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THE CLUSTERING OF LIFESTYLE RISK FACTORS IN THE SERBIAN ADULT POPULATION AND ASSOCIATION WITH SELF-RATED HEALTH

GROZDENJE DEJAVNIKOV TVEGANJA NA PODROČJU ŽIVLJENJSKEGA SLOGA PRI ODRASLEM PREBIVALSTVU SRBIJE IN POVEZAVA S SAMOOCENO ZDRAVJA

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ABSTRACT

Introduction
Our objective was to identify clusters of lifestyle risk factors among Serbian adults and assess associations with socio-demographic characteristics and self-rated health.

Methods
The sample included 7,885 adults aged 18 and over from the 2019 Serbian National Health Survey, who provided information on all four lifestyle risk factors (smoking, physical inactivity, low fruit and vegetable intake and risky drinking). The Two-Step Cluster Analysis was used to identify different health-related lifestyle clusters. Logistic regression models were used to assess the association of obtained clusters with socio-demographic characteristics and self-rated health.

Results
Five distinct clusters of lifestyle risk factors were identified: Healthy lifestyle (cluster 1), Low fruit and vegetable intake (cluster 2), Physical inactivity (cluster 3), Smoking and other risk factors (cluster 4), Risky drinking and other risk factors (cluster 5). Multi-risk groups (cluster 4, cluster 5) exhibit specific socio-demographic characteristics (men, younger adults, living alone, less educated). Adults in unhealthy lifestyle clusters were more likely to report poor self-rated health than adults in the healthy lifestyle cluster.

Conclusions
Individuals who were men, younger, living alone, less educated and those with poor self-reported health were more likely to engage in clusters of lifestyle risk factors and represent high-priority population groups for multiple health behaviour change interventions.

Keywords
Clustering
Lifestyle
Risk factors
Self-rated health

IZVLEČEK

Uvod
Naš cilj je bil identificirati skupine dejavnikov tveganja življenjskega sloga med odraslimi Srbi in oceniti povezave s sociodemografskimi značilnostmi in samooceno zdravja.

Metode
Vzorec je vključeval 7885 odraslih, starih 18 let in več, iz »Nacionalne zdravstvene raziskave Srbije 2019«, ki so posredovali informacije o vseh štirih dejavnikih tveganja življenjskega sloga (kajenje, telesna nedejavnost, nezdrava prehrana in tvegano pitje alkohola). Dvostopenjska analiza grozdov je bila uporabljena za identifikacijo različnih grozdov življenjskega sloga, povezanih z zdravjem. Za oceno povezanosti dobljenih grozdov s sociodemografskimi značilnostmi in samooceno zdravja smo uporabili logistične regresijske modele.

Rezultati
Identificiranih je bilo pet različnih skupin dejavnikov tveganja za življenjski slog: zdrav življenjski slog (1. skupina), nizek vnos sadja in zelenjave (2. skupina), telesna nedejavnost (3. skupina), kajenje in drugi dejavniki tveganja (4. skupina), tvegano pitje alkohola in drugi dejavniki tveganja (5. skupina). Multirizične skupine (cluster 4, cluster 5) izkazujejo specifične sociodemografske značilnosti (moški, mlajši, živijo sami, nižje izobraženi). Odrasli v skupinah nezdravega življenjskega sloga so pogosteje poročali o slabi samooceni zdravja kot odrasli v skupini zdravega življenjskega sloga.

Zaključki
Posamezniki, ki so bili moški, mlajši, živijo sami, manj izobraženi in tisti s slabim zdravstvenim stanjem po lastni oceni, so bili bolj verjetno vključeni v skupine dejavnikov tveganja življenjskega sloga in predstavljajo visoko prednostne skupine prebivalstva za več intervencij za spremembo zdravstvenega vedenja.

Ključne besede
grozdenje
življenjski slog
dejavniki tveganja
samoocena zdravja

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1 INTRODUCTION

Non-communicable diseases (NCDs), including cardiovascular diseases, cancers, chronic respiratory diseases and diabetes, have been the leading causes of death and disability worldwide. The four major lifestyle risk factors (LRFs) for NCDs are smoking, unhealthy diet, physical inactivity and harmful use of alcohol (1). Since these LRFs are modifiable, an understanding of their determinants and interrelationships is important from a health promotion perspective. However, NCDs are also shaped by a broader set of determinants, including genetic predisposition, environmental exposures and climatic influences, which interact with behavioural risks (2, 3). While these factors are not directly addressed in this study, their relevance should be acknowledged as they provide a more comprehensive framework for understanding the multifactorial origins of NCDs.

