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Factors that influence anemia prevalence: a comparative study of datasets from Russia and South Africa

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Abstract

Background The prevalence of anemia is heterogeneous: different countries and population groups face varying risks of the disease. By identifying social, demographic, and economic factors, policymakers can define risk groups based on lifestyle and tailor measures to address the disease. This study examines and compares socioeconomic factors associated with anemia using data from two national surveys. The Russian survey relied solely on questionnaires, while the South African survey included medical examinations to confirm anemia cases.

Methods Multinomial regression was employed to estimate the risks of anemia using a combination of socioeconomic factors.

Results An inverse relationship was observed between bad habits and the risk of anemia in both samples. Education, income, and regular food consumption were found to be insignificant variables in both samples. However, household property ownership emerged as a significant factor. In South Africa, an inverse relationship with anemia risk was identified for households owning electric/gas ovens (OR = 0.769, 95% CI: 0.613–0.967, $p \leq 0.05$) and washing machine (OR = 0.699, 95% CI: 0.564–0.866, $p \leq 0.01$. Increased efforts for housekeeping also manifest themselves as increased risk to be anemic if an individual grows vegetables and fruits (OR = 1.333, 95% CI: 1.063–1.671, $p \leq 0.05$). In Russia, factors associated with a higher socioeconomic status—such as owning a computer (OR = 0.754, 95% CI: 0.629–0.905, $p \leq 0.01$), car (OR = 0.757, 95% CI: 0.610–0.938, $p \leq 0.05$), or DVD player (OR = 0.819, 95% CI: 0.684–0.981, $p \leq 0.05$) — were linked to a lower risk of anemia. Additionally, the habit of seeking medical help rather than self-medicating was negatively associated with anemia in the Russian sample (OR = 0.774, 95% CI: 0.704–0.850, $p \leq 0.01$).

Conclusions The comparison of socio-economic factors influencing the prevalence of anemia between Russian and South African samples has validated self-assessments as a reliable proxy for health status in the context of Russia. This methodological advancement underpins current and future research based on the extensive database of the Russia Longitudinal Monitoring Survey, encompassing approximately 2,500 indicators, to investigate disease prevalence.

Keywords Sociology of health in developing countries, Risk and health, Illness behaviour, Statistical methods

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Introduction

Analyzing the associations between socioeconomic characteristics and disease prevalence is often complex due to the interdisciplinary nature of the topic. However, such analyses are invaluable for public health management. For instance, the findings can be used to estimate the number of years individuals live without chronic diseases based on their lifestyle choices [1]. They can also help identify key risk factors within specific population groups, enabling targeted interventions to optimize healthcare policy outcomes. With modern planning tools and access to robust datasets, researchers can simulate the potential impacts of government interventions in healthcare [2]. Most studies in this field focus on chronic diseases [3, 4] and the promotion of healthy lifestyles [1].

By contrast, diseases like anemia, which do not directly increase mortality rates but contribute to overall health decline and the loss of productive years, receive less attention [5]. Research highlights the macroeconomic effects of anemia, such as increased burdens on healthcare systems [6, 7] and economic losses due to reduced cognitive abilities and productivity [8], underscoring the importance of addressing anemia prevalence. At the individual level, medical studies reveal that anemia, often caused by iron deficiency, weakens the immune system [9, 10], increases the risk of developing tuberculosis [11, 12], and leads to poorer outcomes in patients with traumatic brain injuries [13]. Additionally, anemia reduces the efficacy of common cancer treatments, such as radiotherapy and chemoradiation, due to inadequate oxygenation in tumors [14]. Collectively, these findings emphasize the need to prioritize anemia prevention and treatment.

Globally, the prevalence of anemia varies significantly across countries, with higher rates observed in developing nations [15]. This is particularly evident in Southeast Asia and Africa, where anemia represents a pressing public health issue [16, 17]. These regional disparities are reflected not only in medical research [15, 18] but also in patented inventions. Western countries primarily focus on developing treatment methods, while Eastern countries emphasize preventive measures and techniques [19].

Building on a wide body of literature on anemia, researchers have developed mathematical and computer models to assess anemia prevalence. These models can be used by public institutions to plan interventions addressing the disease. For example, we refer to an agent-based model that simulates food production, consumption, and anemia prevalence across Russian regions [2]. To our knowledge, no other models of this type are currently available. While results of anemia prediction using socioeconomic or medical profiles of individuals can be found in the literature [20–22], we were unable to identify any other comprehensive model that predicts anemia based on data on nutrition consumption and food production at the regional level of a country. The agent-based model in question populates individual agents using official Russian demographic statistics. The authors incorporate additional parameters from the Russian national survey to differentiate individual agents based on food consumption. However, there is room to improve the simulation by introducing population groups vulnerable to anemia. Since the model operates with social and economic data, describing such groups in socioeconomic terms would be a natural extension.

