Original paper

Occurrence of risk factors for non-communicable diseases in Poland and the Podlaskie Voivodeship: trend analysis of mortality rates, 2000–2021

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Key words: risk factors, trend analysis, mortality rate, non-communicable diseases, health inequalities.

Abstract

Introduction: Effective health policy requires the systematic monitoring of population health needs, including identification and evaluation of risk factors. In Poland, the tool used for this purpose is the Maps of Health Needs which are regularly updated with new epidemiological data and serve as a basis for planning preventive actions.
Aim of the research: This study aimed to assess and compare health risk factors in Poland and the Podlaskie Voivodeship, with a focus on emerging regional and sex-specific inequalities.
Material and methods: Analyses were based on data from the Maps of Health Needs. Trends in mortality associated with metabolic, behavioral, and combined environmental and occupational risk factors were examined in Poland and the Podlaskie Voivodeship between 2000 and 2021, stratified by sex. Annual percent changes (APC) with 95% confidence intervals were calculated, and $p < 0.05$ was used to determine statistical significance. Joinpoint regression models were applied using the Joinpoint Regression Program (Version 5.4.0 – April 2023).
Results: Significant differences were observed between sexes and between Poland and the Podlaskie Voivodeship, where mortality rates were lower. Among men, nationwide declines in mortality rates associated with all categories of risk factors were observed, with the largest decrease for environmental factors (–11.81%), whereas in the Podlaskie Voivodeship mortality rates linked to metabolic factors increased (+3.04%). Among women, mortality rates associated with metabolic (+14.63% vs. +5.70%) and behavioral factors (+16.92% vs. +6.03%) showed a marked upward trend.
Conclusions: Of particular concern are the rising mortality rates related to high BMI and elevated fasting plasma glucose. Rising mortality rates related to high BMI and elevated fasting plasma glucose are of particular concern and highlight the urgent need for targeted, population-level preventive strategies.

Introduction

Conducting effective national health policy and planning actions aimed at maintaining and improving population health requires continuous monitoring of the population's health needs. Preventive health programs are crucial from a public health perspective, as they are considered key determinants of population health. Preventive actions should be shaped according to the actual needs of society. An important element in this process is understanding risk factors and assessing their impact on health status [1]. Understanding these factors enables the reduction or elimination of exposure, leading to decreased morbidity and a longer, higher quality of life. In Poland, Health Needs Maps, implemented by the Department of Analysis and Strategy of the Ministry of Health, constitute a tool for planning health protection. They include epidemiological, demographic, and healthcare services data, which together facilitate the estimation of future health needs for the country and individual voivodeships [2].

Negative health status indicators, such as morbidity, incidence, mortality, and lethality, are most commonly used for population health status analysis. In the Maps of Health Needs addressing risk factors and prevention, two key indicators were employed: mortality rate and disability-adjusted life years (DALYs) [2, 3].

The data developed within the Maps of Health Needs originate from the Global Burden of Disease (GBD) study conducted by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington in Seattle. The GBD defines a risk factor as: an attribute, behavior, exposure, or other characteristic causally associated with an increased (or decreased) probability of disease or injury. When the probability decreases, the risk factor is considered protective. Risk factors in the GBD study are categorized into four hierarchical levels. Level 1 encompasses major groups

of risk factors: metabolic, behavioral and environmental and occupational risks. Under these Level 1 groups, Level 2 risk factors are specified. For Level 2 risk factors, which represent broader concepts, further Level 3 and Level 4 risk factors are delineated. A detailed classification of risk factors is presented in Table 1. The Health Needs Maps display mortality rates attributable to risk factors from Level 1 and Level 2 [2, 4].

Behavioral factors are related to human activity. These are modifiable elements over which we have the greatest influence. They include areas such as: nutrition, physical activity and substance use. This group of conditions may result from unawareness of the negative impact of presented attitudes on health or from long-term habits that are difficult to change [5]. The World Health Organization (WHO) closely links behavioral factors with living conditions, having a beneficial or harmful impact on people's health [6].

Metabolic risk factors are all physical and chemical abnormalities of the body, such as too high body mass index (BMI), cholesterol, elevated blood pressure, or glucose levels, also low bone density or organ failure. Metabolic syndrome, which includes a combination of several of these factors, poses a significant health threat, leading to the development of chronic diseases such as type 2 diabetes, cardiovascular diseases, or atherosclerosis. Early detection and appropriate intervention, such as lifestyle changes, can significantly reduce the risk of these conditions [7].

Environmental and occupational factors are a group encompassing threats from the living and working environment. Environmental or physical factors are understood as natural factors including water quality, soil, occurrence of green areas, forests, parks, as well as anthropogenic factors such as safety in the place of residence, work, and road traffic. Employment stability significantly affects health status, as unemployment or lack of job security can predispose to mental disorders, depression, and anxiety states. This is also a situation causing chronic stress, which has a negative impact on health, especially in terms of cardiovascular diseases [8, 9].