If a pattern of LRFs occurs more frequently than would be expected based on marginal prevalence rates, it results in a clustering of these risk factors (4). The presence of multiple LRFs is associated with a significantly increased likelihood of adverse health outcomes, such as the development of chronic conditions, comorbidities, disabilities and premature mortality (5, 6). Furthermore, the clustering of health behaviours is socially patterned, with education, socio-economic and demographic characteristics including rural-urban differences and psychosocial stressors shaping lifestyle trajectories (7, 8). This underlines the importance of examining sociodemographic correlates of clusters, not only as a practical means of targeting interventions but also as a way to illuminate broader mechanisms of health inequalities.

While cluster analysis itself does not “identify risk factors,” it enables recognition of patterns of co-occurrence among existing behaviours, offering insights into population subgroups. Better insight into the socio-demographic characteristics of clusters could be useful in identifying vulnerable groups that would benefit most from public health interventions (9). The latest research evidence from Europe, including the Netherlands (10), Poland (11), Spain (12, 13), Norway (14), and Bosnia and Herzegovina (15), has consistently shown that lifestyle risk behaviours cluster differently across cultural and socioeconomic contexts. Such international variation highlights the importance of studying these phenomena in diverse national settings.

Besides this, LRFs are often associated with self-rated health. Self-rated health (SRH) is a validated measure of overall health that closely aligns with objectively assessed health status (16) and serves as a strong predictor of morbidity and mortality (17, 18). It reflects individuals' overall perception of their physical, mental and social well-being (19, 20). SRH is extensively utilised in population-based surveys as a marker of current health status and functional capability (20). SRH correlates closely with multidimensional measures of health-related quality of life (HRQoL) and has been employed across multicountry and multicentre studies and reviews to monitor population health and identify vulnerable groups (21). However, interpreting SRH requires careful consideration, as cultural factors can significantly affect how individuals evaluate and report their health (22). Previous research found that co-occurrence of multiple LRFs was associated with worse SRH (12, 23, 24).

When examining contextual factors in the context of Serbia, it is essential to note that there are significant regional disparities not only in GDP per capita but also in other areas, e.g. educational attainment, between Belgrade and Vojvodina and the other two regions: Šumadija and Western Serbia, as well as Southern and Eastern Serbia (25). Rural population share is considerably higher in Šumadija and Western Serbia (~55%), Southern and Eastern Serbia (~52.5%) and Vojvodina (43.3%) compared to Belgrade (~19%) (26).

A better understanding of the risk factors for NCDs is essential, as these conditions represent a significant public health concern in Serbia. According to data from the 2019 National Health Survey, half of the Serbian population reported having at least one NCD. The most common conditions were arterial hypertension (29.6%), hyperlipidemia (10.8%) and coronary heart disease/angina pectoris (9.8%) (27). In addition, multimorbidity presents a significant public health issue, affecting 12% of the working-age population, with higher prevalence among vulnerable groups, including women, individuals with lower levels of education and those with lower incomes (28). Additionally, the substantial prevalence of smoking, alcohol consumption, physical inactivity and unhealthy diet, with regional differences, was reported (27). Yet, to date, there has been limited empirical investigation of how these risks cluster within the Serbian population, despite comparable evidence from other European and middle-income countries (23, 24, 29-31). Exploring lifestyle patterns in Serbia is particularly relevant given the country's high burden of NCDs and ongoing health system reforms aimed at prevention.

As of the latest assessments, there is no currently valid strategic document in the Republic of Serbia that comprehensively addresses tobacco control, the prevention of non-communicable diseases, or national programmes targeting biological risk factors such as obesity, nor behavioural risk factors such as insufficient physical activity and excessive alcohol consumption (32, 33). Moreover, Serbia has not fully implemented a comprehensive national tobacco control strategy since 2016; according to the WHO report, despite drafting the Strategy for Tobacco Control 2016–2025, it was never formally adopted and remains without a cohesive action plan at the national level (34, 35). This is particularly concerning given that in regions such as Vojvodina, the adult smoking prevalence now approaches 36%, among the highest in Europe, especially in rural areas, lower-educated populations and among younger adults (33).