Disease prevalence is often associated with specific risk groups — population segments with characteristics that increase their vulnerability to health threats. These characteristics may include biological factors (e.g., age, body mass index, blood pressure), lifestyle behaviors (e.g., physical inactivity, dietary habits), and socioeconomic indicators (e.g., education, employment, general welfare).

The agent-based model for scenario analysis relies heavily on the Russia Longitudinal Monitoring Survey (RLMS). Therefore, to maintain consistency with the model's development methodology, we must investigate socioeconomic factors of anemia in Russia using this survey. However, a proper analysis requires rigorous physical examinations and laboratory tests. The RLMS is a national survey based on self-assessments, and detailed medical investigations of anemia in Russia — including sample details and socioeconomic profiles of individuals — are not publicly available. While the Russian Ministry of Health publishes data on the number of anemia cases detected, there is a need for a comprehensive medical survey to validate the reliability of socioeconomic factors associated with anemia.

Many studies and cross-country comparisons suggest that factors such as income levels and healthcare systems influence anemia prevalence. Research confirms that socioeconomic factors — including income, education, rural versus urban residence, and the quality of medical care—significantly affect the risk of anemia [23–26]. Specific socioeconomic groups are associated with underlying causes of anemia, such as insufficient or unbalanced nutrition, chronic inflammation, blood loss, and reduced lean body mass [27, 28]. Therefore, for this study, we aim to compare the socioeconomic factors identified through RLMS analysis with findings from previous works and a detailed national survey of anemia that includes medical examinations.

In this paper, we use the South African national survey as a reference point to compare factors and their influence on the risk of anemia. As the survey report states, "The uniqueness [of the study] lies in its ability to integrate findings from personal interviews with standardized physical examinations, diagnostic procedures, and a variety of laboratory tests" [29]. The sampling method used in the South African survey is similar to that of the RLMS. The South African survey provides a more detailed picture of anemia prevalence at the country level and uses blood biomarker-based assessments of anemia. However, the WHO reports anemia prevalence in countries using small number of categories only. The values for these categories in Russia and South Africa are presented in Table 1. We also refer to the Global Burden of Disease Study 2021 [30] as a source of anemia prevalence data for Russia and South Africa. According to this study, the total estimate for Russia is 15.1% of the total population (95% CI 13.7–16.6%), while for South Africa, it is 25.7% (95% CI 24.4–27.2%) as of 2021.

Now, after a broad review of the topic, we summarize the problem of the study, state our goal, and outline the purpose of this particular work. Anemia is a disease that is widespread across the world, and many studies address it from various perspectives. Models of anemia prevention incorporate socioeconomic factors to identify risk groups and target them for the most effective interventions. An agent-based model for Russia simulates food production and consumption but lacks a description of risk groups. Our goal is to propose such a description in terms of socioeconomic factors and provide justification for it. Therefore, the purpose of our study is to identify and compare risk groups for anemia based on socioeconomic factors using two surveys. The first survey relies on health self-assessments, while the second employs objective measurements for health evaluation. Self-assessment studies have known limitations, and their usefulness in various research contexts is often questioned. The correspondence of the risk groups identified in the analysis of the two surveys is expected to provide a more robust foundation for the use of self-assessments in public health studies.

Methods

This study analyzed data from two national surveys, focusing on overlapping points in the context of anemia. One survey relates to Russia, and the other to South Africa. The RLMS database (the Russia Longitudinal Monitoring Survey) is widely used as researchers base their work on this dataset to compare socioeconomic factors and disease prevalence [31]. The questionnaire includes questions about health, demographic characteristics, education, employment, income, and expenses. However, the RLMS is a sociological survey: individuals report their health status based on self-assessments or medical conclusions if they underwent a medical examination within the past year. In other words, the observed health status may differ from the actual state of the individual. This discrepancy can lead to paradoxical conclusions. For example, wealthier citizens, on average, appear more vulnerable to diseases. This outcome, however, becomes logical when considering that high-income groups are more likely to undergo regular medical check-ups and, consequently, are more likely to identify health problems even at early stages [32].

The second national database — SANHANES (South African National Health and Nutrition Examination Survey) 2012 — includes both a clinical component (blood sampling, objective measurement of health indicators) and a questionnaire [29]. This is a specialized study aimed, among other objectives, at examining the prevalence of anemia in South Africa. As this study is more context-specific, its questionnaire covers household facilities, welfare, food availability, access to services, and health insurance. The two surveys enable an investigation into the role of socioeconomic factors in anemia prevalence using two methodologically distinct approaches.