Occupational factors include negative aspects resulting from the type of work performed. They also significantly affect the health status of the population. It is worth highlighting factors resulting from industrial activity such as exhaust emissions, toxic fumes, harmful drugs, etc. but also issues related to work safety and ergonomics e.g. incorrect body position or night shift work, which significantly disrupts the body's homeostasis and leads to the development of diseases including cardiovascular diseases [3, 10].

Aim of the research

The aim of the study was to analyze temporal trends in mortality rates associated with behavioral, metabolic, and environmental and occupational risk factors in Poland and the Podlaskie Voivodeship between 2000 and 2021, with particular emphasis on sex differences. Additionally, the study sought to identify and assess health risk inequalities in Poland and in the Podlaskie Voivodeship.

Material and methods

For the assessment of the occurrence of risk factors for non-communicable diseases, data the Maps of Health Needs, developed and published within the framework of the Project called Health Needs Maps – Database of Systemic and Implementation Analyses, implemented by the Department of Analyses and Strategies of the Ministry of Health, were utilized. The data used in the analyses originated from the category *Risk Factors and Prevention* and concerned deaths from all causes.

For the purpose of own analyses, data regarding age-standardized mortality rates per 100,000 inhabitants were extracted for each year, adopting the world population distribution as the standard [11]. These data encompassed deaths related to the main groups of risk factors: metabolic, behavioral, and environmental and occupational, as well as selected factors within each of these groups. Analyses were conducted separately for the total population of Poland and the Podlaskie Voivodeship, stratified by sex. The data were obtained from publicly available reports and compiled in a manner enabling analyses using the Joinpoint software [12].

The percentage contribution of risk factor groups and individual risk factors to the mortality rate was calculated, as well as the percentage change between 2000 and 2021 for females and males, according to the following formula: Change = [(mortality rate$_{2021}$ – mortality rate$_{2000}$)/(mortality rate$_{2000}$)] × 100%.

Temporal trends in mortality rates associated with individual risk factors and their main groups were analyzed separately for females and males in the years 2000–2021 in Poland and in the Podlaskie Voivodeship.

Changes in rate values were estimated using joinpoint models. The joinpoint regression model is based on fitting a segmented linear model to time-series data, where the segments are connected at joinpoints. These points indicate statistically significant changes in trend dynamics. The method allows for precise identification of the moments at which the rate of increase or decrease in the analyzed measure changes, and for each segment, the annual percentage change (APC) is calculated [13].

Statistical analysis

Based on the linear regression model, in which the natural logarithm of the mortality rate was the dependent variable and the calendar year was independent, the annual percent change (APC) of mortality rate values was determined for each trend. The sta-

Table 1. Classification of health risk factors by levels according to the Global Burden of Disease (GBD) methodology

Level 1 risks	Level 2 risks	Level 3 risks	Level 4 risks
Metabolic risk factors	High systolic blood pressure	–	–
	High body mass index (BMI)	–	–
	High fasting plasma glucose	–	–
	High LDL cholesterol	–	–
	Low bone mineral density	–	–
	Kidney dysfunction	–	–
Behavioral risk factors	Tobacco	Smoking Chewing tobacco Second-hand smoke	–
	Dietary risks	Diet low in fruits Diet low in vegetables Diet low in legumes Diet low in whole grains Diet low in nuts and seeds Diet low in milk Diet high in red meat Diet high in processed meat Diet high in sugar-sweetened beverages Diet low in fiber Diet low in calcium Diet low in seafood omega-3 fatty acids Diet low in omega-6 polyun saturated fatty acids Diet high in trans fatty acids Diet high in sodium	–
	High alcohol use	–	–
	Low physical activity	–	–
	Drug use	–	–
	Intimate partner violence	–	–
	Unsafe sex	–	–
	Childhood sexual abuse and bullying	Childhood sexual abuse	–
	Child and maternal malnutrition	Suboptimal breastfeeding	Non-exclusive breastfeeding Discontinued breastfeeding
		Child growth failure	Child underweight Child wasting Child stunting
		Low birth weight and short gestation	Short gestation Low birth weight
		Iron deficiency Vitamin A deficiency Zinc deficiency	–

Table 1. Cont.

Level 1 risks	Level 2 risks	Level 3 risks	Level 4 risks
Environmental and occupational risk factors	Occupational risks	Occupational asthmagens	–
		Occupational particulate matter, gases, and fumes	–
		Occupational injuries	–
		Occupational carcinogens	Occupational exposure to asbestos Occupational exposure to arsenic Occupational exposure to benzene Occupational exposure to beryllium Occupational exposure to cadmium Occupational exposure to chromium Occupational exposure to diesel engine exhaust Occupational exposure to formaldehyde Occupational exposure to nickel Occupational exposure to polycyclic aromatic hydrocarbons Occupational exposure to silica Occupational exposure to sulfuric acid Occupational exposure to trichloroethylene
	Air pollution	Particulate matter pollution	Ambient particulate matter pollution Household air pollution from solid fuels
		Ambient ozone pollution	–
	Non-optimal temperature	High temperature Low temperature	–
	Other environmental risks	Residential radon Lead exposure	–
	Unsafe water, sanitation, and handwashing	Unsafe water source Unsafe sanitation No access to handwashing facility	–

tistical significance of APC was determined by establishing a 95% confidence interval in the analyzed period. The significance level of $p < 0.05$ was adopted as the threshold for statistical significance. Trend analysis and APC calculations were performed using joinpoint models and the Joinpoint Regression Program (Version 5.4.0 – April 16, 2025) [13, 14].

