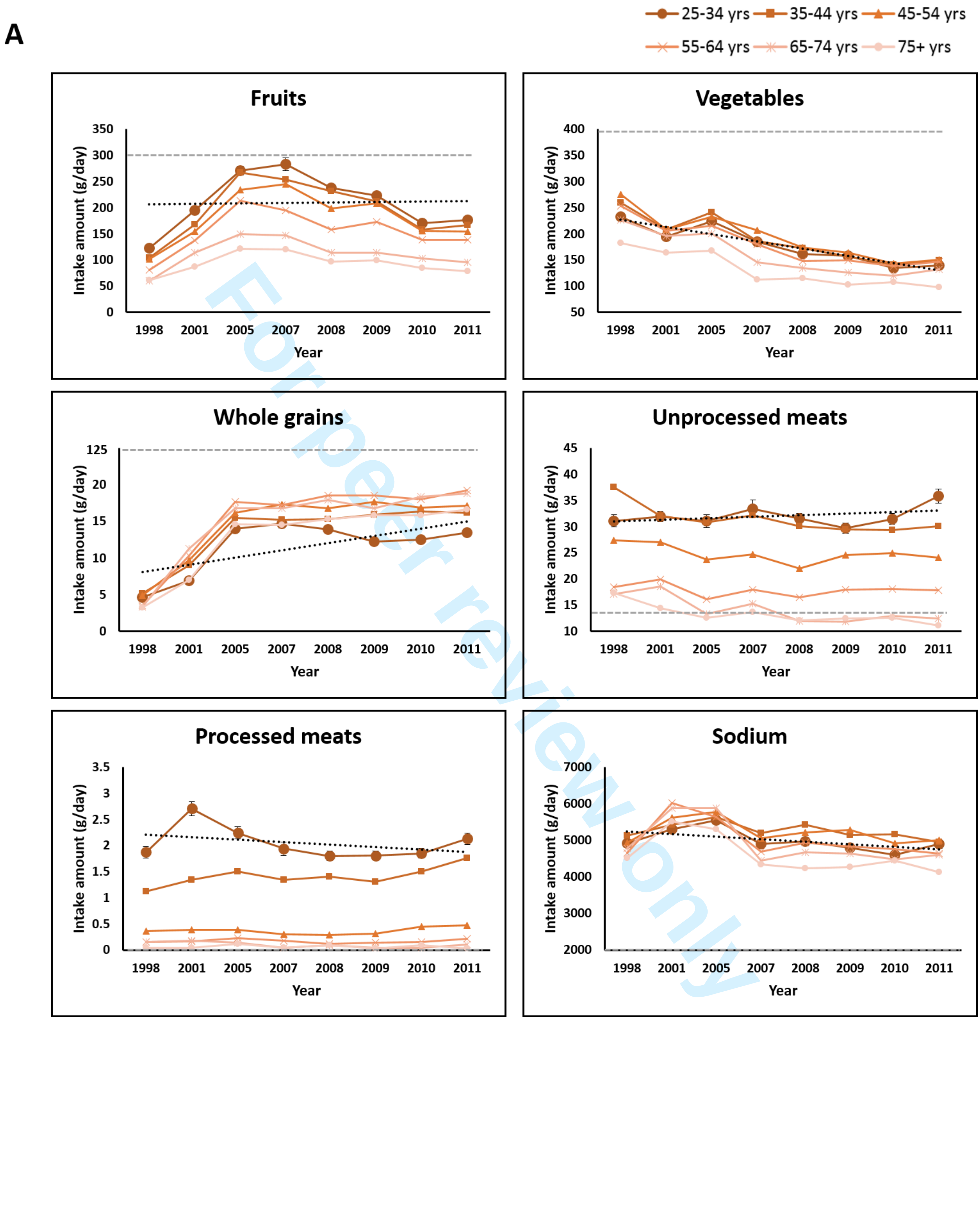
Supplementary Figure 1.

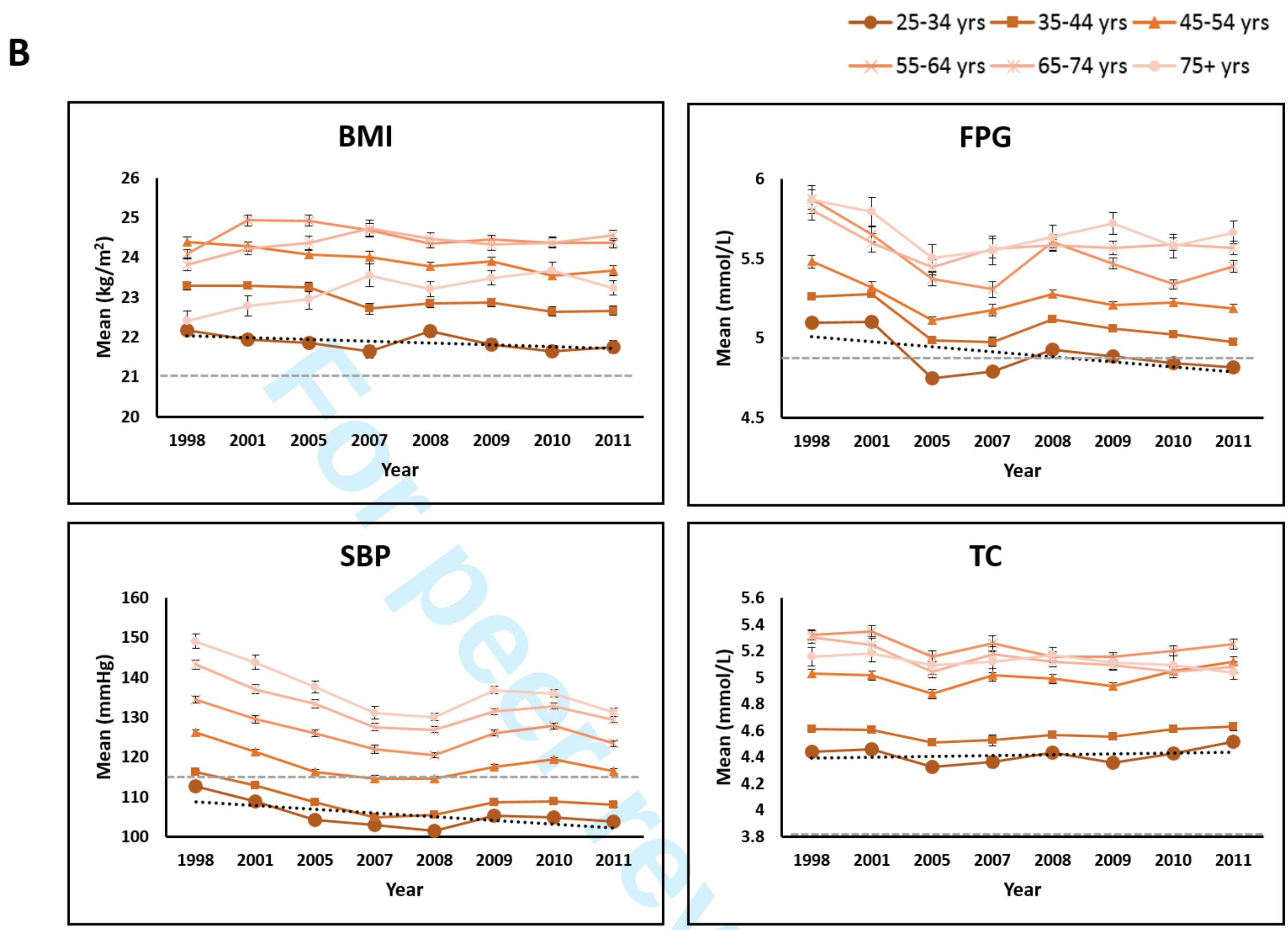


B


25-34 yrs
35-44 yrs
45-54 yrs
55-64 yrs
65-74 yrs
75+ yrs
BMI
Mean (kg/m²)
26
25
24
23
22
21
20
1998
2001
2005
2007
2008
2009
2010
2011
Year
FPG
Mean (mmol/L)
6
5.5
5
4.5
1998
2001
2005
2007
2008
2009
2010
2011
Year
SBP
Mean (mmHg)
160
150
140
130
120
110
100
1998
2001
2005
2007
2008
2009
2010
2011
Year
TC
Mean (mmol/L)
5.2
5
4.8
4.6
4.4
4.2
4
3.8
1998
2001
2005
2007
2008
2009
2010
2011
Year

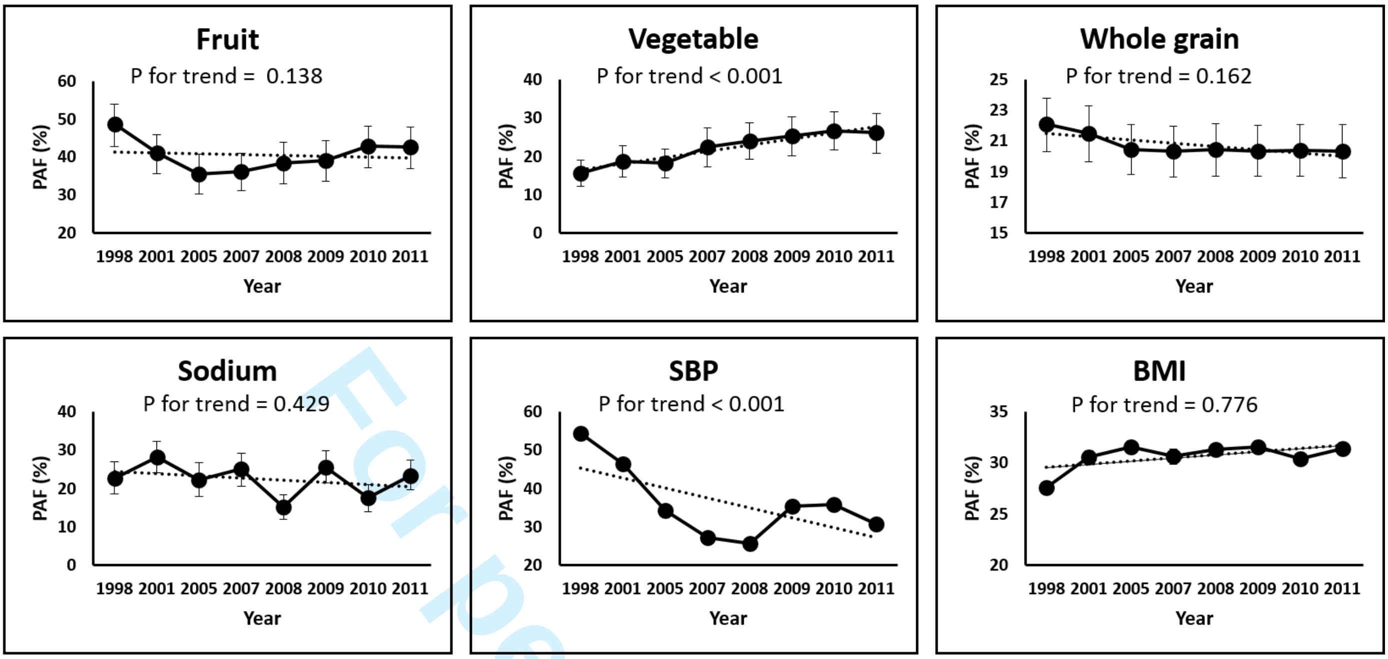
Supplementary Figure 2.