Unfortunately, there is a lack of research providing information about lifestyle patterns among Serbian adults and the association between SRH and multiple LRFs. Aiming to prepare an evidence-based foundation for the implementation of effective public health measures, the following objectives were set: 1) to identify clusters of risk behaviours related to NCDs in the Serbian adult population, 2) to examine the association between socio-demographic characteristics and these clusters, and 3) further assess the association of the identified clusters with SRH.

2 METHODS

2.1 Sample and data collection

The 2019 Serbian National Health Survey was conducted in line with the ethical standards of the Declaration of Helsinki* and the legislation of the Republic of Serbia. Before participating in the study, all respondents were provided with written information about the study and signed the informed consent form. To ensure participant anonymity, identifying information was not collected (necessary identification was replaced with a code) (27). The study was approved by the Ethics Review Board of the Institute of Public Health of Vojvodina (Decision: 1-740/2, date: 17-05-2024).

The 2019 Serbian National Health Survey is a cross-sectional study conducted by the Statistical Office of the Republic of Serbia in cooperation with the Institute of Public Health of Serbia and the Ministry of Health of the Republic of Serbia, using the European Health Interview Survey (EHIS wave 3) (27). The survey included people living in private (non-institutional) households. Individuals living in collective households, such as student dormitories, institutions for children and youth with disabilities, homes for socially endangered children, retirement homes, care facilities for the elderly and infirm, institutions for adults with disabilities, monasteries and convents, were excluded from the study. The 2011 census of the Republic of Serbia was used as a framework for sampling. A stratified two-cluster sample was used and included 5,114 households (response rate 80.7%). Stratification was based on the type of area (urban and other) and regions (Belgrade, Vojvodina, Sumadija and Western Serbia, Southern and Eastern Serbia). In the first stage, census districts (groups of households) were selected randomly with a probability proportional to their size. In the second stage, a sample of households within each district was chosen with an equal probability. To ensure that estimates from the sample accurately represented the general population, each household and individual in the sample was assigned a weight. The main component of the weight is the inverse of the probability of selection at each stage within each stratum, representing the basic sampling weight. The second component accounts for household non-response, with response rates calculated post-fieldwork and applied to adjust the base weights. Final household and individual weights were obtained through calibration of the adjusted household weights, using calibration factors to align population estimates with the official demographic projections for 2019 (27). Out of the number of adults aged 18 and over who agreed to be interviewed (n=12755), 11,015 agreed to fill in the self-completed questionnaire (response rate 86.4%). The final sample included 7,885 adults who provided complete information on all selected LRFs included in the cluster analysis (smoking, alcohol consumption, physical activity, fruit and vegetable intake).

2.2 Measures

2.2.1 Socio-demographic characteristics

Socio-demographic characteristics included in this analysis were: age, gender, level of education, marital status and region. The age variable was divided into three categories: young (18-34 years), middle-aged (35-54 years) and older (55 years and over). Level of education was classified as primary (elementary completed and incomplete school), secondary (secondary completed) and postsecondary (any college or university). Marital status was categorised as married (living together with a partner) and single (widowed, separated, divorced, or never married).

2.2.2 Lifestyle risk factors

For all LRFs, dichotomous (yes/no) variables were created. Smoking of tobacco products, including heated tobacco products (whether daily or occasionally), was coded as a risk factor. Two criteria were used to identify risky alcohol drinking: hazardous alcohol consumption and/or heavy episodic drinking every month in the last year. In the 2019 Survey, the defined criterion for hazardous alcohol consumption was: an average daily consumption exceeding the upper limit of 40 grams of ethanol for men and 20 grams of ethanol for women, while the value of ethanol used in a standard beverage was 13 grams (27). Heavy episodic drinking was defined as drinking riskily on a single occasion (equivalent of 60g of pure ethanol or more) (27). According to the 2014 WHO guidelines, low fruit and vegetable consumption is defined as intake of fewer than five days per week. In our study, low fruit and vegetable intake was defined as the non-daily consumption of fruits (fresh, frozen, canned, dried, excluding freshly squeezed juices) and vegetables (fresh, frozen, dried, canned, excluding vegetable juices and soups). Physical inactivity was defined as insufficient aerobic physical activity in leisure time and insufficient work-related physical activity (27). Physical activity in leisure time (LPA) was calculated by summing up the minutes per week spent on sports, fitness, or recreational LPA which cause at least a small increase in their breathing or heart rate and are performed for at least 10 minutes continuously (for example, brisk walking, ball games, jogging, cycling or swimming). Insufficient LPA was defined as performing less than 150 minutes of moderate-intensity activity in leisure time per week. Insufficient work-related physical activity was defined as mostly sitting or standing, or no activity at work, where work included paid and unpaid jobs. For unemployed individuals, this involves activities focused on job search-related tasks, while for retirees, it refers to household responsibilities such as caring for grandchildren or providing personal care to a family member (36).

