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Original Article

Impact of Dietary Risks on Noncommunicable Disease Mortality between 2000 and 2021: Which Noncommunicable Disease Is Most Affected by Dietary Risks?

Elif Nur Yildirim-Ozturk [1], Mustafa Ozturk [2]

1. *Konya Provincial Health Directorate, Public Health Service, Selcuklu, Konya, Türkiye*
2. *Konya Meram State Hospital, Emergency Service, Meram, Konya, Türkiye*

***Corresponding Author:** Email: elifnyildirim@hotmail.com

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Abstract

Background: This study aimed to analyze trends in the population attributable fraction (PAF) for mortality attributable to dietary risks over a 22-year period between 2000 and 2021 and to determine which type of dietary risk has a significant effect on mortality from which NCDs.

Methods: In this descriptive and ecological study, data were obtained from the Global Burden of Disease Study, 2021. Age-standardized and sex-specific PAFs for mortality attributable to dietary risks and PAFs for mortality attributable to selected and specific dietary risks were calculated for six noncommunicable diseases worldwide for the 22-year period. The trend of PAFs over time was assessed by joinpoint regression analysis.

Results: The two diseases with the highest mean PAF for mortality attributable to dietary risks were hypertensive heart disease followed by ischemic heart disease (0.63±0.01 and 0.45±0.01, respectively). The mean PAF for mortality attributable to dietary risks differed between sexes for four diseases. All six diseases had dietary risk-attributable mortality starting at a young age. Over a 22-year period, PAF for mortality attributable to dietary risks followed a significant decreasing trend for all six diseases. When the PAFs for mortality attributable to selected and specific dietary risks were examined, the majority showed a decreasing trend.

Conclusion: It is essential to clarify the relationship between NCDs and dietary risks. This is because the human body is exposed to nutritional and dietary risks every day, both as individuals and as a community.

Keywords: Noncommunicable disease; Chronic disease; Diet; Risk factors; Mortality

Introduction

Noncommunicable diseases (NCDs) are a group of conditions that are non-infectious and not transmitted from person to person. Characterized by multifactorial causality and a long latent period, this group includes many metabolic and degenerative diseases (1). Each year, 41 million people die from NCDs. NCD mortality accounts for 74% of all deaths (2).

NCDs can affect people of all ages and from all countries. The risk factors for NCDs are many and varied. In addition to the modifiable behavioral risks of unhealthy diet, physical inactivity, tobacco smoke, and harmful use of alcohol, there

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are metabolic and environmental risks. Rapid unplanned urbanization, globalization of unhealthy lifestyles, and population aging are also factors exacerbating the current situation (2,3).

Among modifiable behavioral risk factors, an unhealthy diet accounts for a significant proportion of DALYs and mortality from NCDs. In 2015, unhealthy diet was responsible for 1.5 billion DALYs and 39.2 million deaths from all NCDs, rising to 1.7 billion DALYs and 43.7 million deaths in 2021 (4). The risks associated with an unhealthy diet are numerous and varied. High intakes of sodium, sugar, and fat in the diet can cause problems, as can low intakes of fruits and vegetables (5,6). The importance of a balanced diet is also evident in the context of NCDs (7). The Mediterranean diet has been found to be beneficial in addressing dietary risks for NCDs and is widely recommended (8,9). In a study evaluating two prospective cohorts, red meat consumption was associated with increased total, cardiovascular and cancer mortality (10). A review of 16 meta-analyses found that healthy dietary patterns may reduce the risk of diabetes mellitus type 2, cardiovascular disease, and premature death (11).

The existing literature was dominated by studies that analyze one or a limited number of dietary risk factors in relation to one or a few NCDs. This pattern is also evident in research utilizing data from the Global Burden of Disease (GBD) study. Furthermore, many of these studies have a limited geographical scope, focusing on specific countries or regions (12-15). Understanding which NCDs are affected by which dietary risks, both generally and globally, may be important for public health programmes and individual NCD control efforts.

This study aimed to examine global trends in mortality attributable to dietary risks across major NCDs between 2000 and 2021, using population attributable fraction (PAF) estimates, and to determine which specific types of dietary risk have a significant effect on mortality from which NCDs.

Materials and Methods

Study Design and Setting

This descriptive and ecological study was conducted and reported between 1 Sep 2024 and 1 Feb 2025. The study was reported by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline (16).