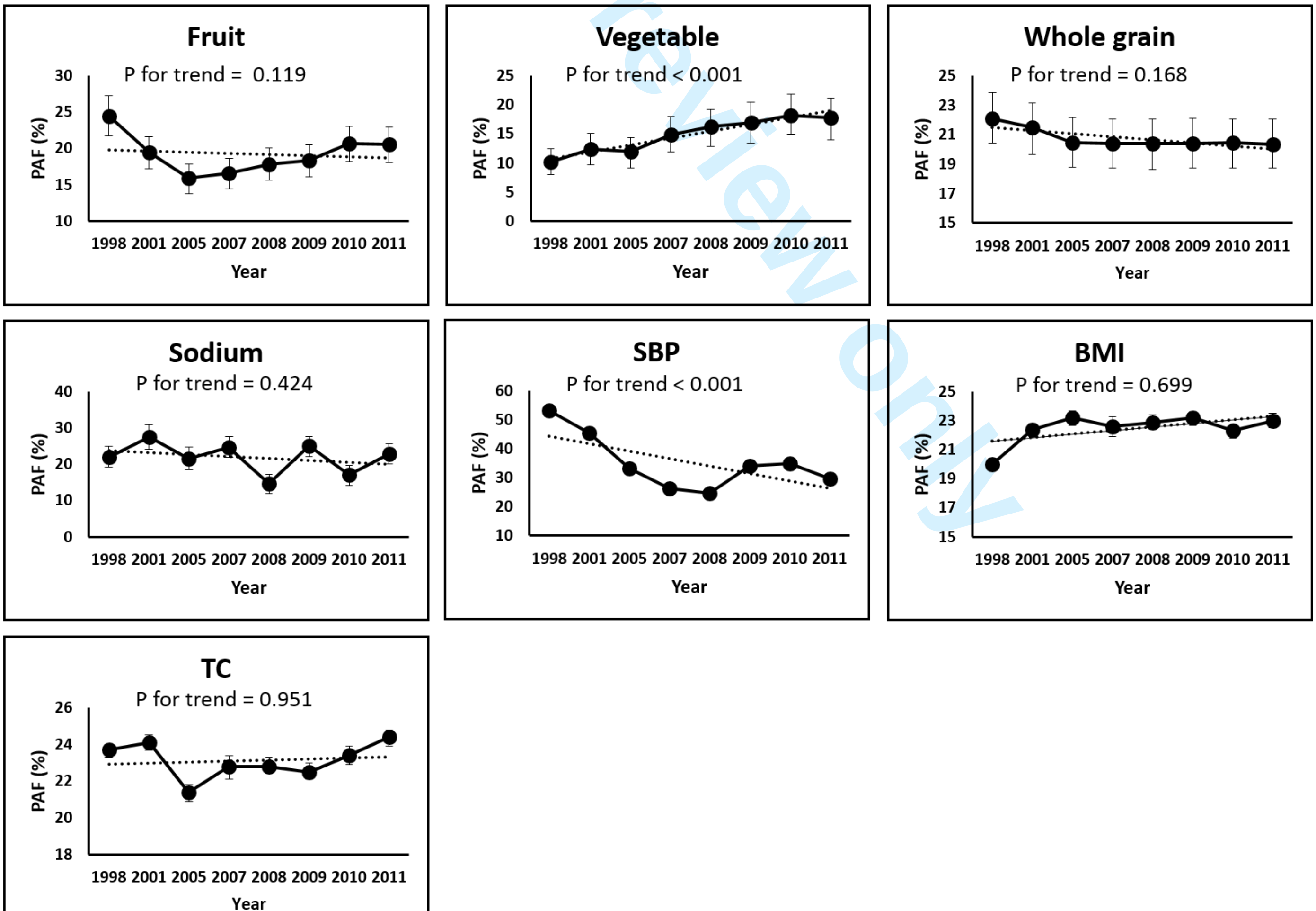

B
25-34 yrs
35-44 yrs
45-54 yrs
55-64 yrs
65-74 yrs
75+ yrs
BMI
Mean (kg/m²)
FPG
Mean (mmol/L)
SBP
Mean (mmHg)
TC
Mean (mmol/L)
Year
1998
2001
2005
2007
2008
2009
2010
2011

Supplementary Figure 3.