Results

From 2000 to 2021, mortality rates in the Podlaskie Voivodeship remained lower than the corresponding rates for Poland as a whole for both males and females (Table 2).

The main groups of risk factors (Level 1 risks): metabolic, behavioral, and environmental and occupational risks

Table 2 presents the analysis of results for the male population in Poland and the Podlaskie Voivodeship. From 2000 to 2021, mortality rates associated with these main risk factor groups decreased among men

Table 2. Trends in the mortality rate per 100,000 population among males in Poland and the Podlaskie Voivodeship from 2000 to 2021

Variables	Poland								Podlaskie voivodeship								Comparative trends
	Deaths per 100,000 population					Trend			Deaths per 100,000 population					Trend			Parallelism test
	2000	%	2021	%	Change 2000–2021 [%]	Time	APC	95% CI	2000	%	2021	%	Change 2000–2021 [%]	Time	APC	95% CI	
Metabolic risk factors	369.48	34.73	368.56	35.89	–0.25	2000–2016 2016–2021	–0.31* 1.20	–0.5; –0.1 –0.2; 2.6	329.32	34.10	339.32	36.15	+3.04	2000–2021	0.14	–0.1; 0.3	$p = 0.0047$
High blood pressure	242.03	22.75	205.34	19.99	–15.16	2000–2021	–0.99*	–1.2; –0.7	209.59	21.71	188.46	20.08	–10.08	2000–2007 2007–2021	0.70 –1.10*	–0.4; 1.9 –1.5; –0.7	$p = 0.0007$
High BMI	69.78	6.56	88.86	8.65	+27.34	2000–2015 2015–2021	0.98* 2.27*	0.7; 1.3 1.1; 3.4	59.92	6.21	76.86	8.19	+28.27	2000–2021	1.20*	1.0; 1.4	$p = 0.1127$
High fasting plasma glucose levels	79.05	7.43	117.94	11.48	+49.20	2000–2021	1.94*	1.8; 2.1	76.19	7.89	107.92	11.50	+41.65	2000–2021	1.66*	1.4; 1.9	$p = 0.0007$
High LDL cholestero levels	117.37	11.03	94.21	9.17	–19.73	2000–2015 2015–2021	–1.42* 0.30	–1.6; –1.2 –0.5; 1.1	92.92	9.62	82.90	8.83	–10.78	2000–2021	–0.47*	–0.7; –0.2	$p = 0.0004$
Behavioral risk factors	493.61	46.40	481.40	46.88	–2.47	2000–2021	–0.11	–0.2; 0.0	452.96	46.91	448.50	47.78	–0.98	2000–2021	–0.01	–0.2; 0.2	$p = 0.0642$
Tobacco use	279.01	26.23	221.62	21.58	–20.57	2000–2014 2014–2021	–1.30* –0.62*	–1.5; –1.1 –1.1; –0.1	239.61	24.81	186.16	19.83	–22.31	2000–2014 2014–2021	–1.46* –0.47	–1.8; –1.2 –1.3; 0.4	$p = 0.0707$
Dietary risks	196.32	18.45	188.41	18.35	–4.03	2000–2014 2014–2021	–0.45* 0.85*	–0.7; –0.2 0.2; 1.5	173.52	17.97	180.23	19.20	+3.87	2000–2021	0.38*	0.2; 0.6	$p = 0.0007$
Alcohol consumption	74.76	7.03	104.64	10.19	+39.97	2000–2007 2007–2021	3.97* 0.64*	2.9; 5.1 0.3; 1.0	82.27	8.52	108.20	11.53	+31.52	2000–2007 2007–2021	4.76* –0.20	4.1; 5.5 –0.4; 0.0	$p = 0.0020$
Low physical activity	8.65	0.81	11.79	1.15	+36.30	2000–2014 2014–2021	1.19* 2.55*	1.0; 1.4 2.0; 3.1	7.82	0.81	9.80	1.04	+25.32	2000–2021	1.03*	0.8; 1.2	$p = 0.0002$
Environmental/ occupational risk factors	200.72	18.87	177.02	17.24	–11.81	2000–2008 2008–2021	0.32 –1.25*	–0.2; 0.8 –1.5; –1.0	183.34	18.99	150.79	16.07	–17.75	2000–2007 2007–2021	0.17 –1.48*	–0.6; 1.0 –1.8; –1.2	$p = 0.0002$
Air pollution	137.12	12.89	92.69	9.03	–32.40	2000–2008 2008–2021	–0.03 –3.17*	–0.6; 0.5 –3.4; –2.9	116.03	12.02	71.65	7.63	–38.25	2000–2008 2008–2021	–0.24 –3.59*	–1.1; 0.6 –4.0; –3.2	$p = 0.0031$
Occupational risks	21.39	2.01	31.05	3.02	+45.16	2000–2015 2015–2021	3.16* –0.94	2.9; 3.4 –1.9; 0.1	20.02	2.07	19.88	2.12	–0.70	2000–2016 2016–2021	0.25* –1.04	0.1; 0.4| –2.1; 0.0	$p = 0.0002$