2.2.3 Self-rated health

Respondents were asked: "How is your health in general: 1) very good, 2) good, 3) fair, 4) bad, 5) very bad". Those responding 4 or 5 were coded as poor SRH in the multivariable regression model.

2.3 Statistical analysis

Descriptive statistics were calculated for socio-demographic data, LRFs and SRH. The data on LRFs were analyzed with a Two-Step Cluster Analysis, which is well-suited for binary variables and large datasets (8, 10, 11, 24). In the pre-clustering step, it compresses data into smaller subclusters, allowing a subsequent hierarchical clustering method to process the data efficiently without requiring a full pass through the entire dataset, unlike traditional hierarchical methods. This approach combines the advantages of hierarchical methods (not requiring the number of clusters to be predetermined) with the efficiency needed for large datasets. The number of clusters was based on the log-likelihood distance and the Schwarz Bayesian Information Criterion. The average Silhouette coefficient was used as a measure of cohesion and separation to indicate the Goodness-of-Fit of the model. The reliability and stability of the cluster solution were examined by randomly taking a subsample (50%) and repeating the cluster analysis on this subsample. A Cohen's Kappa statistic was calculated as a measure of agreement between cluster solutions of the subsample and the total sample. Weighted logistic regression was used as a form of logistic regression that incorporates survey weights into the estimation process in dealing with complex survey data (37). A multinomial logistic regression model was used to estimate the probability that a respondent is in a certain cluster as compared to the reference group of the healthy lifestyle (cluster 1), based on the socio-demographic characteristics as independent variables. A binary logistic regression model examined the association between poor SRH and lifestyle clusters. All statistical analyses were performed using IBM SPSS Statistics version 23.

3 RESULTS

3.1 Prevalence of lifestyle risk factors

Table 1 shows the sample characteristics of adults in Serbia. One in three adults (33.1%) was a current daily smoker. A total of 38.2% of respondents reported physical inactivity. One in ten of the adults (10.5%) were risky drinkers. Less than daily consumption of fruits and vegetables was present in 63.1% of adults.

Table 1. Descriptive statistics for socio-demographic characteristics, lifestyle risk factors and self-rated health in the Serbian adult population.

Variables	n (%)	weighted %
Socio-demographic characteristics		
Gender		
women	4138 (52.5)	53.2
men	3747 (47.5)	46.8
Age (years)		
18-34	1696 (21.5)	24.7
35-54	2578 (32.7)	35.4
55 and over	3611 (45.8)	39.9
Marital status		
married	4975 (63.2)	61.3
single	2896 (36.8)	38.7
Region of Serbia		
Belgrade	1534 (19.5)	20.6
Vojvodina	2109 (26.7)	31.0
Sumadija and Western Serbia	2831 (35.9)	30.4
Southern and Eastern Serbia	1411 (17.9)	18.0
Education level		
postsecondary	1598 (20.3)	22.4
secondary	4513 (57.2)	57.3
primary	1773 (22.5)	20.4
Lifestyle risk factors[1]		
Smoking	2540 (32.2)	33.1
Risky alcohol drinking	758 (9.6)	10.5
Physical inactivity	2960 (37.5)	38.2
Low fruit and vegetable intake	4982 (63.2)	63.1
Self-rated health		
very good	1928 (24.5)	26.7
good	3120 (39.6)	40.2
fair	2002 (25.4)	23.7
bad	696 (8.8)	7.9
very bad	136 (1.7)	1.5
Total[2]	7885 (100.0)	100.0

Legend: [1] Prevalence of lifestyle risk factors; [2] The total sample included participants who provided data for all four lifestyle risk factors

3.2 Cluster profile description

Five distinct homogeneous clusters of LRFs in the Serbian adult population were found (Table 2). The average Silhouette measure of cohesion and separation was 0.6, demonstrating that the quality of the obtained clusters was good and that the respondents were well-matched to their cluster. The Two-Step Cluster Analysis was applied to the subsample (50%) of the total sample. The value of Kappa (0.873) indicates excellent agreement between cluster solutions obtained on this subsample and the overall sample.