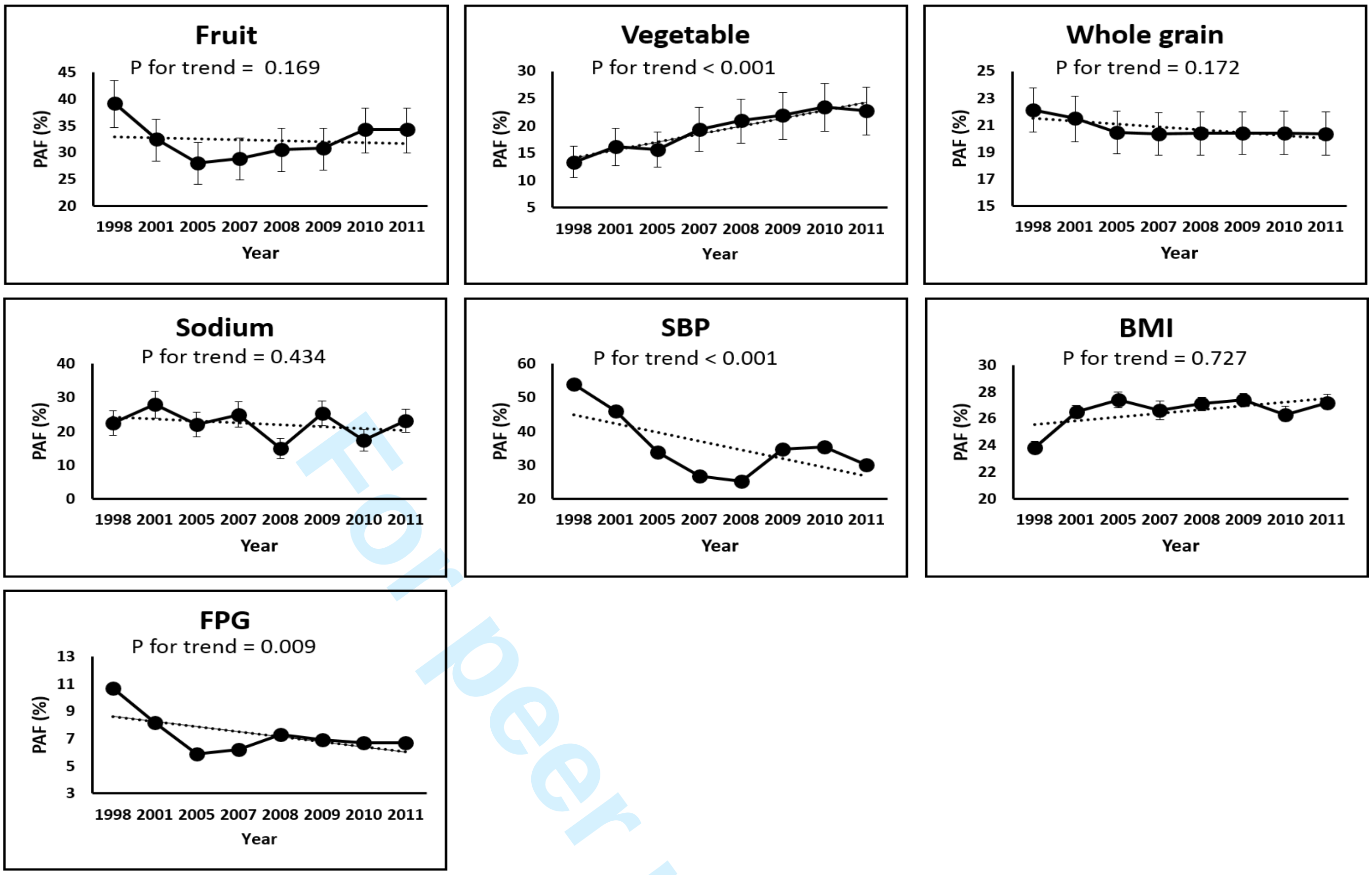
A. Hemorrhagic stroke



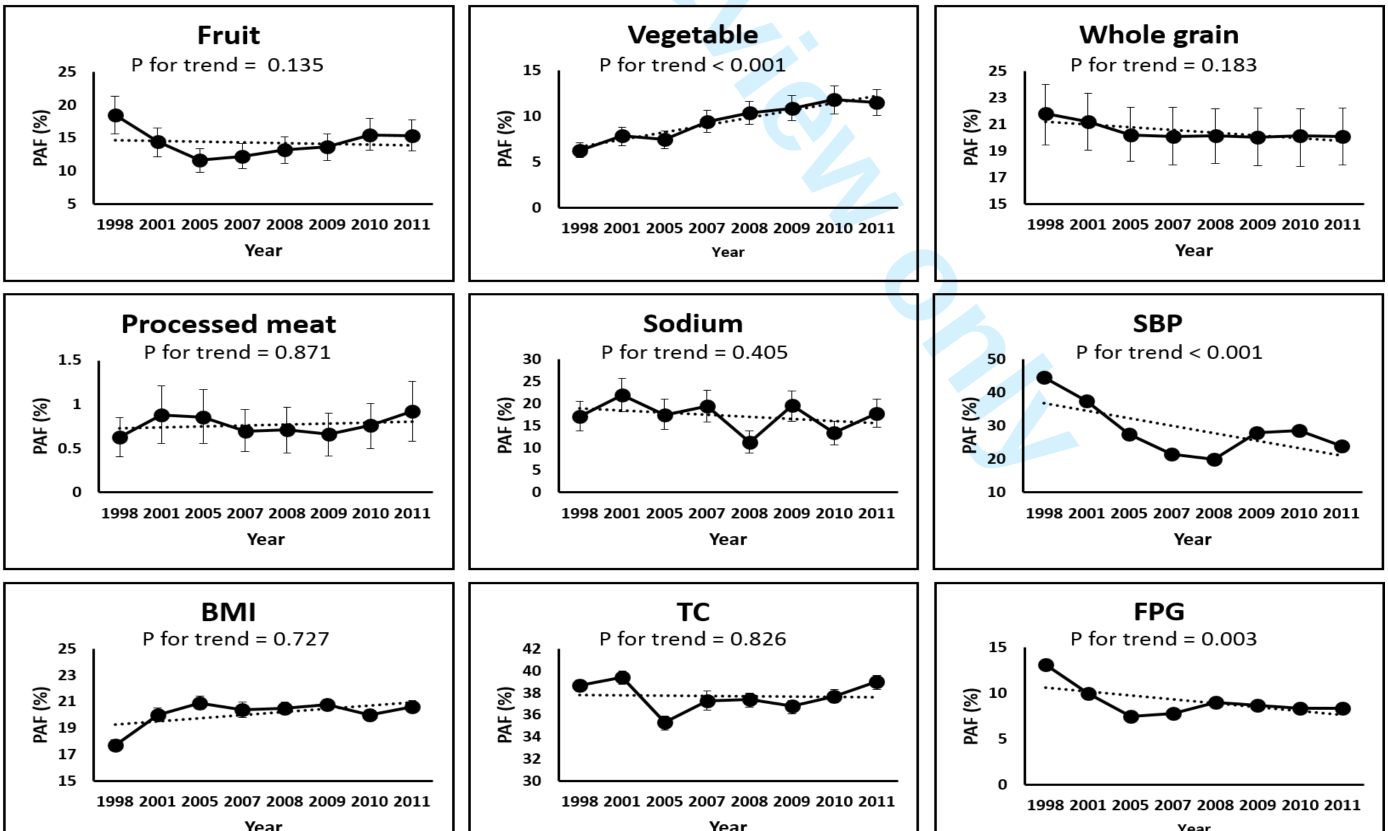
B. Ischemic stroke



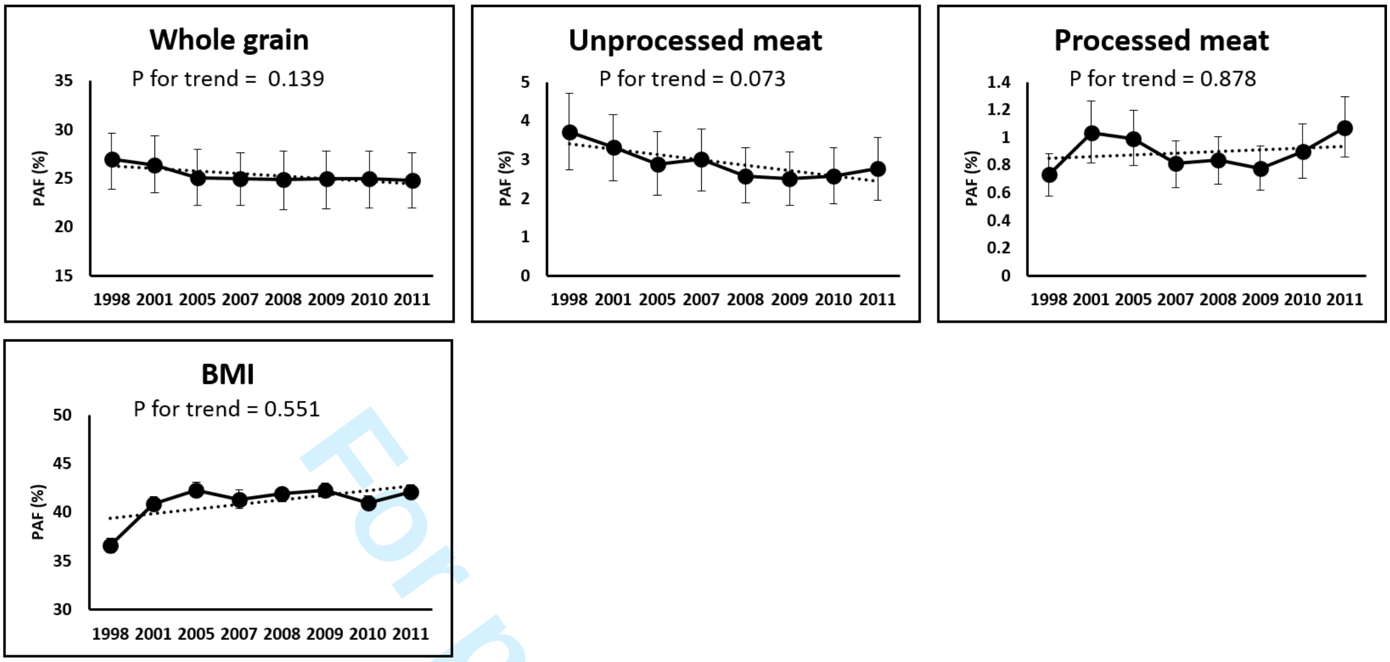
C. Total stroke



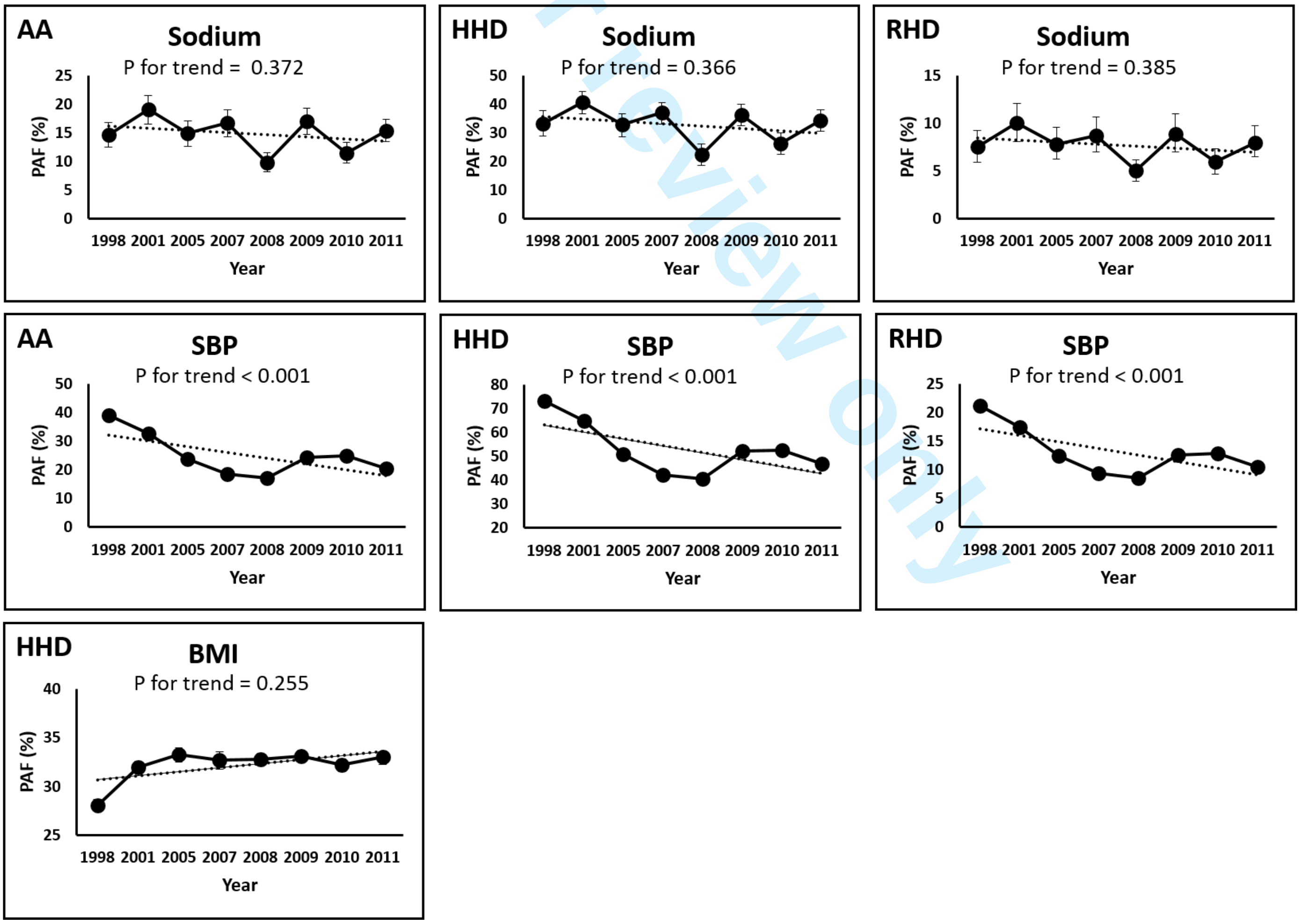