*APC – annual percent change, CI – confidence interval, BMI – body mass index, LDL – low-density lipoprotein. *Statistically significant values.*

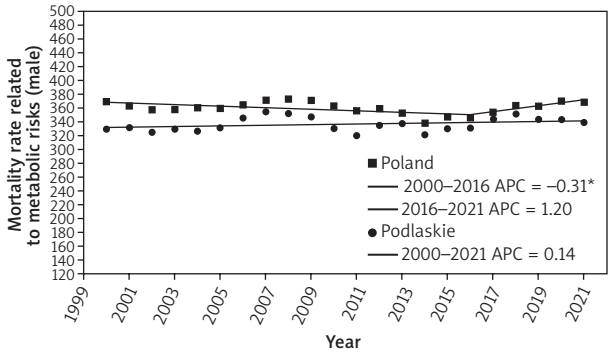

Figure 1. Male mortality trends related to metabolic risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates.: Poland: 1 Joinpoint versus Podlaskie: 0 Joinpoints

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 1 Joinpoint, Podlaskie – 0 Joinpoints. Rejected Parallelism.*

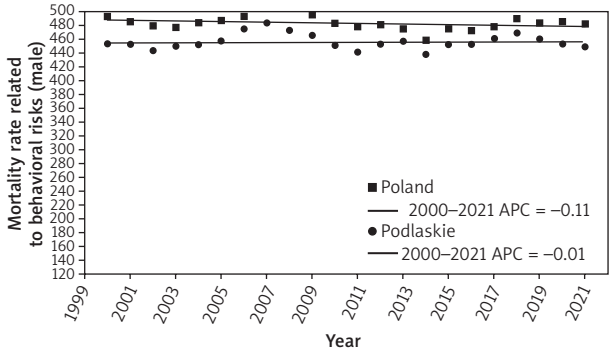

Figure 3. Male mortality trends related to behavioral risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates: Poland: 0 Joinpoint versus Podlaskie: 0 Joinpoints

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 0 Joinpoint, Podlaskie – 0 Joinpoints. Failed to rejected Parallelism.*

in Poland for all three categories. The percentage changes were –0.25% for metabolic risks, –2.47% for behavioral risks, and –11.81% for environmental and occupational risks.

Among men in the Podlaskie Voivodeship, mortality rates related to metabolic risks increased by 3.04% from 2000 to 2021, while those associated with behavioral and environmental and occupational risks decreased by 0.98% and 17.75%, respectively.

Trend analysis showed a statistically significant decline in mortality due to metabolic risk factors in men in Poland from 2000 to 2016 (APC = –0.31; $p = 0.014$) (Figure 1). Significant decreases were also observed in mortality due to environmental and occupational risks: among men in Poland from 2008 to 2021 (APC = –1.25; $p < 0.001$) and in the Podlaskie Voivodeship from 2007 to 2021 (APC = –1.48;

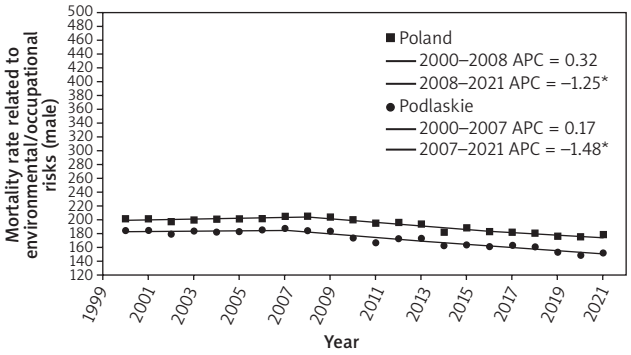

Figure 2. Male mortality trends related to environmental/occupational risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates.: Poland: 1 Joinpoint versus Podlaskie: 1 Joinpoint

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 1 Joinpoint, Podlaskie – 1 Joinpoint. Rejected Parallelism.*

$p < 0.001$) (Figure 2). The mortality trend associated with behavioral risks among men showed a decrease but was not statistically significant (Figure 3).

Table 3 presents the results of the analysis for the female population in Poland and in the Podlaskie Voivodeship. During the analyzed period, among women in Poland, a decrease in mortality rates was observed only for the group of environmental and occupational risk factors, with a percentage change of –10.59%. Mortality rates associated with metabolic and behavioral risks increased, with percentage changes of +5.70% and +6.03%, respectively.