Data were from the Global Burden of Disease Study, 2021 (GBD, 2021), using the 'Cause of death and injury' and 'Risk factor' tabs (4). GBD, 2021 is a large and up-to-date resource of epidemiologic data and is coordinated by the Institute for Health Metrics and Evaluation at the University of Washington. GBD, 2021 consists of data collected and categorized under the various headings (17). Details of the methodology used in the GBD study can be found elsewhere (18,19).

The present study obtained age-standardized total mortality rates and dietary risk-attributable mortality rates per 100,000 population for both sexes, covering neoplasms, ischemic heart disease, hypertensive heart disease, stroke, diabetes mellitus type 2, and chronic kidney disease over the 22-year period from 2000 to 2021. Neoplasms encompassed cancers of the esophagus, stomach, colon and rectum, trachea, bronchus and lung, breast, and prostate. Stroke comprised ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage. Dietary risks included diet low in fruits, diet low in vegetables, diet low in whole grains, diet low in nuts and seeds, diet low in milk, diet low in calcium, diet high in red meat, diet high in processed meat, diet high in sugar-sweetened beverages, diet low in fiber, diet low in seafood omega-3 fatty acids, diet low in omega-6 polyunsaturated fatty acids, diet high in trans fatty acids, and diet high in sodium.

PAF for mortality attributable to dietary risks was calculated for the disease(s) of interest by proportioning age-standardized dietary risk-attributable mortality rate for both sexes per 100,000 population to age-standardized total mortality rate for both sexes per 100,000 population for the disease. After identifying the disease(s), sex, and age groups with the highest PAF values, the second step of the analysis was initiated. In the second step, for each dietary risk subcategory, both the age-standardized mortality rate attributable to selected and specific dietary risks (per 100,000 population, both sexes) and the overall age-standardized dietary risk-attributable mortality rate (per 100,000 population, both sexes) were used to calculate the PAF for mortality attributable to each selected and specific dietary risk.

PAF, calculated as the ratio of morbidity or mortality attributable to a risk factor to the total morbidity or mortality, is an epidemiological indicator that measures the contribution of a particular risk factor to morbidity or mortality in a population. Among the various formulas available for calculating PAF, the one used in this study is presented in Fig. 1. This measure is valuable for guiding public health interventions, as it indicates the potential reduction in morbidity or mortality that could be achieved by eliminating a given risk factor (20).

$$\text{PAF} = \frac{\text{Morbidity or mortality attributable to the risk factor}}{\text{Total morbidity or mortality}}$$

Fig. 1: The PAF Formulation

Study Permissions

The data used in this study were obtained from the GBD, 2021 study, which is publicly available to researchers and the general public. As the study involved no direct contact with human subjects, no official or ethical approval was required.

Statistical Analysis

Data analysis was conducted using Jamovi ver. 2.3.28 and the Joinpoint Regression Program. For each of the six diseases, the 22-year mean and standard deviation of the calculated PAFs were computed. Temporal trends in PAFs between 2000 and 2021 were assessed using joinpoint regression analysis. As required for trend analysis, standard error values for each ratio were calculated and recorded in an Excel spreadsheet along with the other variables. A *P*-value of <0.05 was considered statistically significant.

Results

Mortality Attributable to Dietary Risks for Six NCDs

The 22-year mean of age-standardized PAF for mortality attributable to dietary risks was calculated for both sexes for the six diseases included in the study. Hypertensive heart disease had the highest mean PAF, followed by ischemic heart disease (0.63 ± 0.01 and 0.45 ± 0.01, respectively).

A similar ranking was observed when sex- and age-specific PAF means were examined. For hypertensive heart disease, ischemic heart disease, and stroke, men had a higher mean PAF for mortality attributable to dietary risks compared to women. In contrast, for neoplasms, women had a higher PAF.

For neoplasms, PAF for mortality attributable to dietary risks was higher in early life, specifically in the 25-29, 30-34, and 35-39 age groups, and showed another increase by age 65. For ischemic heart disease, hypertensive heart disease, and diabetes mellitus type 2, PAF values tended to increase earlier in life, then gradually declined but remained elevated in middle and older ages. For stroke, the increases and decreases did not follow a trend, and the highest value was observed in the 60-64 age group. For chronic kidney disease, there was an increase with age, peaking in the 80+ age group (Table 1).