Cluster 1 (Healthy lifestyle): This cluster consisted of 1,202 individuals (15.2%) who presented no lifestyle risk behaviours (no smoking, no risky drinking, daily consumption of fruits and vegetables, sufficient physical activity).

Cluster 2 (Low fruit and vegetable intake): This group comprised individuals with only one lifestyle risk factor, non-daily consumption of fruits and vegetables (n=1847; 23.4%).

Cluster 3 (Physical inactivity): All individuals in the cluster (n=1931; 24.5%) reported insufficient physical activity, the key indicator of this cluster. Moreover, six out of 10 individuals in this cluster were physically inactive.

Cluster 4 (Smoking and other LRFs): Overall, 2,147 (27.2%) individuals made up this cluster. All of them reported smoking, about two-thirds reported non-daily consumption of fruits and vegetables (68.7%), and 37.7% were physically inactive.

Cluster 5 (Risky drinking and other LRFs): All individuals in this cluster (n=758; 9.6%) were risky drinkers. Risky drinking was in conjunction with smoking (52.5%), low fruit and vegetable intake (67.4%), and physical inactivity (30.3%).

3.3 Socio-demographic characteristics of lifestyle clusters

The socio-demographic characteristics of lifestyle clusters were investigated using multinomial logistic regression (Table 3).

In contrast with the healthy lifestyle cluster, individuals in cluster 2 (Low fruit and vegetable intake) were more likely to be males, young, middle-aged, and less educated. Regional differences were also present; individuals were more likely to live in the other three regions (Vojvodina, Sumadija and Western Serbia, and Southern and Eastern Serbia) than in the Belgrade region.

Compared to the healthy lifestyle cluster, individuals in cluster 3 (Physical inactivity) were more likely to be females, young, unmarried, and less educated. They were more likely to live in the Southern and Eastern Serbia regions than in the Belgrade region.

Individuals in multi-risk groups (cluster 4, cluster 5) were more likely to be males, young, middle-aged, and to live in one of the other three regions than in the Belgrade region. Adults in these clusters were more likely to be unmarried and have a lower education.

3.4 Association between self-rated health and lifestyle clusters

Almost one in ten adults (9.4%) perceived their health as poor (bad or very bad), while about two-thirds (66.9%) rated their health as good or very good (Table 1).

Physically inactive adults (cluster 3) and adults in the multi-risk cluster 4 were more likely to report their health as poor compared to adults in the healthy lifestyle cluster (unadjusted multinomial logistic regression model). There was no evidence of an association between an unhealthy diet lifestyle (cluster 2) and a combination of risky drinking and other LRFs (cluster 5) with poor SRH (Table 4). After adjustment for age and gender (Model 1) and all socio-demographic variables (Model 2), adults in unhealthy lifestyle groups (cluster 3-5) were more likely to report poor health than adults in cluster 1 (Healthy lifestyle).

4 DISCUSSION

Our objective was to identify population groups exhibiting multiple LRFs to determine where targeted public health interventions might be most needed. According to the findings, participants were classified into five different clusters: a cluster with no LRFs (cluster 1), two clusters with one or two LRFs (cluster 2, cluster 3), and two multi-risk groups (cluster 4, cluster 5). These clusters are similar to those identified in previous studies (10, 29, 38). Researchers utilising cluster analysis have identified patterns that closely match ours, clustering of smoking, unhealthy diet and physical inactivity (9, 10, 23, 38), and clustering of risky drinking, smoking, unhealthy diet and physical inactivity (9, 10, 23, 29, 30, 38, 39).

In line with existing literature, cluster 1 (Healthy lifestyle) comprised mostly females and individuals with higher levels of education, as they tend to live a healthier lifestyle concerning smoking and alcohol consumption (10). Two high-risk groups (cluster 4, cluster 5) exhibit specific socio-demographic characteristics (males, young and middle-aged, living alone, less educated), in line with existing literature (7, 11, 38, 39).