In the female population of the Podlaskie Voivodeship, similar to women in Poland overall, a decrease in mortality rates was observed only for environmental and occupational risk factors, with a percentage change of –7.63%. Mortality rates related to metabolic and behavioral risks increased, with percentage changes of +14.63% and +16.92%, respectively.

Trend analysis revealed significant changes in all main risk groups among women. Mortality linked to metabolic risks increased significantly among women in Poland from 2015 to 2021 (APC = +1.26; $p = 0.007$) and the Podlaskie Voivodeship from 2014 to 2021 (APC = +1.54; $p = 0.001$) (Figure 4). Behavioral risk-related mortality in women increased significantly in Poland (2002–2021, APC = +0.54; $p < 0.001$) and the Podlaskie Voivodeship (2000–2012, APC = +0.49; $p = 0.020$; 2012–2021, APC = +1.60; $p < 0.001$) (Figure 5). Environmental and occupational risk-related mortality significantly decreased in women in Poland (2009–2021, APC = –1.02; $p < 0.001$) and the Podlaskie Voivodeship (2000–2021, APC = –0.46; $p < 0.001$) (Figure 6).

Selected risk factors (Level 2 risks)

Selected Level 2 risk factors were also examined. Among metabolic risks, mortality associated with

Table 3. Trends in the mortality rate per 100,000 population among females in Poland and the Podlaskie Voivodeship from 2000 to 2021

Parameter	Poland								Podlaskie voivodeship								Comparative trends
	Deaths per 100,000 population					Trend			Deaths per 100,000 population					Trend			
	2000	%	2021	%	Change 2000–2021 [%]	Time	APC	95% CI	2000	%	2021	%	Change 2000–2021 [%]	Time	APC	95% CI	Parallelism test
Metabolic risk factors	403.50	47.90	426.49	49.34	+5.70	2000–2015 2015–2021	0.01 1.26*	–0.2; 0.2 0.4; 2.1	346.70	48.77	397.43	50.44	+14.63	2000–2014 2014–2021	0.28 1.54*	–0.0; 0.6 0.7; 2.4	$p = 0.0011$
High blood pressure	257.97	30.63	227.55	26.33	–11.79	2000–2021	–0.76*	–1.0; –0.5	215.71	30.34	215.21	27.32	–0.23	2000–2021	–0.18	0.0; –2.1	$p = 0.0002$
High BMI	87.30	10.36	117.39	13.58	+34.47	2000–2014 2014–2021	1.18* 2.46*	0.9; 1.4 1.8; 3.2	82.44	11.60	112.65	14.30	+36.64	2000–2014 2014–2021	1.14* 2.33*	0.9; 1.4 1.6; 3.1	$p = 0.3842$
High fasting plasma glucose levels	97.47	11.57	135.15	15.64	+38.66	2000–2014 2014–2021	1.42* 2.42*	1.2; 1.7 1.8; 3.1	88.16	12.40	122.08	15.50	+38.48	2000–2013 2013–2021	1.03* 2.63*	0.6; 1.5 1.7; 3.6	$p = 0.0589$
High LDL cholesterol levels	101.75	12.08	90.21	10.44	–11.34	2000–2014 2014–2021	–0.98* 0.53	–1.2; –0.8 –0.1; 1.2	71.90	10.11	79.27	10.06	+10.25	2000–2011 2011–2021	–0.15 1.26*	–0.7; 0.4 0.6; 1.9	$p = 0.0002$
Behavioral risk factors	274.17	32.55	290.70	33.63	+6.03	2000–2002 2002–2021	–2.69 0.54*	–7.9; 2.8 0.4; 0.7	220.10	30.96	257.34	32.66	+16.92	2000–2012 2012–2021	0.49* 1.60*	0.1; 0.9 1.0; 2.2	$p = 0.0002$
Tobacco use	81.07	9.62	76.59	8.86	–5.53	2000–2002 2002–2021	–2.09 0.00	–6.1; 2.1 –0.1; 0.1	53.38	7.51	52.85	6.71	–0.99	2000–2021	0.27*	0.1; 0.5	$p = 0.0002$
Dietary risks	172.44	20.47	181.69	21.02	+5.36	2000–2014 2014–2021	0.00 1.51*	–0.3; 0.3 0.7; 2.3	144.36	20.31	177.84	22.57	+23.19	2000–2012 2012–2021	0.71* 2.07*	0.2; 1.2 1.3; 2.8	$p = 0.0002$
Alcohol consumption	12.19	1.45	17.70	2.05	+45.20	2000–2007 2007–2021	3.64* 1.19*	2.4; 4.9 0.8; 1.6	10.70	1.51	13.28	1.69	+24.11	2000–2005 2005–2021	4.33* 0.12	2.2; 6.5 0.1; –0.2	$p = 0.0002$
Low physical activity	20.72	2.46	24.00	2.78	+15.83	2000–2014 2014–2021	0.56* 1.42*	0.3; 0.8 0.8; 2.0	17.51	2.46	20.29	2.58	+15.88	2000–2021	0.71*	0.5; 0.9	$p = 0.4676$
Environmental/ occupational risk factors	164.63	19.55	147.19	17.03	–10.59	2000–2009 2009–2021	–0.12 –1.02*	–0.6; 0.4 –1.3; –0.7	144.08	20.27	133.08	16.89	–7.63	2000–2021	–0.46*	–0.6; –0.3	$p = 0.0002$
Air pollution	119.61	14.20	85.20	9.86	–28.77	2000–2009 2009–2021	–0.38 –2.66*	–0.9; 0.1 –3.0; –2.3	93.00	13.08	64.36	8.17	–30.80	2000–2008 2008–2021	–0.61 –2.42*	–1.6; 0.4 –2.9; –2.0	$p = 0.0280$
Occupational risks	3.62	0.43	6.82	0.79	+88.40	2000–2017 2017–2021	4.17* 0.62	3.7; 4.6 –3.0; 4.4	3.34	0.47	4.75	0.60	+42.22	2000–2002 2002–2021	–2.47 2.25*	–9.7; 5.3 2.0; 2.5	$p = 0.0002$