D. Ischemic Heart Disease



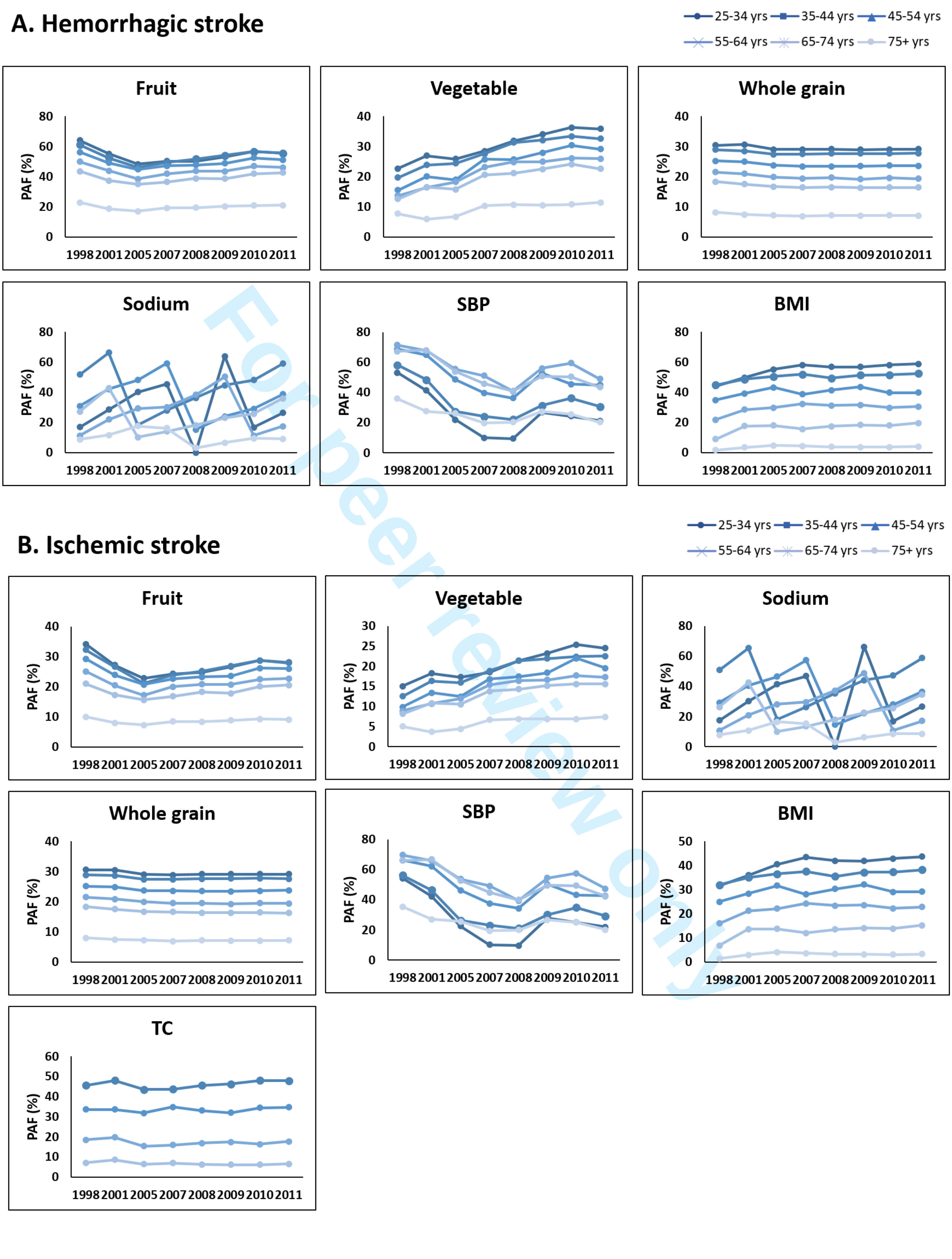
E. Diabetes



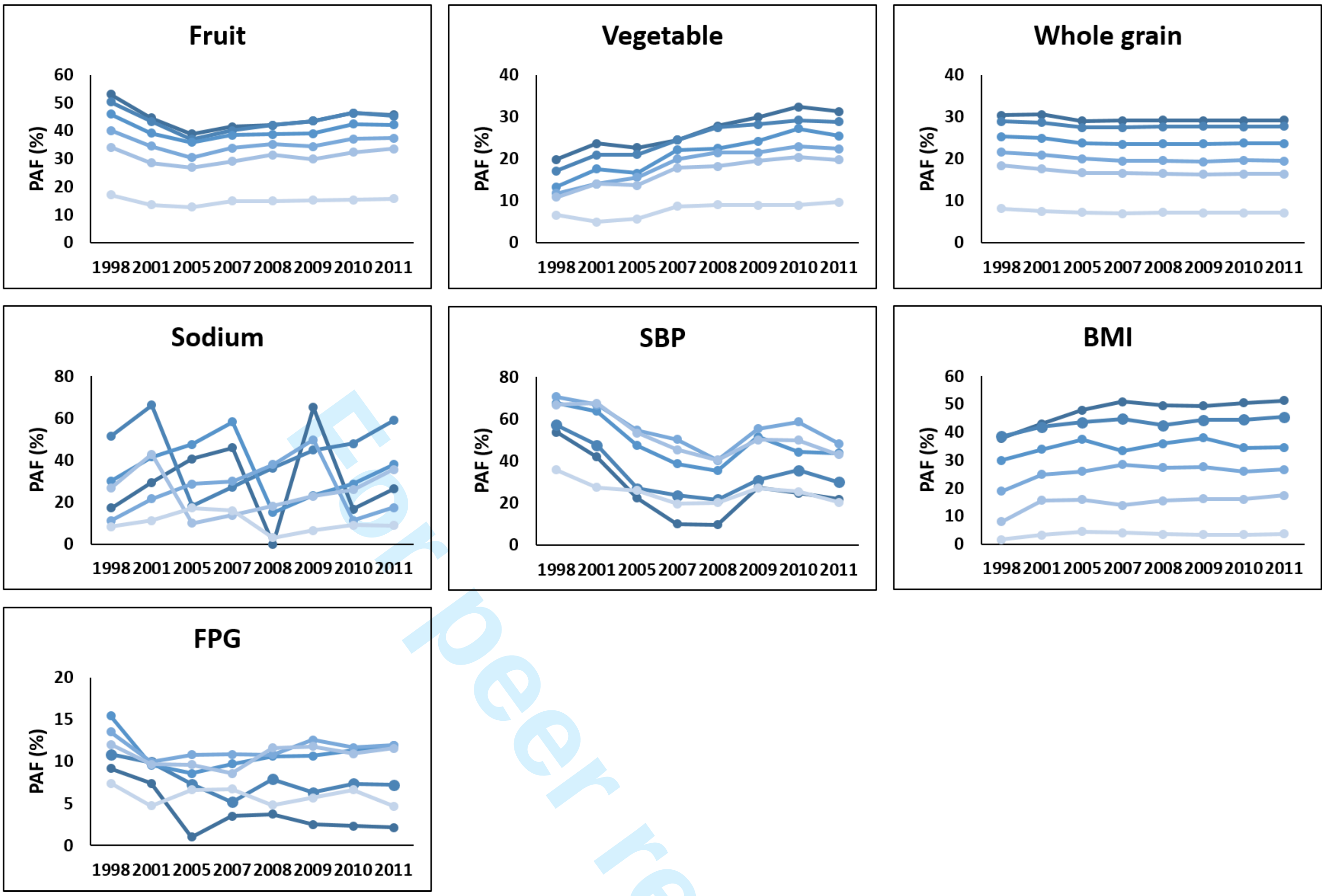
F. Other CVD



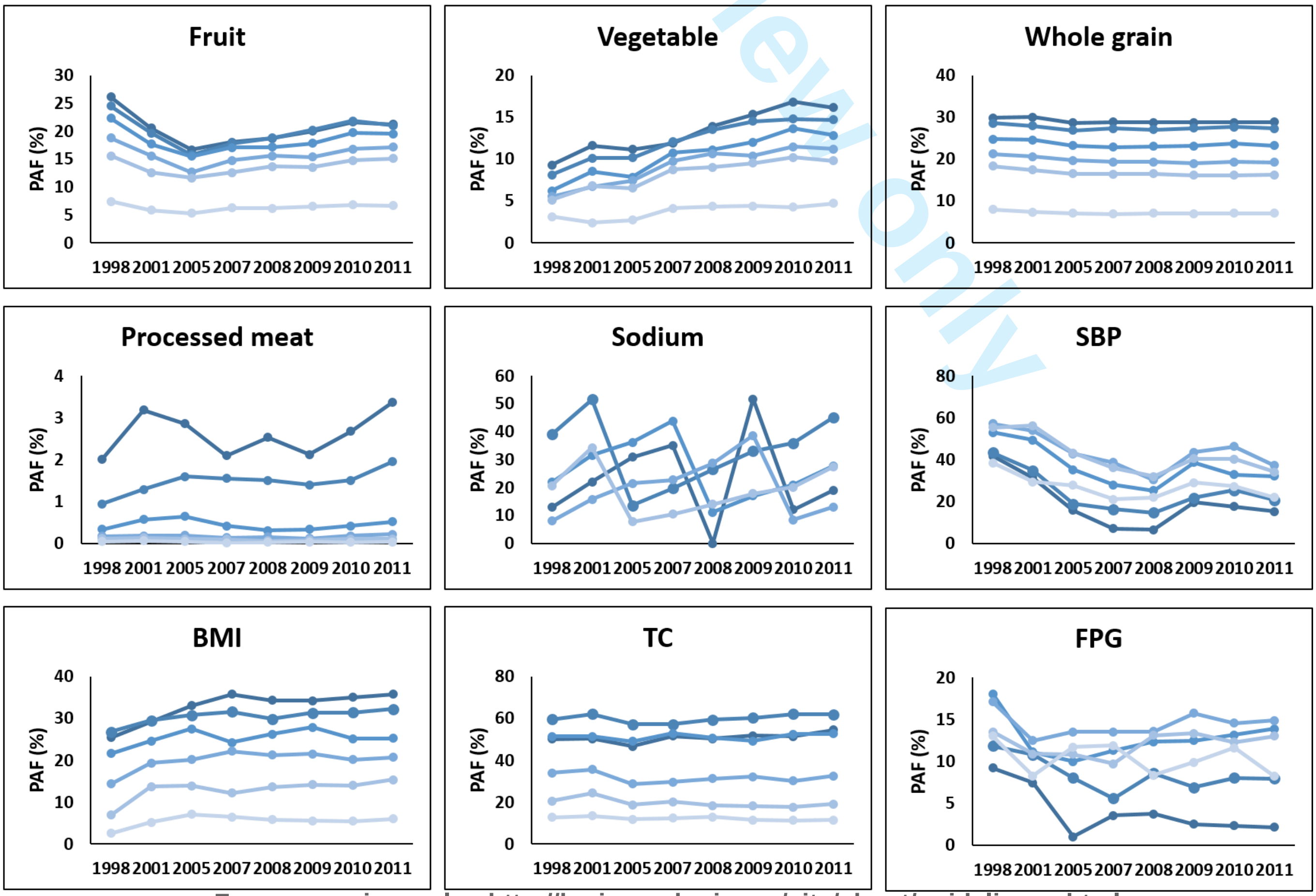
Supplementary Figure 4.