When the trend of PAF for mortality attributable to dietary risks between 2000 and 2021 was analyzed, a significant annual decrease was observed across all six diseases. Ischemic heart disease and diabetes mellitus type 2 showed the highest annual decrease. PAFs showed joints in different years with varying trends, with the most significant decrease in neoplasms between 2000-2006 and hypertensive heart disease between 2000-2002 (Table 2 and Fig. 2).

Table 1: Means and Standard Deviations of PAFs for Mortality Attributable to Dietary Risks for Six NCDs

Variable	Neoplasms+	Ischemic heart disease	Hypertensive heart disease	Stroke	Diabetes mellitus type 2	Chronic kidney disease
Age standardized-both sex	0.12±0.00	0.45±0.01	0.63±0.01	0.15±0.00	0.25±0.01	0.21±0.00
Age standardized-female spesific	0.15±0.00	0.43±0.01	0.60±0.01	0.13±0.00	0.24±0.01	0.21±0.00
Age standardized-male spesific	0.10±0.00	0.46±0.01	0.68±0.02	0.17±0.00	0.25±0.01	0.21±0.00
Both sex-25-29 yr spesific	0.17±0.00	0.68±0.01	0.55±0.04	0.19±0.01	0.29±0.01	0.12±0.01
Both sex-30-34 yr spesific	0.16±0.00	0.68±0.01	0.80±0.02	0.20±0.01	0.28±0.01	0.12±0.01
Both sex-35-39 yr spesific	0.15±0.00	0.68±0.01	0.87±0.01	0.20±0.01	0.27±0.00	0.13±0.01
Both sex-40-44 yr spesific	0.14±0.00	0.66±0.01	0.87±0.01	0.20±0.01	0.26±0.00	0.15±0.00
Both sex-45-49 yr spesific	0.13±0.00	0.65±0.02	0.80±0.01	0.22±0.01	0.26±0.00	0.17±0.00
Both sex-50-54 yr spesific	0.13±0.00	0.62±0.02	0.73±0.02	0.21±0.01	0.25±0.00	0.18±0.00
Both sex-55-59 yr spesific	0.13±0.00	0.57±0.01	0.70±0.02	0.22±0.01	0.24±0.00	0.21±0.00
Both sex-60-64 yr spesific	0.12±0.00	0.53±0.02	0.65±0.02	0.22±0.01	0.24±0.00	0.22±0.00
Both sex-65-69 yr spesific	0.12±0.00	0.48±0.02	0.65±0.02	0.21±0.00	0.24±0.00	0.23±0.00
Both sex-70-74 yr spesific	0.12±0.00	0.44±0.02	0.63±0.01	0.18±0.00	0.24±0.01	0.23±0.00
Both sex-75-79 yr spesific	0.13±0.01	0.41±0.01	0.58±0.01	0.14±0.00	0.24±0.01	0.23±0.01
Both sex-80+ yr spesific	0.16±0.01	0.38±0.01	0.62±0.01	0.10±0.00	0.26±0.01	0.23±0.01

+Prostate cancer data were not included in age-specific calculations due to inconsistent data.

Table 2: Joinpoint Analyzes of PAFs for Mortality Attributable to Dietary Risks for Six NCDs

Variable	Trend 0		Trend 1		Trend 2		Trend 3		Joint year(s)
	Years	APC	Years	APC	Years	APC	Years	APC	
Neoplasms	2000-2021	-0.3*	2000-2006	-0.8*	2006-2012	-0.4*	2012-2021	-0.0	2006, 2012
Ischemic heart disease	2000-2021	-0.4*	2000-2004	-0.3*	2004-2010	-0.6*	2010-2021	-0.3*	2004, 2010
Hypertensive heart disease	2000-2021	-0.3*	2000-2002	-0.7*	2002-2010	-0.5*	2010-2021	-0.1*	2002, 2010
Stroke	2000-2021	-0.4*	2000-2016	-0.5*	2016-2021	0.2			2016
Diabetes mellitus type 2	2000-2021	-0.4*	2000-2006	-0.4*	2006-2013	-0.6*	2013-2021	-0.1*	2006, 2013
Chronic kidney disease	2000-2021	-0.2*	2000-2018	-0.2*	2018-2021	-0.0			2018

APC: Annual Percentage Change
*Indicates statistical significance ($P<0.05$)