Socioeconomic factors often include household wealth status or wealth index, the mother's level or years of education, and maternal literacy. Previous studies have found an association between socioeconomic factors and the risk of anemia in children [33]. In low- and lower-middle-income countries (LLMICs), literacy may have a significant impact on population nutritional status. For married women younger than 24 years of age, low levels of education and wealth index were correlated with adolescent anemia [34], while Shimanda, Amukugo & Norström [35] identified associations between maternal education, household wealth status, and anemia in children. SANHANES reported socio-demographic results for adults based on population background, which is important for both readers and policymakers. The socio-demographic variables presented included sex, income, income sources, education, locality, province, race, employment, health insurance, marital status, household goods and services, and housing [29].

We test the hypothesis that a sociological study can predict vulnerable population groups based on factors identified through objective health observations. To do

Table 1 Anemia estimates for groups of population in Russia and South Africa

2019, %	Russia	South Africa
Anemia in children aged 6–59 months	21.9	44.4
Prevalence of anemia in women of reproductive age (aged 15–49)	21.1	30.5
Prevalence of anemia in non-pregnant women (aged 15–49)	21.1	30.5
Prevalence of anemia in pregnant women (aged 15–49)	23.4	30.8

Source: WHO(https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_children (Accessed 13 January 2025).)

this, we list the variables in focus, treat the presence or absence of anemia as the dependent variable, and use multinomial regression to estimate the significance of the factors. This type of regression is a common analytical tool in similar studies. Styszynski et al. [36] employed multiple logistic regression for their analysis—a similar statistical tool that compares samples between two categories. Goswami & Das [16] involve multinomial regression—a generalization of logistic regression for three or more categories.

To begin our analysis, we first highlight the similarities and differences between the two surveys in the context of a comparative study. Next, we describe the data preparation process. In the third section, we perform a multinomial regression analysis on socioeconomic factors related to anemia. Finally, we discuss the results in the context of published literature and conclude our work.

RLMS vs. SANHANES

The Russia Longitudinal Monitoring Survey (RLMS), supervised by the Higher School of Economics, is a study based on population health self-assessments. This ongoing study began in 1994 and structurally consists of a household questionnaire, an adult questionnaire, and a child questionnaire. In total, the RLMS questionnaires for households and adults cover 2,474 variables. Since the reference study, SANHANES, was conducted in 2012, we use RLMS data from 2012 only.

The household questionnaire identifies the place of residence (region and housing conditions), family members, available property, participation in agriculture and animal breeding, nutrition (including sources of products, their quantity, and prices), expenses for goods and services, external assistance in housekeeping, income (sources and amount), savings, and debts. The individual adult questionnaire records personal characteristics (gender, age, nationality, religion), family status, household ID, participation in the labor market (employment status, workplace, industry, position, earnings, responsibilities, and working conditions), level of education, IT usage, health status and medical care received, lifestyle (substance use, sports, regular diet), and general attitudes toward others. The child questionnaire records details on parenting and education, health status, and medical care. For this study, we use data for adults aged 18 years and older. These participants are randomly selected, and the sample is representative of Russia. A brief summary of the sample, consisting of 13,735 individuals, is provided in Table 2. Most participants are female, live in urban areas, and 43.4% of the sample is over 50 years old. RLMS distinguishes four types of localities: a regional center ("oblastnoy center"), town, PGT (poselok gorodskogo tipa), and rural areas. In this study, the first two are considered urban, while the last two are classified as rural.

Table 2 Demographic characteristics of RLMS sample for 2012

	N	**Freq., %**
Gender		
Male	5663	41.2
Female	8072	58.8
Place of residence (locality)		
Urban	9345	68.0
Rural	4390	32.0
Age		
18–30	3169	23.0
31–40	2401	17.5
41–50	2204	16.0
51–60	2534	18.5
61 and above	3427	25.0

SANHANES is a referential survey with medical examinations, used to compare results with the RLMS. It was conducted in 2012 by the Human Sciences Research Council. Part of the survey also includes a questionnaire — not just objective health observations. The questionnaire captures household characteristics and describes each individual included in the survey. A household is characterized by its place of residence (location and housing conditions, accessibility of social infrastructure), family members, available property, participation in agriculture and animal breeding, food expenses, regular diet, primary language of communication, level of education and employment of family members, sources of income, substance use, access to medical care, and the perceived cost of living. Individual characteristics are primarily described in terms of health indicators: blood pressure, objective measurements of blood composition (including hemoglobin and ferritin, which are important in the context of anemia), smoking and alcohol consumption, dietary habits, height and weight, age, and race. In total, the survey data used in this study cover 396 variables. And in this paper, we analyze data for adults only. A brief summary of the sample, consisting of 14,794 individuals, is provided in Table 3. Similar to the Russian sample, most participants are female and live in urban areas. However, the South African sample is significantly younger compared to the Russian one, with less than 30% of the sample being over 50 years old.