*APC – annual percent change, CI – confidence interval, BMI – body mass index, LDL – low-density lipoprotein, *statistically significant values.*

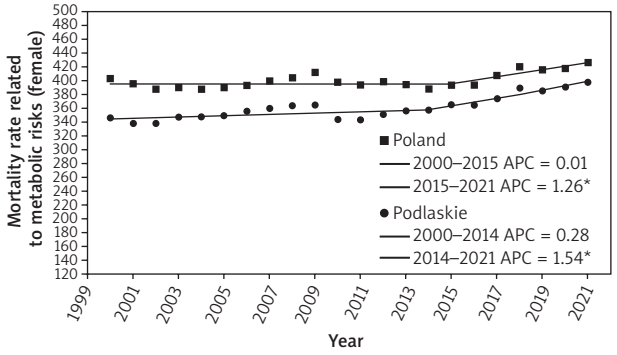

Figure 4. Female mortality trends related to metabolic risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates: Poland: 1 Joinpoint versus Podlaskie: 1 Joinpoint

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 1 Joinpoint, Podlaskie – 1 Joinpoint. Rejected Parallelism.*

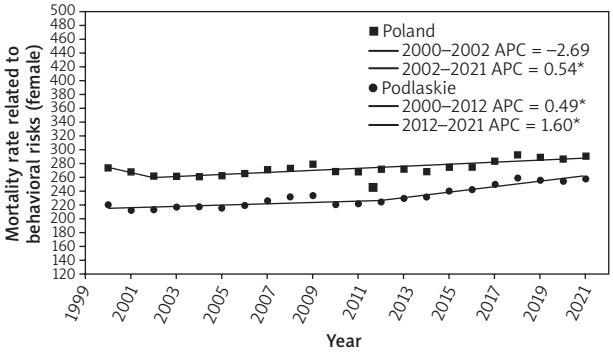

Figure 5. Female mortality trends related to behavioral risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates: Poland: 1 Joinpoint versus Podlaskie: 1 Joinpoint

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 1 Joinpoint, Podlaskie – 1 Joinpoint. Rejected Parallelism.*

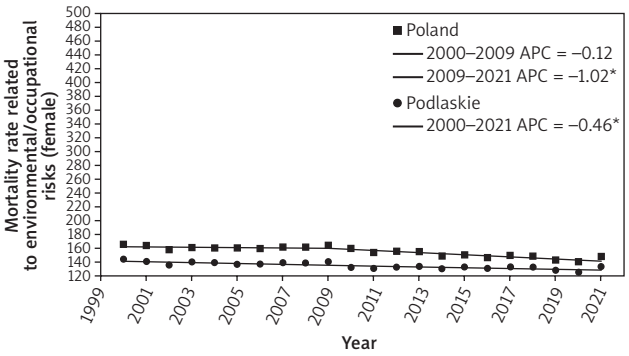

Figure 6. Female mortality trends related to environmental/occupational risk factors: Poland versus Podlaskie Voivodeship, 2000–2021 – Joinpoint regression analysis of age-standardized mortality rates: Poland: 1 Joinpoint versus Podlaskie: 0 Joinpoints

**Indicates that the Annual Percent Change (APC) is significantly different from zero at the a = 0.05 level. Final Selected Model: Poland – 1 Joinpoint, Podlaskie – 0 Joinpoints. Rejected Parallelism*

high blood pressure, high BMI, elevated fasting plasma glucose, and high LDL cholesterol was analyzed. Behavioral risks comprised tobacco use, dietary risks, alcohol consumption, and low physical activity. Environmental and occupational risks comprised air pollution and occupational hazards.