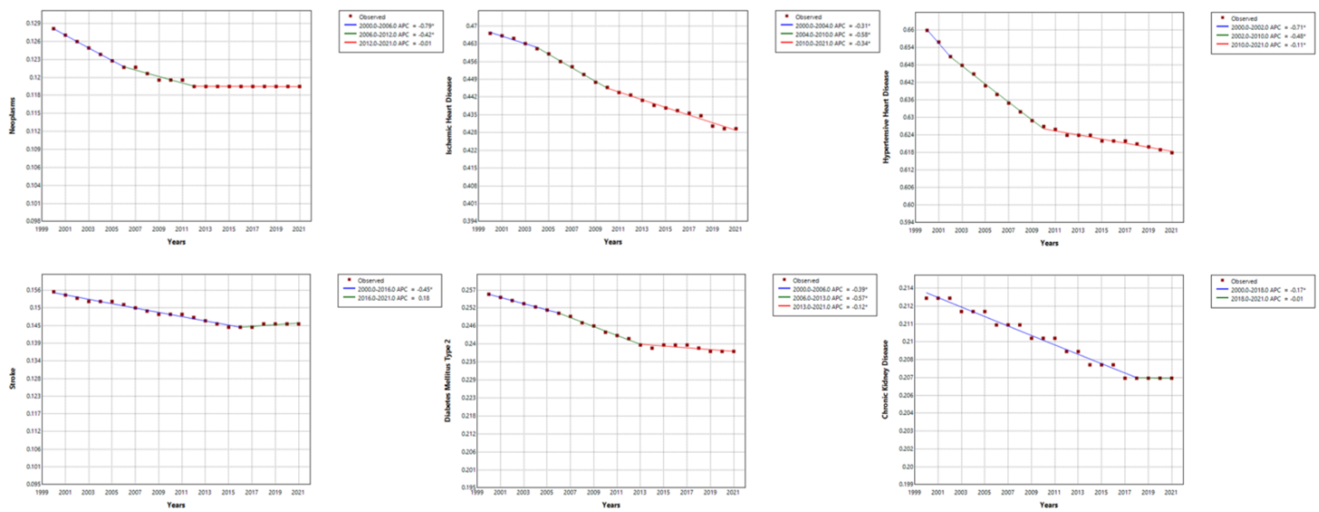

Fig. 2: Joinpoint Analyzes of PAFs for Mortality Attributable to Dietary Risks for Six NCDs

Mortality Attributable to Selected and Specific Dietary Risks for Six NCDs

The selected and specific dietary risks for each disease were calculated for 22 years and mean±standard deviation are presented in Table 3. Ischemic heart disease was affected by all 15 dietary risks, while hypertensive heart disease was affected by a total of three dietary risks. Low fruit and vegetable consumption were common dietary risk factors associated with all six diseases examined in the study.

The trend was analyzed by joinpoint regression analysis for the 22-year PAF calculated for selected and specific dietary risks for each disease in the study. PAF attributable to low in fruits showed no significant APC for diabetes mellitus type 2, but exhibited a significant decreasing trend for the other five diseases. PAF attributable to low in vegetables showed a significant decrease in APC for all six diseases. The PAF trends for low in legumes, low in nuts and seeds, low in omega 3, and high in trans fatty acids, which are dietary risks for ischemic heart disease only, showed a significant decreasing trend. The annual percentage change (APC) values and their statistical significance are presented in Table 4.

Table 3: Means and Standard Deviations of PAFs for Mortality Attributable to Selected and Specific Dietary Risks for Six NCDs

Variable	Neoplasms	Ischemic heart disease	Hypertensive heart disease	Stroke	Diabetes mellitus type 2	Chronic kidney disease
Diet low in fruits	0.01±0.00 (tracheal, bronchus and lung ca)	0.07±0.00	0.37±0.01	0.05±0.00	0.05±0.00	0.09±0.00
Diet low in vegetables	0.01±0.00 (esophageal ca)	0.03±0.00	0.29±0.012	0.01±0.00	0.01±0.00	0.07±0.00
Diet low in legumes		0.05±0.00				
Diet low in whole grains	0.03±0.00 (colon and rectum ca)	0.13±0.00		0.01±0.00	0.07±0.00	0.02±0.00
Diet low in nuts and seeds		0.08±0.00				
Diet low in milk	0.02±0.00 (colon and rectum ca, prostate ca)					