Consistent with previous studies (9, 15, 23, 24, 31, 40), younger adults were more likely to be in the unhealthy lifestyle clusters. These results may be attributed to a lack of awareness regarding NCDs in young people or selection bias, as individuals with a higher risk of exhibiting two or more risk factors may not reach older age due to premature death (31).

Single individuals had a higher probability of showing one LRF (cluster 3) or multiple LRFs (cluster 4, cluster 5) than married individuals. These findings were consistent with previous research showing an association between living alone and less favourable health behaviours (7, 9, 40). A possible explanation for this association could be that

Table 2. Distribution of lifestyle risk factors in the clusters.

Lifestyle risk factors	Cluster 1. Healthy lifestyle (n=1202)	Cluster 2. Low fruit and vegetable intake (n=1847)	Cluster 3. Physical inactivity (n=1931)	Cluster 4. Smoking and other LRFs (n=2147)	Cluster 5. Risky drinking and other LRFs (n=758)	Total (n=7885)
Smoking (%)	0.0	0.0	0.0	100.0	52.5	33.1
Physical inactivity (%)	0.0	0.0	100.0	37.7	30.3	38.2
Risky drinking (%)	0.0	0.0	0.0	0.0	100.0	10.5
Low fruit and vegetable intake (%)	0.0	100.0	59.6	68.7	67.4	63.1

Values in the table are weighted.

Table 3. Multinomial logistic regression model estimating the association between cluster membership and socio-demographic characteristics.

Lifestyle risk factors	Cluster 2. Low fruit and vegetable intake; OR (95% CI)	Cluster 3. Physical inactivity; OR (95% CI)	Cluster 4. Smoking and other LRFs; OR (95% CI)	Cluster 5. Risky drinking and other LRFs; OR (95% CI)
Gender				
women	1	1	1	1
men	1.33 (1.32-1.33)*	0.78 (0.77-0.78)*	1.01 (1.01-1.02)*	4.99 (4.95-5.04)*
Age (years)				
18-34	1.88 (1.86-1.90)*	1.04 (1.03-1.05)*	1.42 (1.40-1.43)*	3.53 (3.48-3.57)*
35-54	1.51 (1.50-1.52)*	0.99 (0.98-1.00)*	2.01 (1.99-2.02)*	2.37 (2.34-2.39)*
55 and over	1	1	1	1
Marital status				
married	1	1	1	1
single	1.01 (1.00-1.01)	1.38(1.37-1.39)*	1.21 (1.21-1.22)*	1.22 (1.21-1.23)*
Region of Serbia				
Belgrade	1	1	1	1
Vojvodina	1.76 (1.74-1.77)*	0.97 (0.97-0.98)*	1.28 (1.27-1.29)*	1.58 (1.56-1.60)*
Sumadija and Western Serbia	3.00 (2.97-3.03)*	0.99 (0.98-0.99)*	1.27 (1.26-1.28)*	1.22 (1.20-1.24)*
Southern and Eastern Serbia	1.60 (1.58-1.61)*	1.06 (1.05-1.07)*	1.03 (1.02-1.05)*	2.42 (2.39-2.48)*
Education level				
postsecondary	1	1	1	1
secondary	1.44 (1.43-1.45)*	0.83 (0.82-0.83)*	1.49(1.48-1.50)*	1.45 (1.44-1.47)*
primary	1.95 (1.93-1.97)*	1.11(1.10-1.12)*	1.79 (1.77-1.81)*	1.19 (1.17-1.21)*

Legend: The reference category for the dependent variable in a multinomial logistic regression model is Cluster 1 (Healthy lifestyle) ; OR=odds ratio; CI=confidence interval; *p<0.01

Table 4. Association between poor SRH and lifestyle clusters.