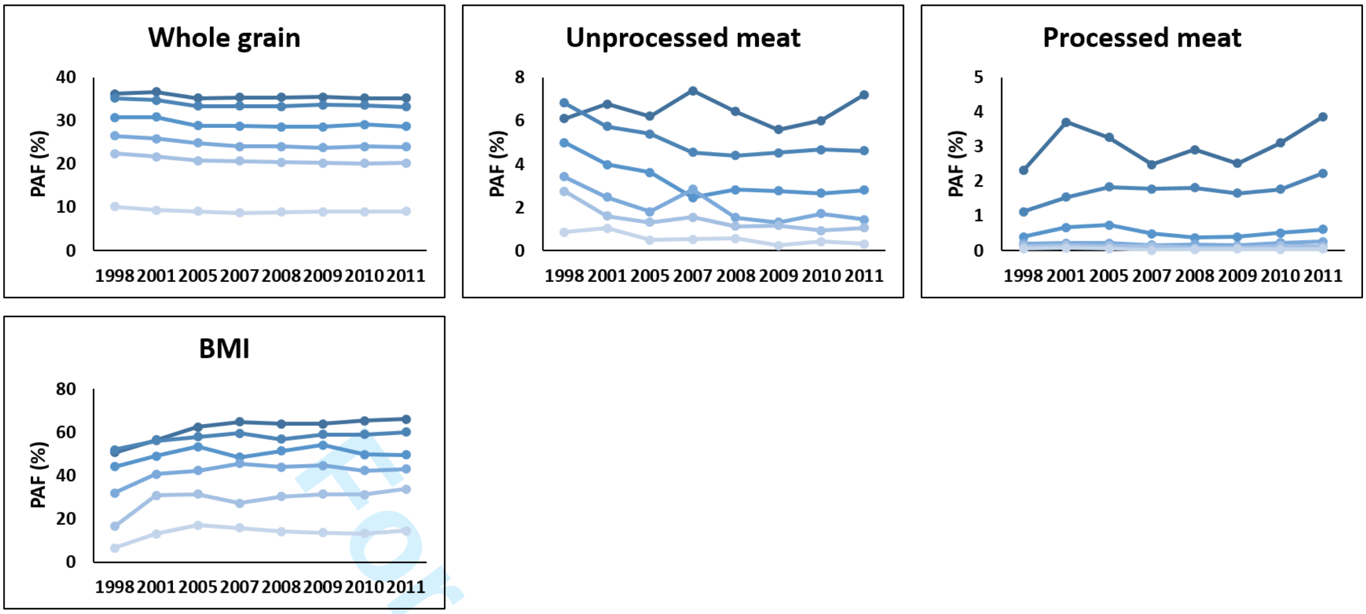
C. Total stroke



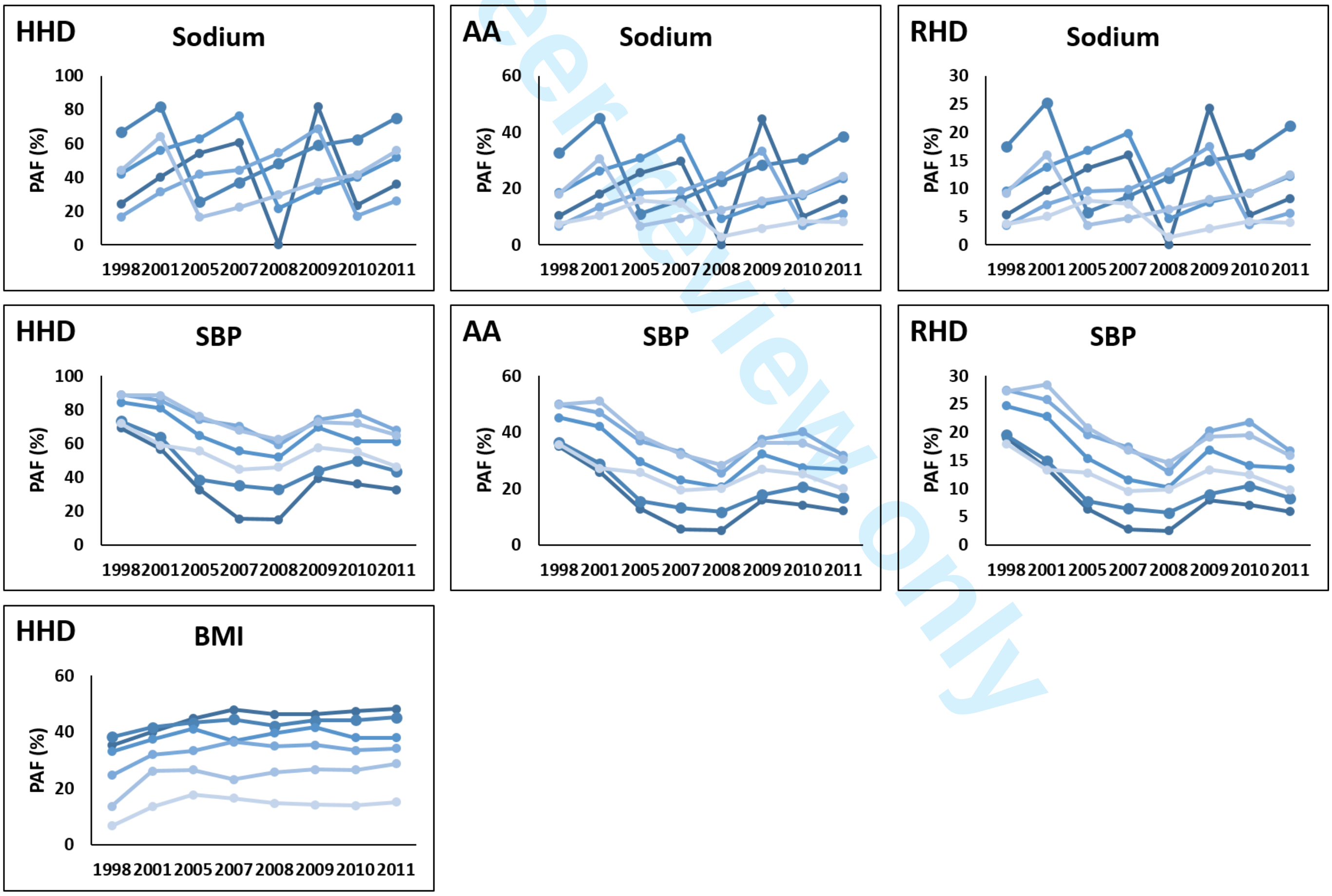
D. Ischemic Heart Disease



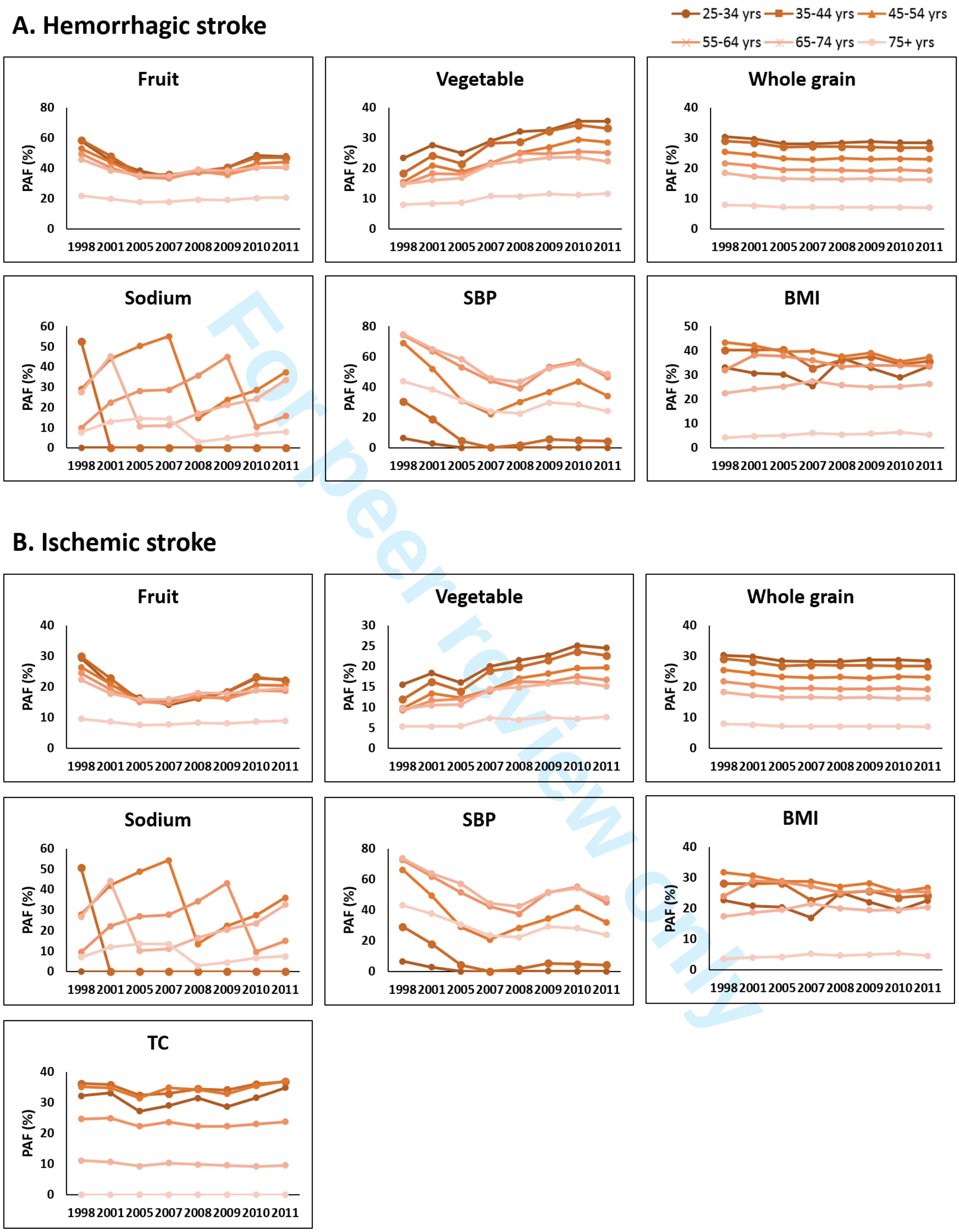
E. Diabetes



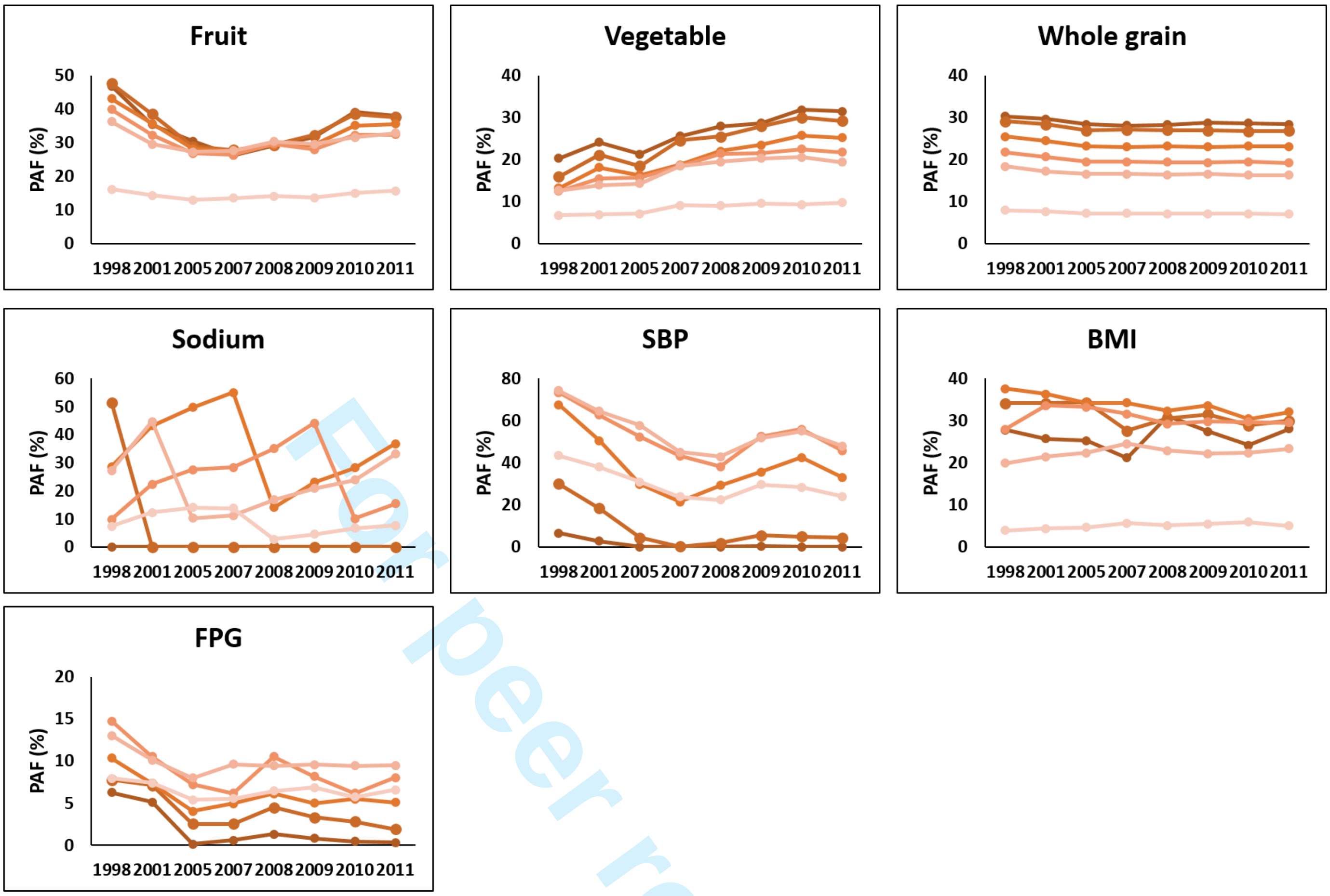
F. Other CVD



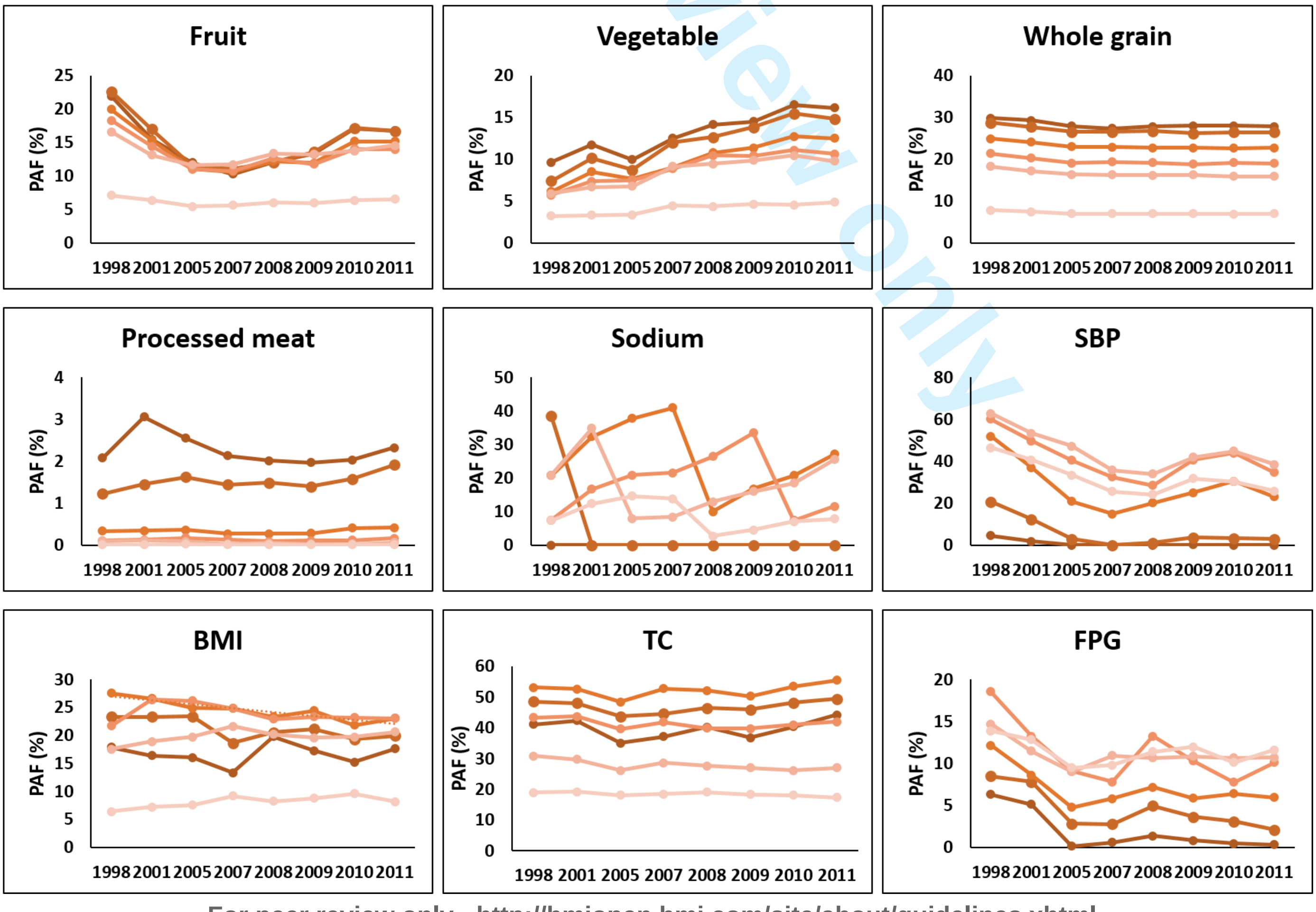
Supplementary Figure 5.