Table 3: Continued…

Diet low in calcium	0.02±0.00 (colon and rectum ca, prostate ca)					
Diet high in red meat	0.04±0.00 (colon and rectum ca, breast ca)	0.02±0.00		&	0.05±0.00	0.01±0.00
Diet high in processed meat	0.01±0.00 (colon and rectum ca)	0.01±0.00		0.00±0.00	0.08±0.00	0.01±0.00
Diet high in sugar-sweetened beverages		0.00±0.00		0.00±0.00	0.03±0.00	0.00±0.00
Diet low in fiber	0.00±0.00 (colon and rectum ca)	0.06±0.01		0.02±0.00	0.01±0.00	
Diet low in seafood omega-3 fatty acids		0.08±0.01				
Diet low in omega-6 polyunsaturated fatty acids		0.08±0.00		0.00±0.00		
Diet high in trans fatty acids		0.02±0.00				
Diet high in sodium	0.02±0.00 (stomach ca)	0.07±0.00	0.23±0.01	0.10±0.00		0.05±0.00

& The data provided for stroke were inconsistent and therefore not analyzed

Table 4: Trend Analysis and Annual Percentage Changes of PAFs for Mortality Attributable to Selected and Specific Dietary Risks for Six NCDs

APC	Neoplasms	Ischemic heart disease	Hypertensive heart disease	Stroke	Diabetes mellitus type 2	Chronic kidney disease
Diet low in fruits	-0.5* (Tracheal, bronchus and lung ca)	-0.4*	-0.5*	-0.5*	-0.1	-0.4*
Diet low in vegetables	-2.5* (esophageal ca)	-0. 7*	-0.8*	-0.7*	-2.1*	-0.3*
Diet low in legumes		-0.9*				
Diet low in whole grains	0.4* (colon and rectum ca)	-0.4*		-0.4*	-0.5*	-0.4*
Diet low in nuts and seeds		-0.8*				
Diet low in milk	0.8* (colon and rectum ca, prostate ca)					
Diet low in calcium	0.0 (colon and rectum ca, prostate ca)					
Diet high in red meat	0.4* (colon and rectum ca, breast ca)	-0. 6*		&	-0.5*	0.1
Diet high in processed meat	-0.3* (colon and rectum ca)	-4.8*		-3.1*	-0.8*	0.2
Diet high in sugar-sweetened beverages		0.0		0.0	0.4*	0.0
Diet low in fiber	-2.3* (colon and rectum ca)	-1.4*		-1.4*	-1.1*	
Diet low in seafood omega-3 fatty acids		-1.3*				
Diet low in omega-6 poly-unsaturated fatty acids		0.1*		-0.0		
Diet high in trans fatty acids		-3.5*				
Diet high in sodium	-1.3* (stomach ca)	0.4*	-0.3*	-0.1*		-0.2*

APC: Annual Percentage Change
&The data provided for stroke were inconsistent and therefore not analyzed.
*Indicates statistical significance (P<0.05)

Discussion

In this study, the disease with the highest 22-year mean PAF for mortality attributable to dietary risks was hypertensive heart disease followed by ischemic heart disease. Hypertensive heart disease was influenced by three dietary risks according to the data in this study, with low in fruits leading the way, followed by low in vegetables. High sodium levels, although an important factor, ranked last. This may be explained by the antioxidants and fiber contained in fruits and vegetables, as well as the hormonal mechanisms triggered by sodium. Current evidence also emphasises the link between high fruit and vegetable consumption and a reduced risk of hypertension (21). The relationship between sodium or salt intake and hypertension has been widely highlighted in the literature (22). It is also widely recognized by the general public as a dietary risk for hypertension. Since the 1990s, the Dietary Approaches to Stop Hypertension (DASH), characterized by high consumption of fruits and vegetables, lean meats, dairy products, and reduced sodium intake, has also become prominent in hypertension prevention (23).

The mean PAF values for mortality attributable to dietary risks calculated in this study differed by sex for four diseases. Accordingly, mortality attributable to dietary risks was predominantly male for hypertensive heart disease, ischemic heart disease, and stroke and female for neoplasms. Sex differences may be accounted for by biological, behavioral and sociocultural factors. Developmental and hormonal differences between the male and female sexes, as well as behavioral patterns related to gender roles, are possible reasons for the difference (24,25). Women are also known to be more sensitive to chemicals, pollutants, and toxins (26). Studies from various countries have generally shown that men were at greater risk in terms of NCD mortality and risk factors (27-33). Conversely, although women generally appeared to have a lower risk profile than men with regard to dietary and physical activity risk factors, some findings also suggested that they may be at a higher risk of certain diseases, such as diabetes mellitus, heart disease and cancer (30-32).