In the male population, percentage changes for metabolic risks were similar between Poland and the Podlaskie Voivodeship. Mortality related to high blood pressure decreased by 15.16% in Poland and 10.08% in the Podlaskie Voivodeship. Mortality linked to high LDL cholesterol levels decreased by 19.73% and 10.78%, respectively. Mortality associated with high BMI increased by 27.34% in Poland and 28.27% in the Podlaskie Voivodeship. Mortality due to elevated fasting glucose increased by 49.20% in Poland and 41.65% in the Podlaskie Voivodeship (Table 2).

Among behavioral risks in men, mortality linked to dietary risks decreased by 4.03% in Poland but increased by 3.87% in the Podlaskie Voivodeship. Trends for other behavioral factors were similar, with decreases in tobacco-related mortality rates (20.57% Poland; 22.31% Podlaskie Voivodeship), and increases in alcohol-related (39.97% Poland; 31.52% Podlaskie Voivodeship) and low physical activity-related mortality rates (36.30% Poland; 25.32% Podlaskie Voivodeship) (Table 2).

For environmental and occupational risks in men, occupational risk-related mortality increased by 45.16% in Poland but decreased by 0.70% in the Podlaskie Voivodeship. Mortality related to air pollution decreased by 32.40% and 38.25%, respectively (Table 2).

In women, a difference was observed in mortality related to high LDL cholesterol levels, which decreased by 11.34% in Poland but increased by 10.25% in the Podlaskie Voivodeship. Trends for other metabolic factors were similar: mortality decreased for high blood pressure (11.79% Poland; 0.23% Podlaskie Voivodeship), and increased for high BMI (34.47% Poland; 36.64% Podlaskie Voivodeship) and high fasting glucose (38.66% Poland; 38.48% Podlaskie Voivodeship).

Mortality trends related to behavioral and environmental and occupational risks in women were similar in Poland and the Podlaskie Voivodeship. Tobacco-related mortality rates decreased (5.53% Poland; 0.99% Podlaskie Voivodeship), dietary risk-related mortality rates increased (5.36% Poland; 23.19% Podlaskie Voivodeship), and alcohol-related mortality rates increased more in Poland (45.20%) than in the Podlaskie Voivodeship (24.11%). Mortality related to low physical activity increased similarly (15.83% Poland; 15.88% Podlaskie Voivodeship). The largest increase was observed in occupational risk-related mortality: 88.40% in Poland and 42.22% in the Podlaskie Voivodeship. Mortality associated with air pol-

lution decreased comparably (28.77% Poland; 30.80% Podlaskie Voivodeship) (Table 3).

Discussion

A substantial proportion of mortality rates attributable to behavioral risk factors presents a significant public health challenge, representing a strategic yet particularly difficult area to manage effectively [15]. In the male population in 2021, nearly 50% of deaths were associated with behavioral risks. Among women, the greatest threats were metabolic factors – approximately 50% of mortality and behavioral factors – about 33%, with both groups showing significantly increasing trends in recent years.

The increasing value of the mortality rate may result in a series of negative consequences for the society, the healthcare system, and the country's economy [15]. According to 2022 data, the overall mortality decline rate in Poland slowed markedly between 2014 and 2019. The COVID-19 pandemic (2020–2021) caused a sharp increase in deaths of approximately 25% for both men and women. Consequently, the standardized overall mortality rate in 2021 reached levels comparable to those observed in 2005 [16]. According to the latest health status report published by the National Institute of Public Health – National Research Institute (PZH), cardiovascular diseases and malignant neoplasms have been the leading causes of death in Poland for years [17].

From 2000 to 2021, mortality rates increased for half of the analyzed risk factors in men and nearly two-thirds in women. Particularly notable in men was an almost 50% increase in deaths related to elevated fasting plasma glucose levels in Poland and over 40% in the Podlaskie Voivodeship. High increases in mortality were also observed for alcohol consumption, physical inactivity, high BMI in men both nationally and regionally, as well as an over 45% rise in occupational risk-related mortality in Poland overall. Among women, the largest increase concerned occupational risk-related deaths – nearly 90% in Poland and over 40% in the Podlaskie Voivodeship. Similar to men, women in both Poland and the Podlaskie Voivodeship exhibited significant increases in mortality rates linked to alcohol consumption, elevated fasting glucose, and high BMI. Although the current recommendation is to use multi-level frameworks that consider complex risk factors and their interactions, as well as the impact of social determinants of health, the present results indicate that daily behaviors and living conditions remain key for health outcomes [18].

Men more frequently engage in risky health behaviors, such as smoking, excessive alcohol consumption, and lack of physical activity, while women, despite more often caring for their health through healthy eating and medical care, are more exposed to some chronic diseases, which leads to higher morbidity but not necessarily higher mortality rate from these causes compared to men. The conclusions from Gorman's research analysis are reflected in the percentage share of the mortality rate related to behavioral factors, while it is a concerning fact that among women, both in Poland overall and in the Podlaskie Voivodeship in 2000–2021, this rate increased by over 6% and nearly 17%, respectively. The slight decrease of this rate among men in Poland and the Podlaskie Voivodeship (below 1%) is also not optimistic. Unfortunately, even among people who highly care for their health, there is no guarantee of avoiding disease. Other factors or situations over which we have no control may appear, and then medical help becomes crucial. Nevertheless, one should not give up caring for health. The demand for healthcare in aging societies is growing, and good physical condition facilitates overcoming potential diseases [19, 20].