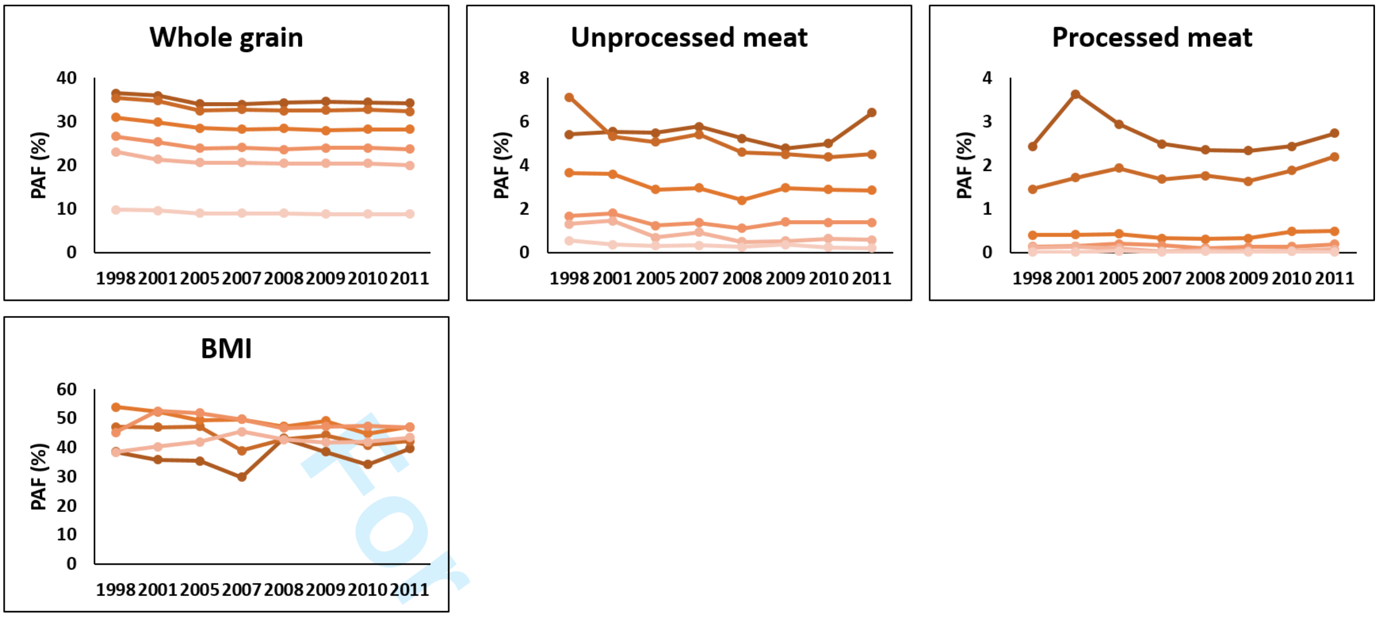
C. Total stroke



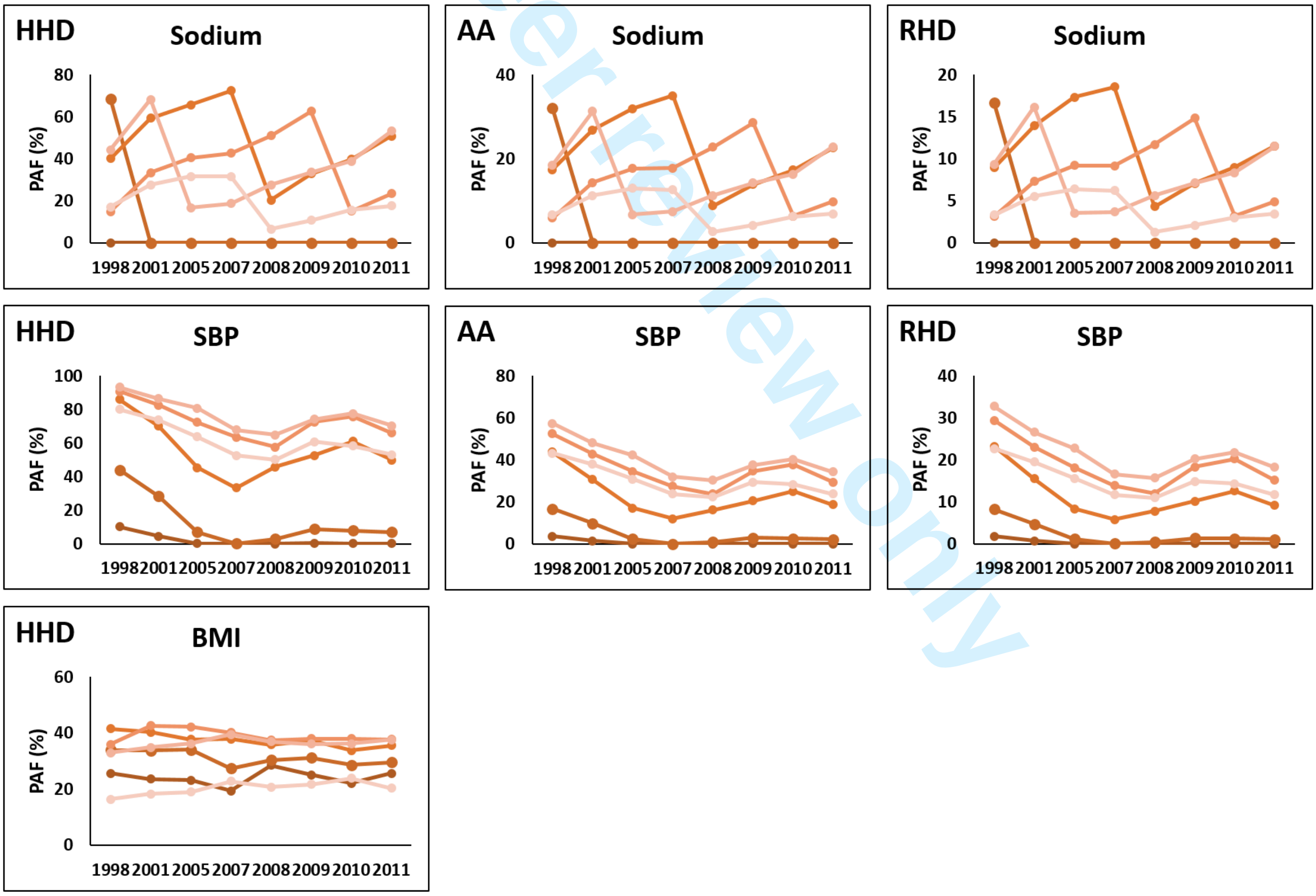
D. Ischemic Heart Disease



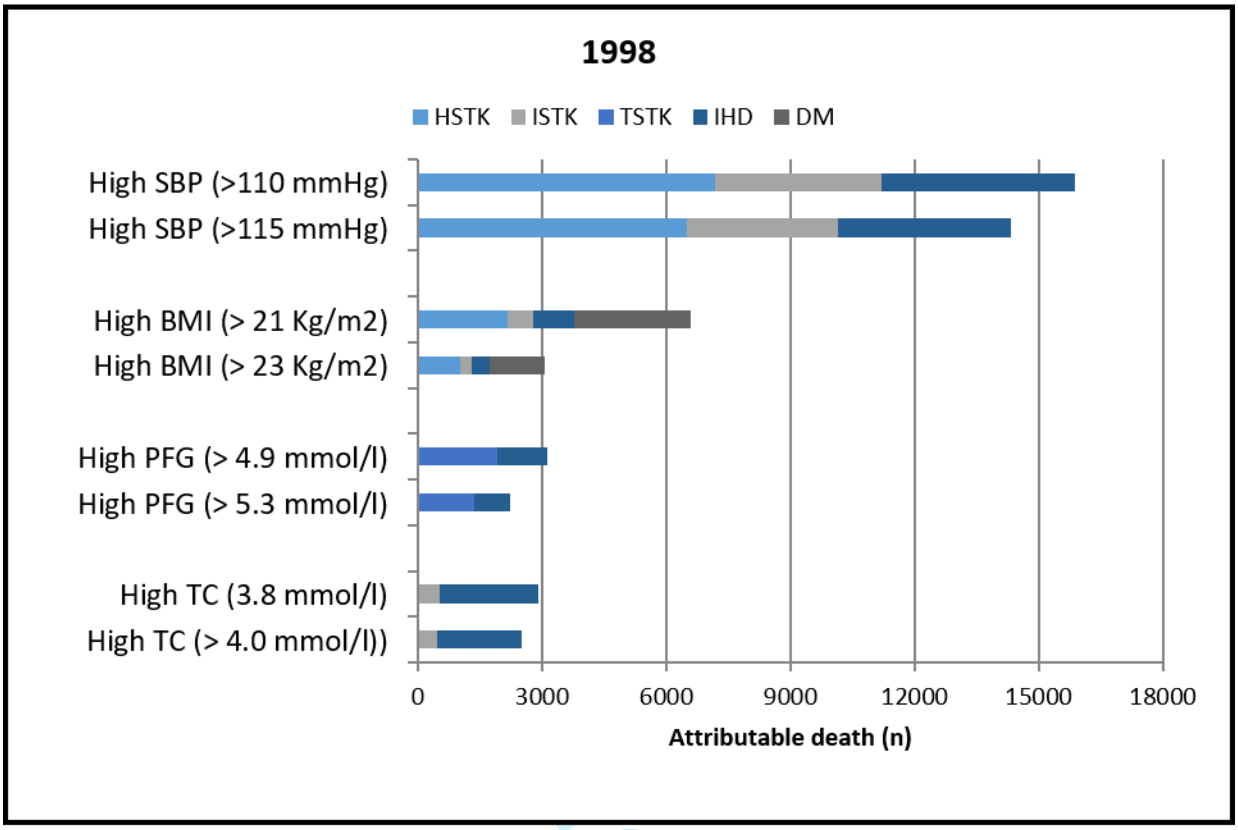
E. Diabetes

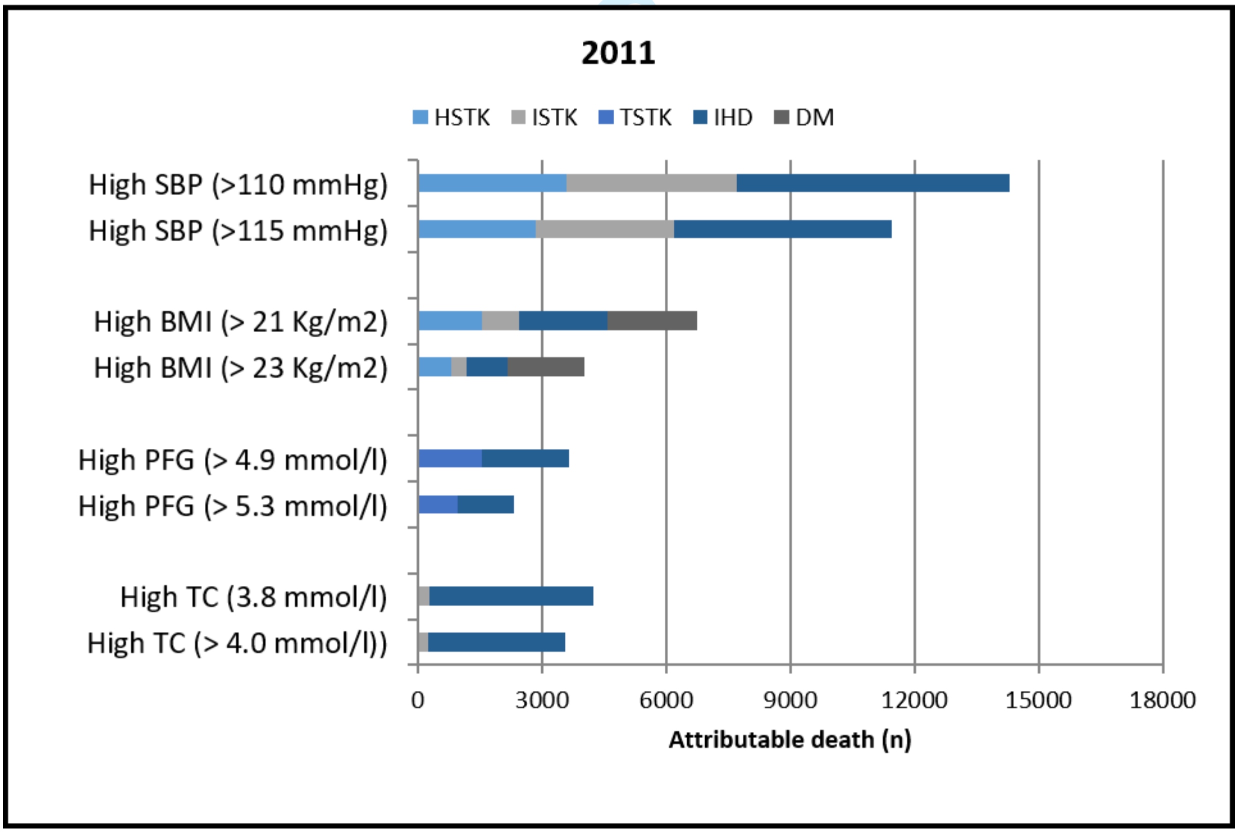


F. Other CVD



Supplementary Figure 6.





Supplementary Table 1. Total sample sizes for each risk factor across year by age and sex.

Risk factor	Number of participants (n)								Total (n)
	Year								
	1998	2001	2005	2007	2008	2009	2010	2011	
Number of total participants in KNHANES[1]									
	39060	37769	33848	4594	9744	10533	8958	8518	153024
Number of participants completing assessment[2]									
Dietary risk factors									
Low intake of fruits	4573	6237	5862	2698	5723	6290	5259	5168	41810
Low intake of vegetables	4603	6269	5914	2725	5756	6303	5271	5180	42021
Low intake of whole grains	4655	6299	5977	2764	5830	6393	5352	5254	42524
High intake of processed meats	4571	6244	5879	2720	5729	6282	5264	5153	41842
High intake of unprocessed meats	4546	6222	5835	2710	5734	6286	5260	5169	41762
High intake of sodium	4578	6234	5874	2726	5748	6286	5279	5164	41889
Metabolic risk factors									
High fasting plasma glucose	7216	5777	5008	2778	6066	6583	5498	5461	44387
High total cholesterol	7298	5953	5100	2763	6163	6670	5563	5541	45051
High systolic blood pressure	7286	5549	5134	2857	6350	6966	5921	5809	45872
High body mass index	7312	6058	5128	2849	6307	6969	5892	5782	46297

KNHANES, Korea National Health and Nutrition Survey

[1] Nutrition survey and health examination of KNHANES was conducted in selected subpopulation between 1998 and 2005, considering selection bias.

[2] Study subjects were selected following described criteria in method section.

Supplementary Table 2. Total deaths due to cardiovascular disease, stroke, and diabetes in Korea (1998-2011).

Year	Age group (yrs)	Deaths number caused by specific diseases (n)							
		IHD	ISTK	HSTK	TSTK	DM	HHD	AA	RHD
Total									
1998	All	8282	6744	10864	17608	10735	1148	379	83
2001		12954	11774	12347	24121	13385	3932	590	190
2005		17665	15448	10942	26390	14122	3430	861	333
2007		19554	15958	9727	25685	14125	4084	891	294
2008		17154	14602	9471	24073	12984	3244	921	294
2009		17554	13142	8903	22045	12510	2783	847	219
2010		18507	12872	9302	22174	13537	3006	904	257
2011		19323	12723	8996	21719	14250	3330	984	239
Men									
1998	25-34	116	21	150	171	47	1	5	2
	35-44	401	80	554	634	275	18	16	2
	45-54	668	174	870	1044	615	29	21	4
	55-64	1163	666	1413	2079	1521	81	54	6
	65-74	1115	1007	1137	2144	1423	129	50	7
	75+	1273	1303	1106	2409	1451	178	63	11
2001	25-34	117	18	114	132	52	2	2	5
	35-44	420	80	564	644	278	20	11	2
	45-54	803	229	1021	1250	685	40	21	6
	55-64	1292	761	1327	2088	1439	116	53	10
	65-74	1572	1360	1282	2642	1737	222	92	16
	75+	2384	2804	1362	4166	2129	823	140	19
2005	25-34	83	11	88	99	31	1	5	1
	35-44	397	51	480	531	242	11	30	9
	45-54	890	203	813	1016	790	35	40	13
	55-64	1270	666	951	1617	1361	74	60	27
	65-74	1978	1742	1087	2829	1980	142	110	34
	75+	3752	4013	1494	5507	2315	620	218	40
2007	25-34	77	15	76	91	25	1	6	0
	35-44	375	38	335	373	226	6	15	2
	45-54	902	195	791	986	725	29	36	15
	55-64	1347	527	770	1297	1033	66	52	14
	65-74	2097	1698	1011	2709	1952	168	134	17
	75+	4499	4229	1475	5704	2659	732	243	37
2008	25-34	58	6	64	70	24	1	10	1
	35-44	345	36	331	367	170	7	12	0
	45-54	915	176	768	944	606	37	37	8
	55-64	1125	451	718	1169	900	54	64	16
	65-74	2015	1449	988	2437	1814	126	141	22
	75+	3883	4101	1539	5640	2606	598	257	56
2009	25-34	63	6	52	58	25	2	5	3
	35-44	338	36	335	371	134	11	20	6
	45-54	905	147	700	847	590	30	33	5
	55-64	1173	398	637	1035	866	60	39	8
	65-74	1962	1251	890	2141	1631	107	112	11
	75+	4132	3855	1490	5345	2615	459	272	20
2010	25-34	54	6	62	68	23	3	7	2
	35-44	309	41	307	348	149	7	19	4
	45-54	875	138	689	827	583	30	31	11
	55-64	1151	359	661	1020	878	54	37	15
	65-74	1879	1114	883	1997	1675	105	128	19
	75+	4498	3733	1691	5424	2991	526	244	30

2011	25-34	43	8	53	61	17	2	5	0
	35-44	267	32	264	296	94	3	16	2
	45-54	847	99	685	784	570	25	41	10
	55-64	1155	334	647	981	923	46	43	16
	65-74	1856	960	768	1728	1787	108	121	16
	75+	4769	3749	1664	5413	3345	585	294	18
Women									
1998	25-34	23	14	71	85	32	0	0	4
	35-44	87	25	249	274	87	10	4	5
	45-54	153	90	500	590	177	18	8	7
	55-64	412	362	1077	1439	802	64	33	12
	65-74	891	893	1488	2381	1741	145	55	12
	75+	1980	2109	2249	4358	2564	475	70	11
2001	25-34	26	20	61	81	40	2	2	1
	35-44	73	29	234	263	88	8	6	9
	45-54	155	84	491	575	194	26	12	4
	55-64	500	355	937	1292	745	77	34	20
	65-74	1292	1241	1566	2807	2086	311	72	29
	75+	4320	4793	3388	8181	3912	2285	145	69
2005	25-34	10	8	35	43	31	0	3	0
	35-44	76	22	202	224	71	2	6	2
	45-54	191	80	429	509	211	10	15	16
	55-64	402	283	636	919	615	41	21	41
	65-74	1439	1334	1200	2534	1917	221	94	54
	75+	7177	7035	3527	10562	4558	2273	259	96
2007	25-34	13	6	50	56	17	0	3	0
	35-44	55	20	174	194	67	4	4	4
	45-54	178	70	385	455	194	19	13	13
	55-64	364	220	489	709	451	34	28	32
	65-74	1485	1180	1044	2224	1635	248	94	58
	75+	8162	7760	3127	10887	5141	2777	263	102
2008	25-34	3	9	33	42	20	1	2	1
	35-44	43	26	149	175	59	2	6	6
	45-54	148	76	396	472	167	3	7	8
	55-64	319	180	415	595	425	30	23	21
	65-74	1183	993	987	1980	1451	157	91	48
	75+	7117	7099	3083	10182	4742	2228	271	107
2009	25-34	5	10	44	54	23	1	5	1
	35-44	48	21	129	150	50	4	4	2
	45-54	144	51	390	441	145	8	4	10
	55-64	285	158	373	531	336	26	23	18
	65-74	1119	775	841	1616	1328	141	79	44
	75+	7380	6434	3022	9456	4767	1934	251	91
2010	25-34	6	7	32	39	14	2	3	1
	35-44	36	18	159	177	52	2	7	0
	45-54	131	51	415	466	136	6	7	6
	55-64	284	144	428	572	318	14	27	21
	65-74	1163	671	849	1520	1315	113	69	36
	75+	8121	6590	3126	9716	5403	2144	325	112
2011	25-34	9	8	26	34	17	1	2	0
	35-44	40	19	141	160	55	2	1	1
	45-54	107	53	359	412	147	5	6	3
	55-64	270	127	412	539	356	16	25	20
	65-74	1023	593	750	1343	1228	94	72	48
	75+	8937	6741	3227	9968	5711	2443	358	105