Lifestyle clusters	Unadjusted model; OR (95% CI)	Model 1; OR (95% CI)	Model 2 OR (95% CI)
Cluster 1 (Healthy lifestyle)	1	1	1
Cluster 2 (Low fruit and vegetable intake)	0.95 (0.94-0.96)*	1.16 (1.14-1.17)*	0.99 (0.97-1.00)
Cluster 3 (Physical inactivity)	2.88 (2.84-2.91)*	3.07 (3.04-3.11)*	2.97 (2.93-3.01)*
Cluster 4 (Smoking and other LRFs)	1.49 (1.48-1.51)*	1.88 (1.85-1.90)*	1.82 (1.80-1.85)*
Cluster 5 (Risky drinking and other LRFs)	0.61 (0.60-0.63)*	1.13 (1.11-1.16)*	1.09 (1.07-1.11)*

Legend: Model 1 was adjusted for gender and age; Model 2 was adjusted for all socio-demographic variables (gender, age, marital status, region, education); OR=odds ratio; CI=confidence interval; *p<0.01

marital status has a protective effect on health status by maintaining a healthy lifestyle through social, psychological and economic support between married people (41).

Compared to the healthy lifestyle cluster, adults in cluster 2 (Low fruit and vegetable intake) and multi-risk clusters 4 and 5 were more likely to have a lower education level (primary or secondary school) than those with college or university education. These results go beyond previous reports, showing that lower education was significantly associated with higher odds of one or multiple LRFs (7, 11, 14, 15, 30, 40, 42). People with lower educational backgrounds are more likely to have a smoking lifestyle (9) and risky alcohol consumption, which was partly linked to a higher level of stress due to material limitations, although there was no evidence suggesting that these groups cope with stressful situations less effectively (43). Education is linked to future employment and income opportunities, as well as to improvements in health literacy and knowledge that contribute to better health-related behaviours (44).

In line with previous research, men were more likely to be in an unhealthy diet lifestyle cluster (15, 38), whereas women were more likely to be in a physically inactive cluster (8, 15). Individuals in multi-risk clusters 4 and 5 were more likely to be men, which is supported by the other studies (7, 45). In addition, women were more likely to engage in healthier lifestyle behaviours and more frequently adhered to recommendations regarding diet, tobacco use, and alcohol consumption compared to men, and this may be a result of social role differentiation (14).

Additionally, we identified a significant association between geographic regions and lifestyle clusters. Individuals in cluster 2 (Low fruit and vegetable intake) and multi-risk clusters 4 and 5 were more likely to live in one of the other three regions of Serbia than in the Belgrade region. Compared to the other three regions of Serbia, Belgrade has the smallest percentage of its population living in rural areas. In addition, the Belgrade region has the highest employment rate, the highest gross domestic product and the highest proportion of well-educated working-age people. At the same time, these indicators are lowest in Southern and Eastern Serbia. This may partly explain the clustering of unhealthy behaviours outside the capital, as confirmed by Serbian studies showing that sufficient intake of fruit and vegetables is strongly associated with higher education and better socioeconomic status, more common in urban areas (46, 47). Our results are similar to the findings of Cissé et al., who demonstrated that lower consumption of fruits and vegetables and higher alcohol consumption are more prevalent in rural areas (45).

Furthermore, we investigated the association between SRH and lifestyle clusters. Unlike disease-specific measures, SRH captures an individual's overall perception of health, integrating physical, mental and functional dimensions. As such, it is particularly well-suited for examining associations with lifestyle-related patterns. Within the context of health inequalities, SRH also represents a useful indicator for identifying the need for targeted policies and interventions aimed at addressing disparities across population subgroups defined by sex, age, educational level, place of residence and other socio-demographic factors (27). Accordingly, the association between SRH and lifestyle clusters was adjusted for socio-demographic variables. Numerous studies conducted among the adult population in Serbia have used SRH to assess socio-economic inequalities in health (48), to examine changes in population health during the transition period (49), and to explore the association between various demographic, socio-economic factors and LRFs, such as smoking and alcohol consumption (50). Our results provide further evidence that clustering of simultaneous LRFs is associated with poor SRH. Adults belonging to unhealthy clusters (cluster 3-5) were more likely to report their health as poor than adults in the healthy cluster (adjusted regression model). The negative relationship between cluster 5 (Risky drinking and other LRFs) and poor SRH in the unadjusted model becomes positive in adjusted models, resulting from age and gender adjustment. Individuals in cluster 5 are mostly younger and male, probably less concerned about the harmful consequences of unhealthy habits, and the negative association in the unadjusted model was confounded by their better health, in line with a prior study (51). Some studies have further suggested that good health may actually predict alcohol consumption, rather than alcohol consumption predicting health outcomes (52).