A comparison of the questionnaires reveals a significant overlap in questions about lifestyle, nutrition, income, and expenses. Importantly, issues related to nutrition, property, and involvement in agricultural activities are captured at the household level, while health conditions are recorded at the individual level. These similarities highlight the methodological alignment of the surveys. Next, we identify the groups of socioeconomic factors that are of interest in this study.

Next, we select the groups of variables that were observed in both surveys. The selection of variables

Table 3 Demographic characteristics of SANHANES sample for 2012

	N	Freq., %
Gender		
Male	5978	40.4
Female	8816	59.6
Place of residence (locality)		
Urban	9869	66.7
Rural	4925	33.3
Age		
18–30	5188	35.0
31–40	2745	18.6
41–50	2546	17.2
51–60	2154	14.6
61 and above	2161	14.6

used in this study was guided by a review of the risk factors associated with anemia in cross-country studies, as cited above. Table 4 summarizes the list of independent variables for further statistical investigation, with the dependent variable being anemia status. A detailed correspondence between the variables, their short names, and the specific questions in the surveys is provided in the Supplementary Materials (Appendix A).

Table 4 shows the generalized names of variables that represent specific factors. Strictly speaking, the questions used to assess these factors differ in wording between the SANHANES and RLMS questionnaires. Let us briefly characterize the variables. The presence of anemia in SANHANES (the "Anemia" variable) is determined using hemoglobin levels from blood tests, and a rank variable (values from 1 to 4) distinguishes the stages of anemia: 1 = no anemia (Hb > = 13.0 grams per deciliter (g/dL) in men and Hb > = 12.0 g/dL in women), 2 = mild anemia (Hb 11–12.9 g/dL in men and Hb 11–11.9 g/dL in women), 3 = moderate anemia (Hb 8–10.9 g/dL in both men and women) and 4 = severe anemia (Hb < 8 g/dL in both men and women) [37]. In RLMS, the rank variable (M62, values from 1 to 2 and options with no information in anemia) captures the answer to the question "In the last 12 months has a doctor told you that you had anemia?" (1 - "Yes", 2– "No").

The level of education is captured by categorical variables in both surveys: "educ" for SANHANES and "J72.18A" for RLMS. SANHANES distinguishes four levels, ranging from "No education" (coded as 1) to "Higher education" (coded as 4). "J72.18A" includes 12 categories, numbered from 1 to 14. Since general education is mandatory in Russia, RLMS educational categories begin with "General or incomplete secondary school" (coded as 1), proceed through "Doctoral degree" (coded as 14), and include vocational courses (codes 4–5). For more details on codes for education see Supplementary Materials (Appendix B).

Both surveys also track alcohol consumption and smoking behavior using rank variables. The variable "Regular food consumption" in SANHANES identifies irregular food consumption within the household (1 = cases of hunger in the household, 0 = no cases of hunger). In RLMS, this variable reflects the respondent's agreement with the statement that they manage to eat an appropriate number of times per day. The variable "Source of regular medical care" distinguishes between different ways of addressing health problems. In SANHANES, this was assessed through nine variables to track answer to the question "Where do you usually get your health care from?". There is only one non-zero variable of the nine above for every individual. Therefore, we introduce new categorial variable that distinguishes an option to the answer on medical care. And this variable is used further in statistical models. In RLMS, variable of medical care tracks the answer to the question "What did you do to address your health problems in the past 30 days? " (categorial variable with five options). Farming is captured by a categorical variable based on the household's involvement in cultivating vegetables and fruits. In SANHANES, this question is part of the household questionnaire, while in RLMS, it is included in the household

Table 4 Comparison of RLMS and SANHANES variables

Variable	SANHANES Codes	RLMS codes
Dependent variable		
Presence/absence of anemia	Anemia	M62
Independent variables		
Alcohol consumption	AuditC3_MF	M80
Smoking	Cursmoker	M71
Regular food consumption	B3Q14A_VP	M152
Source of Regular Medical Care	D1Q_1_VP - D1Q_9_VP	L58
Involvement in agriculture activity	E20Q_VP	D7
Education	Educ	J72.18 A
Employment	Employ	J1
Income	G2Q_VP	F14
Household property	E17Q_1_VP - E17Q_14_VP	C9.1 - C9.15