For all six diseases in the study, mortality related to dietary risk began at a young age, with higher PAFs at younger ages for hypertensive heart disease, ischemic heart disease, diabetes mellitus type 2, and neoplasms. While PAFs calculated for stroke were similar across all age groups, PAFs for chronic kidney disease increased with age. Contrary to expectations, mortality attributable to dietary risk did not increase with age, except in the case of chronic kidney disease. This may be related to a lack of adequate nutritional awareness and more unhealthy dietary choices at younger ages. Alternatively, the various NCD risk factors added to the list with increasing age make diet-related mortality appear to decrease in relative terms. Although the association between increasing age and NCDs has been highlighted, 17 million of the 41 million NCD deaths occur before the age of 70, and NCDs can affect people of all ages (2). The relationships between dietary risks as NCD risk factors and age, and between mortality related to dietary risks and age have been examined in various studies. Still, the findings have sometimes been found to be inconsistent and confusing (27,28,32,34).

Over a 22-year period, the PAFs for mortality attributable to dietary risks showed a significant decreasing trend for all six diseases. When the PAFs for mortality attributable to selected and specific dietary risks for each disease are analyzed, the majority of them show a decreasing trend. The significant decreasing trend can be interpreted as a positive development that has occurred under the influence of various issues such as public awareness, the content of food produced and presented to the public, and public health policies. However, a significant increase in APC was found in PAFs attributable to low in whole grains for colon and rectum ca, low in milk for colon and rectum ca and prostate ca, high in red meat for colon and rectum ca and breast ca, high in sugar-sweetened beverages for diabetes mellitus type 2, low in omega 6 and high in sodium for ischemic heart disease. This finding may indicate the need to focus on PAFs for mortality attributable to selected and specific dietary risks for diseases with an increasing trend or no significant change. However, before making these interpretations and inferences, it should be properly assessed whether these decreases and increases in trends are real or relative changes influenced by decreases/increases in other factors. A study using data from the GBD study 2019 found an increase in the number of deaths attributable to dietary risk and a decrease in mortality rates over the years (27). A study evaluating data from the GBD study 2015 for sub-Saharan Africa found an increase in NCD mortality rates attributable to dietary risk (35).

Study Highlights and Limitations

The study was conducted worldwide using up-to-date and comprehensive data. The PAFs for mortality attributable to dietary risk were calculated and the trend was determined over a 22-year period. The PAFs were presented for age-standardized, sex-specific, age-group-specific, selected and specific dietary risks. Since the NCDs most affected by dietary risks have been identified, this inference may shed light on which disease(s) to prioritize in public health programs to be developed on nutrition and diet. These are the advantages of this study.

The six NCDs included in the study were diseases that are already associated with dietary risks. Because the study was based on population-based data rather than individual-based data, it was important to make interpretations on a population basis to overcome the ecological fallacy. Since this study evaluated global data, there may be different results on a country basis. These are the limitations of this study.

Conclusion

The 22-year means of age-standardized and both sexes PAF for mortality attributable to dietary risks were highest for hypertensive heart disease and ischemic heart disease. Male age-standardized PAF means were higher for three diseases. For five diseases, younger age groups had higher PAFs for mortality attributable to dietary risks. Ischemic heart disease was affected by all 15 dietary risks, whereas hypertensive heart disease was affected by a total of three dietary risks. Low in fruits and low in vegetables were dietary risks for all six diseases covered. The PAFs for mortality attributable to dietary risks for the six diseases showed a significant decrease in the 22-year trend. Ischemic heart disease and diabetes mellitus type 2 showed the highest annual declines. When the trend of the PAFs for mortality attributable to selected and specific dietary risks for each disease was analyzed, it was found that although there were mostly decreases, there were also trends of increase or no change.

It is essential to have a clear understanding of the relationship between NCDs and dietary risks. This is because individual human bodies and groups of people are fed every day, and nutrition and dietary risks are factors to which people are exposed every day. In addition to examining the situation, policies and public health programs to be developed to reduce mortality attributable to dietary risk should be age-standardized, sex-specific, age-group-specific, disease-specific, and dietary risk-specific, and should cover the entire population. Various methods such as legislation, taxation, labelling, and education, proven to be effective, can restrict communities' access to unhealthy diets. There is also a need for local and national as well as international and global actions that recognize unhealthy diets as a preventable and real risk factor for NCDs.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declared no conflict of interest in this study.

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