Supplementary Table 3. Number of cardiometabolic mortality attributable to each risk factor by sex from 1998 to 2011 with 95% uncertainty intervals

Risk factor	Disease	Percentage of death (95% UI)							
		Year							
		1998	2001	2005	2007	2008	2009	2010	2011
Men									
Low intake of fruits	HSTK	2378.4 (1913.7-2768.3)	2178.7 (1690.7-2576.4)	1630.8 (1265.2-1974.1)	1554.8 (1202.0-1855.8)	1566.9 (1233.0-1874.2)	1475.2 (1176.0-1762.5)	1604.7 (1274.7-1891.2)	1504.0 (1189.5-1795.7)
	ISTK	593.2 (462.6-715.8)	697.2 (549.6-863.1)	737.6 (555.4-922.3)	804.4 (606.6-997.3)	754.2 (572.4-937.8)	692.0 (527.2-846.5)	699.8 (521.5-876.3)	650.9 (472.6-814.3)
	TSTK	2971.6 (2498.6-3390.8)	2875.9 (2379.9-3299.5)	2368.4 (1964.4-2762.1)	2359.2 (1961.7-2707.0)	2321.1 (1950.9-2688.6)	2167.3 (1822.6-2499.7)	2304.5 (1938.8-2640.5)	2154.9 (1791.3-2489.6)
	IHD	762.8 (592.4-940.0)	787.4 (600.5-982.1)	804.1 (600.6-1003.7)	976.8 (754.4-1226.5)	923.1 (698.4-1144.3)	957.8 (729.6-1200.4)	1027.7 (778.8-1282.0)	1026.3 (771.3-1283.5)
Low intake of vegetables	HSTK	702.4 (459.3-943.9)	879.8 (589.2-1155.3)	740.1 (494.3-978.5)	857.7 (565.4-1124.7)	873.7 (587.5-1144.8)	837.2 (566.7-1082.6)	902.5 (620.4-1181.8)	835.7 (576.9-1092.0)
	ISTK	237.9 (147.5-330.0)	379.5 (224.7-521.6)	477.3 (280.8-678.1)	642.4 (386.3-919.1)	601.7 (343.8-851)	558.8 (328.1-785.3)	535.9 (316.4-756.1)	514.6 (282.1-732.8)
	TSTK	940.3 (695.0-1189.0)	1259.3 (953.3-1577.5)	1217.5 (890.7-1534.1)	1500.1 (1107.4-1858.6)	1475.4 (1102.2-1827.7)	1396.0 (1044.4-1739.0)	1438.4 (1104.2-1774.9)	1350.3 (995.2-1687.7)
	IHD	245.8 (197.6-299.7)	375.3 (296.9-448.5)	445.1 (350.7-543.9)	652.4 (518.2-796.8)	626.9 (506.0-758.6)	657.3 (526.2-788.7)	688.9 (535.1-839.5)	690.0 (538.1-830.1)
Low intake of whole grains	HSTK	1028.7 (901.6-1161.9)	1055.0 (919.6-1186.9)	829.4 (726.4-932.5)	718.1 (625.5-803.6)	704.7 (616.8-786.6)	646.8 (560.8-727.9)	661.7 (578.4-742.6)	620.2 (543.6-696.2)
	ISTK	505.7 (430.4-578.9)	691.3 (588.1-795.4)	781.0 (656.9-898.4)	739.9 (618.4-861.3)	673.2 (559.1-790.9)	601.1 (490.1-710.1)	565.0 (468.9-657.6)	524.9 (434.6-620.9)
	TSTK	1534.4 (1384.7-1682.4)	1746.3 (1584.8-1914.7)	1610.3 (1441.4-1764.5)	1458.0 (1313.2-1606.3)	1377.9 (1232.1-1524)	1247.9 (1117.8-1388.2)	1226.7 (1104.4-1355.6)	1145.1 (1032.4-1266.7)
	IHD	866.4 (728.6-1001.7)	1064.2 (902.6-1224)	1178.8 (989.6-1373.7)	1242.5 (1019-1441.9)	1143.3 (957.8-1328.2)	1148.0 (952.6-1344.0)	1151.4 (955.2-1344.4)	1143.9 (939.4-1322)
	DM	1171.6 (951.8-1380.3)	1273.2 (1040.1-1490.7)	1278.1 (1035.2-1525.5)	1177.1 (954.4-1387.2)	1056.6 (859.9-1268.9)	993.3 (802.5-1173.7)	1043.0 (822.6-1239.1)	1086.5 (855.9-1305.4)
High intake of processed meats	IHD	12.3 (8.0-17.2)	19.9 (12.7-27.4)	20.7 (13.4-28.4)	15.7 (9.1-22.5)	13.6 (8.1-19.1)	13.5 (8.6-18.7)	15.4 (9.3-21.7)	17.3 (10.8-23.6)
	DM	12.6 (9.7-15.6)	18.4 (14.6-22.7)	18.1 (13.8-22.3)	12.5 (9.4-15.5)	9.9 (7.7-12)	9.0 (7.0-11.0)	11.5 (9.0-14.0)	12.3 (9.7-15.1)
High intake of unprocessed meats	DM	155.7 (97.1-220.2)	132.2 (85.1-181.9)	105.7 (66.8-143.7)	103.4 (60.9-142.6)	75.2 (49.4-101.2)	60.4 (37.3-83.6)	67.2 (41.7-92)	63.8 (40.7-86.2)
High intake of sodium	HSTK	1146.2 (868.5-1425.3)	1835.8 (1477-2200.4)	1166.4 (854.0-1493.5)	1209.4 (906.0-1507.7)	741.5 (531.7-953.4)	976.5 (769.9-1205.6)	820.1 (612.2-1033.9)	975.2 (770.3-1201.9)
	ISTK	535.2 (407.1-679.8)	1189.3 (955.6-1421.3)	1134.8 (798.7-1495.4)	1157.9 (843.9-1495.7)	589.6 (417.1-772.1)	769.4 (591.9-961.6)	705.0 (534.8-887.2)	767.9 (598.9-947.6)

	TSTK	1681.5 (1376.4-2002)	3025.0 (2570.9-3458.9)	2301.2 (1844.1-2770.3)	2367.3 (1923.3-2835.4)	1331.1 (1061.3-1610.9)	1745.9 (1463.7-2043.6)	1525.1 (1250.2-1796.3)	1743.1 (1462.4-2023.0)
	AA	27.1 (21.1-33.3)	60.7 (48.3-73.5)	69.9 (54.3-87.7)	76.2 (59.5-94.6)	46.8 (35.4-58.4)	59.5 (45.8-72.0)	57.9 (46.0-70.3)	75.2 (61.0-91.1)
	HHD	128.7 (100.0-156.7)	430.2 (342.2-514.5)	312.7 (233.9-390.2)	356.9 (253.7-461.7)	122.2 (72.7-173.1)	167.3 (124.7-209.9)	178.5 (134.4-224.2)	207.8 (164.7-253.7)
	RHD	2.1 (1.5-2.7)	6.1 (4.5-7.7)	9.8 (6.9-13.2)	8.0 (5.6-10.9)	4.6 (3.1-6.2)	4.9 (3.7-6.1)	5.3 (3.9-6.9)	5.3 (3.9-6.7)
	IHD	749.9 (556.9-943.7)	1508.7 (1192.3-1825.0)	1495.3 (1068.0-2014.3)	1758.9 (1281.0-2336.5)	923.3 (677.8-1183.4)	1369.7 (1052.7-1700.6)	1190.7 (888.8-1533.8)	1455.5 (1121.6-1795.9)
High fasting plasma glucose	TSTK	963.4 (908.7-1018.6)	853.4 (792.4-914.7)	939.0 (842.8-1048.7)	874.8 (767.3-975.8)	812.1 (754-869.4)	800.8 (748.0-855.4)	816.0 (745.1-884.2)	685.5 (634.4-740.5)
	IHD	695.0 (651.4-740.2)	674.4 (618.9-729.0)	948.3 (835.4-1068.2)	1047.1 (915.6-1182.4)	887.6 (825.1-949.3)	995.0 (931.7-1066.7)	1064.0 (975.4-1157.9)	947.2 (875.3-1018.5)
High total cholesterol	ISTK	298.7 (286.8-309.0)	388.8 (374.8-403.4)	305.7 (291.7-320.9)	292.7 (275.7-309.9)	243.8 (232.1-255.1)	212.8 (203.1-222.0)	195.8 (187.4-203.6)	175.3 (167.5-182.6)
	IHD	1427.5 (1381.1-1473.9)	1895.6 (1833.1-1956.6)	1884.0 (1771.1-1989.1)	2111 (1986.1-2240.2)	1922.0 (1837.9-2001.9)	1887.9 (1812.6-1971.8)	1871.4 (1777.6-1963.2)	1917.2 (1822.2-2005.3)
High systolic blood pressure	HSTK	3173.6 (3098.2-3253.1)	3128.9 (3031.5-3222.9)	2048.8 (1961.0-2138.5)	1551.9 (1449.4-1645.5)	1368.4 (1297.5-1436.1)	1703.1 (1645.0-1753.3)	1708.8 (1640.8-1771.4)	1389.1 (1326.2-1447.5)
	ISTK	1762.9 (1692.2-1831.6)	2356.6 (2225.2-2494.5)	2414.8 (2224.9-2598.2)	1925.2 (1735.8-2116.7)	1645.4 (1531.9-1773.0)	1954.1 (1848.0-2058.7)	1766.6 (1658.6-1872.1)	1372.0 (1276.2-1465.5)
	TSTK	4936.5 (4838.9-5036.4)	5485.5 (5328.1-5647.4)	4463.7 (4250.9-4663.7)	3477.1 (3259.2-3685.4)	3013.8 (2885.6-3169.0)	3657.1 (3543.0-3771.0)	3475.4 (3335.9-3601.7)	2761.1 (2648.6-2875.4)
	IHD	2346.7 (2267.2-2429.5)	2859.5 (2724.1-2992.4)	2840.4 (2641.3-3030.3)	2544.0 (2328.9-2762.5)	2118.9 (1972.5-2260.0)	2938.0 (2794.8-3081.4)	2895.1 (2750-3038.6)	2444.9 (2287.4-2598.1)
	HHD	352.7 (343-361.6)	826.3 (768.6-875.7)	534.7 (493.5-575.2)	505.6 (451.4-558.1)	406.7 (377.7-436.0)	413.4 (394.7-430.3)	429.6 (405.9-454.4)	389.5 (363.3-415.8)
	RHD	7.3.0 (6.9-7.7)	12 .0 (11.3-12.7)	20.2 (19-21.6)	10.7 (9.7-11.7)	11.6 (10.7-12.6)	8.0 (7.6-8.4)	12.8 (12.2-13.4)	8.5 (8.1-9.0)
	AA	91.4 (87.8-95.0)	122.3 (114.9-129.1)	137.8 (127.7-148.2)	117.7 (107.2-129.0)	117.3 (108.6-125.8)	143.1 (136.2-151.0)	135.9 (128.8-143.4)	123.5 (115.1-131.8)
High body mass index	HSTK	1046.6 (1010.4-1084.1)	1384.1 (1336.9-1432.2)	1191.2 (1151.6-1230.3)	995.1 (947.7-1040.2)	974.8 (945.4-1004.4)	926.8 (901.4-952.7)	886.0 (858.7-914.0)	857.1 (832.0-885.3)
	ISTK	269.7 (253.7-286.0)	528.8 (496.2-563.4)	638.4 (586.5-695.2)	563.5 (510.8-616.1)	504.7 (469.9-536.1)	455.6 (428.0-483.4)	407.5 (379.0-436.1)	392.7 (368.1-419.3)
	TSTK	1316.3 (1276.1-1356.7)	1912.9 (1857.7-1968.4)	1829.6 (1762.2-1898.3)	1558.7 (1488.6-1626)	1479.5 (1433.3-1523.4)	1382.3 (1346.1-1420.8)	1293.5 (1254.1-1332.3)	1249.8 (1215.2-1285.1)
	IHD	558.3 (533.9-582.6)	945.8 (894.6-992.8)	1192.8 (1115.5-1271.4)	1211.4 (1124.3-1304.0)	1101.9 (1047.0-1155.9)	1141.6 (1092.8-1190.7)	1078.3 (1025.5-1133.3)	1126.1 (1072.1-1186.4)
	DM	1248.4 (1186.8-1319.9)	1914.7 (1817.8-2018.0)	2168.9 (2056.5-2286.2)	1918.0 (1805.6-2044.2)	1733.8 (1655.1-1814.9)	1667.6 (1598.3-1736.9)	1681.5 (1603.0-1761.6)	1831.6 (1746.0-1918.7)
	HHD	66.5 (61.8-72.1)	230.2 (202.2-259.1)	192.4 (164.4-216.4)	197.5 (169.5-227.9)	157.7 (140.3-175.1)	133.6 (122.3-144.2)	135.1 (122.3-148.6)	147.2 (132.9-161.9)
Women									
Low intake of fruits	HSTK	2155.9 (1680.4-2564.2)	2014.8 (1514.4-2493.5)	1506.5 (1083.4-1921.5)	1297.8 (950.2-1644.9)	1355.1 (981.5-1689.9)	1250.7 (913.6-1587.8)	1425.9 (1048.8-1787.7)	1379.6 (996.2-1758)