The next group of risk factors, namely metabolic factors, are also closely related to lifestyle. Diet, physical activity, smoking, and alcohol consumption affect the body's metabolic processes, shaping parameters such as blood pressure, glucose levels, blood lipids, and body weight. During the analyzed period, at the national level, women experienced a higher burden of metabolic risk factors compared to men. In a more detailed perspective, men showed a greater decline in mortality rates associated with high blood pressure and high LDL cholesterol levels, as well as a greater increase in deaths related to high fasting plasma glucose levels. Among women, a more pronounced increase was observed in mortality rates associated with high BMI. Findings from the study by Chew *et al*. (2000–2019) demonstrate that, at the global level, men exhibited higher absolute mortality rates attributable to metabolic diseases. The analyses also showed slight differences in the direction of growth between genders/sexes: women showed a slightly stronger relative increase in the frequency of obesity and non-alcoholic fatty liver disease, while men had minimally greater increases in hypertension and hyperlipidemia [21].

Environmental factors also have a significant impact on health, not only physically but also psychologically. The World Health Organization recognizes air pollution as one of the main health threats, contributing to millions of premature deaths annually and reducing quality of life. Moreover, environmental factors also affect mental health, causing stress and negatively affecting people's wellbeing [22, 23]. Anthropogenic activity has contributed to climate warming, bringing natural consequences. Droughts, floods, fires, and higher temperatures translate into health problems in the areas of cardiovascular, respiratory, and metabolic diseases. Higher temperatures also favor the development of microorganisms, intensifying the problem of infectious diseases [24]. During the study period, this risk group experienced the larg-

est mortality rate declines in both sexes, with greater reductions observed in men in the Podlaskie Voivodeship and women nationally.

Although the Constitution of the Republic of Poland guarantees all citizens equal access to healthcare (Article 68), significant health inequalities still exist in practice. They often result from demographic, social, and economic differences that may be difficult to completely eliminate. Nevertheless, recognizing and analyzing these inequalities allows for the implementation of appropriate actions that can reduce them. In health policy, initiatives related to health education, health promotion, and prevention should be crucial, aimed at improving the overall health status of the society. However, simply increasing health awareness is not always sufficient to solve the problem/issue of inequalities, so it is necessary to include actions aimed at reducing differences in access to healthcare. Avoidable deaths, both those resulting from preventive and medical factors, are a good indicator of health inequalities. Although in Poland theoretically everyone has guaranteed equal access to health services, in practice the quality of care and availability differ depending on the region and social groups. Therefore, it is necessary to take actions aimed at reducing these inequalities to improve the overall effectiveness of the healthcare system and the health status of the population [25, 26].

A limitation of the study may be the fact that risk factors often occur in correlation, and their mutual relationships were not thoroughly investigated. It should also be noted that some data are burdened with error because they come from survey studies [12]. It would be advisable to conduct further research that takes into account detailed relationships between risk factors, including their co-occurrence and mutual influence, and the application of advanced statistical methods to capture complex interactions. It is also worth using various data sources to minimize errors related to survey studies. Taking these suggestions into account in future research could improve the accuracy of results and deepen understanding of the relationships between risk factors.

Conclusions

The analysis of trends in mortality rates associated with the main groups of risk factors (metabolic, behavioral, and environmental and occupational) from 2000 to 2021 revealed significant differences between male and female populations, as well as between Poland overall and the Podlaskie Voivodeship. Mortality rates in the Podlaskie Voivodeship were consistently lower than the national averages for both sexes.

Among men, favorable trends were observed across all main risk factor groups at the national level, with the greatest reduction noted for environmental and occupational factors (11.81%). In the Podlaskie Voivodeship, however, an unfavorable upward trend was recorded for metabolic risk factors (3.04%), while other main risk groups showed declines. Joinpoint analysis confirmed a statistically significant decrease in mortality related to metabolic factors in Poland (2000–2016) and environmental and occupational factors in both regions.

In women, the opposite pattern emerged – mortality related to metabolic and behavioral risk factors increased, while deaths linked to environmental and occupational factors declined. The Podlaskie Voivodeship exhibited greater dynamics of adverse changes than Poland overall, particularly for metabolic (+14.63% vs. +5.70%) and behavioral (+16.92% vs. +6.03%) risk factors. All identified trends among women were statistically significant.

At the level of specific risk factors (Level 2), increasing mortality rates associated with high BMI and elevated fasting plasma glucose are of particular concern, evident in both sexes. Positive trends included reductions in deaths related to high blood pressure, tobacco use, and air pollution.

Although the Podlaskie Voivodeship generally presents lower mortality rates, it demonstrates concerning upward trends, especially among women, highlighting the need for targeted preventive interventions addressing metabolic and behavioral risk factors.

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Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

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