Some commonly used methods for examining risk factor patterns include co-occurrence analysis, composite score methods, counting the number of LRFs or unsupervised learning techniques (e.g., cluster analysis, latent class analysis and factor analysis), which are designed to identify latent structures within the data (42). Recent research comparing Latent Class Analysis and Two-Step Cluster Analysis has confirmed that Two-Step Cluster Analysis can generate stable and valid clusters, particularly when applied in fields with large sample sizes and heterogeneous data types (53). Additionally, the clustering of LRFs, obtained by using Two-Step Cluster Analysis, remained stable over time (10).

Our findings are consistent with recent studies highlighting substantial regional disparities in health behaviours and outcomes within Serbia and the Western Balkans. For example, a spatio-temporal analysis of hypertension in the Autonomous Province of Vojvodina identified significant regional variations, with certain settlements exhibiting higher rates, suggesting the need for targeted public health interventions in these areas (54). Similarly, a geographic overview of NCDs in Vojvodina, using cluster analysis and the Getis-Ord Gi* method, revealed that specific counties were more burdened by cardiovascular diseases and diabetes, emphasising the importance of region-specific health strategies (55). Beyond Serbia, cluster analysis of health indicators across Western Balkan countries has demonstrated the influence of healthcare infrastructure, socioeconomic conditions and regional disparities on health outcomes, grouping countries into clusters with distinct health profiles (56). These findings collectively underscore the value of employing advanced statistical methods to uncover regional patterns of health behaviour and disease burden, informing more efficient allocation of resources and tailored public health interventions.

The study has some limitations. Information about health behaviours was self-reported, which has well-known disadvantages (e.g., recall bias, social desirability, under-estimation, or over-estimation). Due to the cross-sectional nature of the data, no conclusions about the causality of the relationship between clusters of LRFs and SRH can be drawn from the current study. In addition, SRH may be influenced by an individual's temporary or short-term health status (20) and other broader groups of contextual indicators. Our study included participants who provided complete information on the four LRFs included in cluster analysis. While complete-case analysis (CCA) may introduce bias in small-sample contexts with high missingness, existing evidence suggests that in larger samples, CCA can remain stable and yield results similar to other imputation methods (57), though the limitations must be acknowledged. Missing data were more prevalent among older participants and those with lower educational attainment; both were accounted for as covariates in the multivariable models, thereby enabling partial statistical adjustment for potential bias. Binary variables were used in the cluster analysis to ensure comparability with previous studies; however, this approach did not allow for capturing variation in the intensity or quantity of the behaviours (10). SRH was also dichotomised to ensure comparability with previous studies (12, 23, 20, 51).

However, the limitations of the study should be balanced against its strengths, such as the source of data: a large population-based sample. To the best of our knowledge, it was the first study focusing on the patterning of LRFs in the Serbian adult population by using cluster analysis and identifying high-risk population groups for NCDs. Finally, as far as we know, this is the first study examining the association between multiple LRFs and SRH in the Serbian adult population.

5 CONCLUSIONS

This research shows that in Serbia, the clustering of lifestyle risk factors is more common among men, younger adults, people living alone, those in regions outside of Belgrade, and individuals with lower education levels. People with multiple concurrent lifestyle risk factors were more likely to report worse self-rated health. These findings emphasise the need to go beyond single-risk-factor approaches in public health and instead prioritise multiple health behaviour change strategies. High-risk population groups identified in this study should be prioritised in designing and implementing such interventions. However, current evidence on the best ways to modify multiple LRFs at the same time remains limited. More research is necessary to develop integrated, inclusive, and context-specific strategies that can sustainably improve health behaviours and reduce health inequalities across different socio-demographic groups.

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CONFLICTS OF INTEREST

The authors declare no competing interests.

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The study was approved by the Ethics Review Board of the Institute of Public Health of Vojvodina (Decision: 1-740/2, date: 17-05-2024).

INFORMED CONSENT

All participants signed an informed consent to participate. The study was conducted in accordance with the Declaration of Helsinki.

AVAILABILITY OF DATA AND MATERIALS

All data and materials used in this study are available upon reasonable request.

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During the preparation of this article, the authors used ChatGPT to:

- review and amend grammatical and spelling mistakes,
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