	ISTK	524.7 (397.7-640.3)	730.6 (524.4-923.8)	806.7 (567.3-1062.3)	835.9 (566.8-1127.5)	819.3 (544.0-1080.1)	698.1 (484.4-934.9)	740.8 (476.9-998.5)	758.4 (484.1-1009.6)
	TSTK	2680.6 (2174.8-3113.9)	2745.4 (2212.6-3267.7)	2313.2 (1789.3-2797.8)	2133.7 (1701.4-2595.8)	2174.4 (1736.6-2608.4)	1948.9 (1544.2-2390.2)	2166.7 (1697.7-2609.2)	2138.0 (1662.9-2581.7)
	IHD	419.4 (316.4-524.5)	557.5 (384.0-727.1)	636.7 (397.0-870.0)	699.4 (438.3-972.1)	653.9 (412.7-889.6)	646.3 (397.1-891.6)	746.9 (468.4-1051.5)	794.0 (458.1-1116.1)
Low intake of vegetables	HSTK	700.4 (454.1-945.6)	883.9 (552.2-1216.3)	756.3 (455.3-1039.3)	813.1 (486.9-1136.7)	809.5 (512.6-1113.4)	801.1 (488.6-1090.5)	848.6 (528.2-1150.6)	804.3 (479.1-1116.4)
	ISTK	245.4 (135.8-355.1)	448.0 (243.5-674.5)	572.4 (287.0-874.0)	787.0 (349.3-1204.9)	693.4 (313.1-1065)	645.6 (307.4-974.7)	623.1 (263.4-961.4)	643.7 (244.6-1038.6)
	TSTK	945.7 (687.7-1216.2)	1332.0 (951.3-1717.6)	1328.6 (898.9-1763.3)	1600.1 (1036.3-2114.6)	1502.9 (1027.3-1980.8)	1446.7 (986.4-1900.2)	1471.7 (970.1-1938.5)	1448.0 (934.5-1989.2)
	IHD	158.7 (120.0-197.3)	290.4 (215.9-369.3)	392.5 (273.3-507.5)	558.9 (406.9-724.6)	480.1 (339.4-615.6)	507.0 (354.7-670.4)	546.7 (381.4-718.3)	583.6 (385.5-766.4)
Low intake of whole grains	HSTK	907.5 (790.1-1024.4)	927.8 (799.5-1046.4)	739.9 (626.8-845.6)	642.6 (549.4-737.0)	603.5 (509.6-690.4)	562.9 (481.8-648.6)	591.6 (505.5-681.0)	555.6 (475.7-639.9)
	ISTK	443.6 (368.2-513.9)	689.1 (563.4-809.4)	808.7 (641.5-986.5)	818.8 (635.2-997.5)	733.6 (572.7-897.9)	640.5 (496.4-790.2)	623.5 (473.9-771.9)	614.2 (464.1-767.1)
	TSTK	1351.1 (1213.5-1482.6)	1616.9 (1430.7-1790.4)	1548.6 (1339.7-1745.7)	1461.4 (1257.6-1661.5)	1337.1 (1159.0-1533.5)	1203.5 (1042.7-1370.5)	1215.1 (1043.1-1379.3)	1169.8 (996.4-1342.7)
	IHD	475.2 (387.1-563.4)	713.9 (575.5-857.7)	885.7 (655.9-1101.0)	945.8 (706.8-1187.6)	797.0 (583.1-991.9)	799.1 (589-999.8)	844.5 (629.2-1066.8)	878.9 (642.7-1113.6)
	DM	965.0 (747.0-1186.6)	1116.0 (852.1-1354.3)	1047.3 (784.6-1294.6)	990.1 (746.0-1230.2)	898.3 (673.7-1118.2)	839.8 (639.1-1032.3)	884.0 (634.2-1102.4)	899.0 (666.5-1139.3)
High intake of processed meats	IHD	3.7 (2.3-5.1)	3.7 (2.3-5.1)	5 (3.2-6.9)	6.3 (3.8-9.3)	3.5 (2.2-5.1)	3.7 (2-5.4)	2.5 (1.5-3.5)	3.8 (1.9-6)
	DM	6.3 (4.8-8.0)	6.3 (4.8-8.0)	8.3 (6.4-10.4)	8.2 (6.4-10.1)	4.2 (3.2-5.3)	4.7 (3.6-5.8)	3.2 (2.5-4)	4.4 (3.3-5.7)
High intake of unprocessed meats	DM	64.7 (40.0-90.2)	72.5 (43.2-104.9)	46.4 (29.6-63.4)	48.9 (30.4-68)	32.3 (19.8-45.9)	36.6 (21.8-53.2)	33 (19.4-46.4)	31.8 (20.3-43.9)
High intake of sodium	HSTK	961.1 (725.9-1215.7)	1568.2 (1193.0-1971.2)	1029.2 (687.1-1434.6)	913.7 (608.6-1263.0)	460.8 (310.5-629.2)	582.5 (425.9-768.1)	582.3 (404.0-783.7)	705.2 (521.1-904.5)
	ISTK	460.4 (349.9-574.5)	1228.6 (932.8-1527.7)	1205.3 (818.3-1614.2)	1266.2 (847.7-1752.3)	430.9 (224.1-694.6)	524.0 (352.2-721.7)	621.3 (422.4-854.2)	728.4 (522.3-945.4)
	TSTK	1421.5 (1149.4-1719.5)	2796.8 (2333.1-3297.4)	2234.4 (1696.3-2860.3)	2179.9 (1677.2-2772.6)	891.7 (643.1-1194.6)	1106.5 (866.8-1355.1)	1203.6 (947.4-1482.5)	1433.6 (1153.2-1717.8)
	AA	19.5 (15.1-24.3)	46.9 (36.8-57.7)	48.6 (35.1-63.5)	49.6 (35.9-64.5)	23.2 (14.6-32.2)	29.0 (21.1-37.7)	34.7 (24.6-45)	45.1 (34.1-57.0)
	HHD	169.1 (130.4-211.3)	883.9 (673.4-1080.7)	778.1 (539.9-1026.3)	954.3 (625.7-1255.6)	207.0 (60.7-383.7)	274 (158.4-399.1)	382.9 (247.3-520.1)	486.8 (347.6-642.6)
	RHD	3.3 (2.4-4.3)	10.5 (7.2-14.1)	14.6 (9.7-20.3)	13.8 (9.2-19.0)	6.9 (4.6-9.6)	8.4 (6.2-10.9)	7.6 (5.0-10.5)	10.5 (6.9-14.1)
	IHD	428.1 (314.9-553.9)	1119.4 (795.4-1454.6)	1320.6 (758.3-1951.0)	1406.7 (807.7-2131.7)	449.8 (230.8-718.6)	639.1 (407.9-933.3)	841.0 (542.3-1219.7)	1027.3 (662.4-1471.5)
High fasting plasma glucose	TSTK	957.0 (903.4-1012.7)	1089.9 (994.9-1186.5)	865 (773.3-974.8)	887.6 (775.3-999.2)	944.6 (865.0-1026.8)	871.6 (791.3-955.5)	765.8 (689.1-854.8)	851.6 (770.3-929.4)
	IHD	510.0 (472.3-550.0)	789.7 (705.9-873.6)	859.4 (742.8-978.9)	1000.5 (852.8-1156.1)	990.6 (893.7-1086.9)	1042.6 (939.7-1151.3)	975.5 (855.8-1104.2)	1180.7 (1058.1-1313.5)

High total cholesterol	ISTK	233.1 (226.5-239.7)	266.7 (257.8-275.6)	220.9 (212.6-229.9)	205.7 (195.9-215.2)	175.5 (169.8-181.1)	136.2 (131.9-140.6)	121.7 (117.5-125.8)	116.1 (112.5-119.8)
	IHD	961.5 (922.8-996.2)	1558.1 (1490.6-1628.9)	1965.6 (1837.8-2096.1)	2203.3 (2042.8-2361.7)	1911.7 (1810.8-2011.9)	1863.2 (1763.1-1962.9)	1984.1 (1833.3-2124.1)	2023.6 (1915.1-2129.7)
High systolic blood pressure	HSTK	3323.8 (3248.8-3396.6)	3214.1 (3097.5-3330.7)	2281.4 (2165.9-2393.4)	1528.7 (1417.4-1644.9)	1410.3 (1340.4-1479.9)	1691.0 (1626.7-1754.5)	1797.7 (1723.4-1867.5)	1464.8 (1392.6-1537.6)
	ISTK	1896.7 (1816.9-1959.8)	2864 (2709.7-3011.9)	3088.1 (2874.0-3305.5)	2461.2 (2201.3-2715.2)	2087.3 (1933.5-2229.0)	2382.8 (2249.1-2500.0)	2320.3 (2187.9-2460.7)	1959.6 (1818.0-2104.1)
	TSTK	5220.5 (5119.1-5319.8)	6078.1 (5896.7-6263.3)	5369.5 (5124.4-5596.3)	3989.9 (3686.1-4264.7)	3497.6 (3328.0-3661.3)	4073.9 (3924.7-4213.1)	4118.0 (3966.4-4277.1)	3424.4 (3258.2-3591)
	IHD	1825.3 (1757.8-1892.1)	2764.5 (2630.6-2907.3)	3278.7 (3038.5-3496.5)	2771.0 (2467.3-3089.2)	2245.3 (2090.1-2396.7)	2967.2 (2813.1-3128.3)	3157.1 (2993.5-3344.9)	2825.8 (2634.1-3011.8)
	HHD	593.2 (579.2-605.4)	2037.5 (1965.6-2106.6)	1660.9 (1561.9-1747.4)	1653.4 (1512.9-1797.2)	1235.0 (1156.0-1307.3)	1302.5 (1249.9-1353.0)	1352.0 (1289.8-1417.3)	1374.0 (1286.2-1456.7)
	RHD	12.1 (11.7-12.5)	26.8 (25.4-28.4)	36.0 (34.1-38.0)	26.7 (24.5-28.9)	22.4 (21.1-23.8)	26.8 (25.5-28.0)	28.8 (27.4-30.3)	24.4 (23.1-25.8)
	AA	83.3 (80.7-85.7)	108.5 (103.2-112.9)	129.4 (121.2-137.6)	101.5 (92.3-110.6)	94.6 (89.0-100.4)	112.5 (107.1-117.6)	131.7 (124.9-138.4)	118.7 (111.3-126.5)
High body mass index	HSTK	1114.6 (1075.8-1154.3)	1215.6 (1173.7-1261.8)	980.1 (937.6-1017.6)	875.2 (832.0-918.4)	775.6 (751.0-802.3)	728.5 (704.1-752.5)	769.7 (740.3-801.1)	702.1 (676.6-727.6)
	ISTK	355.9 (336.4-375.0)	566.8 (526.2-605.2)	672.6 (616.7-729.7)	743.4 (668.5-815.5)	604.6 (566.1-645.9)	534.4 (497.9-570.2)	545.9 (501.2-590.5)	484.9 (448.8-522.3)
	TSTK	1470.5 (1430.2-1511.3)	1782.4 (1721.0-1837.3)	1652.7 (1582.8-1724.9)	1618.5 (1527.1-1698.4)	1380.2 (1333.9-1429.9)	1262.9 (1219.5-1304.0)	1315.6 (1259.9-1372.4)	1187.1 (1142.4-1230.1)
	IHD	438.9 (413.8-464.3)	749.0 (693.9-801.3)	995.4 (901.2-1092.9)	1215.8 (1092.0-1337.0)	940.8 (874.7-1011.2)	980.7 (910.3-1051.3)	1111.9 (1015.1-1212.5)	1034.3 (952.0-1121.1)
	DM	1574.2 (1496-1656.2)	2062.7 (1955.3-2173.4)	2096.3 (1966.6-2246.1)	2211.4 (2043.2-2375.4)	1857.8 (1755.4-1964.4)	1801.7 (1704.4-1904.4)	2015.8 (1881.8-2147.3)	1896.0 (1785.2-2007.3)
	HHD	159.0 (146.1-173.3)	570.9 (509.5-638.0)	532.7 (470.3-599.9)	749.2 (656.9-840.9)	531.0 (484.4-582.2)	484.1 (441.7-523.7)	560.4 (508.9-612.8)	537.7 (485.1-588.5)

The values were expressed as death number for each risk factors (95% Uncertainty Intervals). HSTK, hemorrhagic stroke; ISTK, ischemic stroke; TSTK, total strokes; IHD, ischemic heart disease; DM, diabetes; AA, aortic aneurysm and dissection; HHD, hypertensive heart disease; RHD, rheumatic heart disease.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.