Table 5 Statistical summary of the SANHANES sample (fragment)

Variable SANHANES	Obs	Mean	Std. Dev.	Min	Max
Presence/absence of anemia	4740	0.234	0.575	0	3
Alcohol consumption	13,770	0.200	0.400	0	1
Smoking	13,894	0.196	0.397	0	1
Involvement in agriculture activity	14,840	0.193	0.394	0	1

Table 6 Statistical summary of the RLMS sample (fragment)

Variable RMLS	Obs	Mean	Std. Dev.	Min	Max
Presence/absence of anemia	14,380	0.037	0.188	0	1
Alcohol consumption	9514	0.684	0.465	0	1
Smoking	14,443	0.295	0.456	0	1
Involvement in agriculture activity	9316	0.901	0.298	0	1

section as well. Since the SANHANES survey was conducted in 2012, the corresponding comparison requires using the 21st wave of RLMS data (a representative sample of individuals). Additionally, for ease of statistical evaluation and interpretation of results, we recoded categorial and binary variables so that the presence of a feature is represented by 1, and its absence by 0. After recoding, the "Anemia" variable in SANHANES takes values from 0 (no anemia) to 3 (severe anemia).

Data

The SANHANES-1 was conducted in 2011–2012. At the beginning of the survey 10 000 households (visiting points - VP) were sampled. In the 8 166 valid VPs/households that agreed to participate in the survey, 27 580 individuals were eligible to be interviewed. A total of 25 532 individuals (92.6%) completed the interview, 12 025 underwent physical examinations and 8 078 provided blood specimens for biomarker testing. The data records available for researchers are anonymized.

The SANHANES results are generalized by a representative sample across age groups: adults, adolescents, and children. Therefore, one could process the data as they are assuming re-coding mentioned above. The RLMS results are given in the following categories: general household observations, general individual observations, representative sample of the households, representative sample of individuals. To compare the two surveys correctly, representative data on individuals should be treated. In the case of RLMS the 21st observation wave should be chosen, which corresponds to 2012. This is because the SANHANES data relate to this period. But some information (for example, about the availability of property) about individuals should be taken from the RLMS questionnaire for households. In this regard, the representative RLMS sample of not personalized individuals is enriched with variables related to households. To do so, we use the household's identifier for each individual to address the values of specific variables. As a result of this procedure, we get two representative samples of adults aged 18 years and older with similar variables to compare across countries– Russian and South African ones. And after re-coding the categorical variables in two samples so that the absence of a feature corresponds to zero value (0), as mentioned above, we present the data characteristic. The Tables 5 and 6 report only fragments of data, whereas full tables are listed in Supplementary Materials (Appendix C and D).

The mean value for household involvement in agricultural activities in Table 6 suggests that nearly all Russian households grow something on their land. This finding contradicts to the intuition that most of the population is urban (68%, as seen in Table 2). The high mean value likely results from biases in responses to questions. Firstly, we observe the number of responses—only 9,316 out of 13,735 individuals answered the question on their involvement in agriculture activity. Secondly, many urban residents have access to land for growing vegetables in Russia. This may include owning a dacha (a plot of land with a house in a rural area)—approximately 28% of households in urban area own one (variable C9.10.1). And the most of them are among the above 9.316 answers. Additionally, individuals might rent land in rural area or even own property with land within an urban area. These factors are challenging to estimate using RLMS data. Furthermore, territorial divisions in Russia classify some de facto rural households, who live in homes on their own land, as part of urban areas.

Results

To analyze the relationship between factor values and the presence or absence of anemia, we use multinomial regression. For our analysis we distinguish two groups of independent variables. One group relates to the lifestyle and includes indicators of alcohol consumption, smoking, regularity food consumption, source of regular medical care, involvement in agriculture activity. And another group includes proxy variables of a household's welfare– availability of households property. We present multinomial models for these groups of independent variables in Supplementary Materials (Appendix E, F, G and H). Calculations were performed using Stata software. The dependent variable indicates the anemia status of an individual. The "Anemia" variable in the case of SANHANES and the M62 variable in the case of RLMS were recoded as described earlier in the comments to Table 4. There is no significant regression for any group of independent variables or any of both countries. However, the estimates leave a room for statistical models that

Table 7 Spearman correlation. Lifestyle variables, South Africa

Variable number	Lifestyle variables, SANHANES	1	2	3	4	5
1	Alcohol consumption	1				
2	Smoking	**0.36**	1			
3	Involvement in agriculture activity	-0.02	-0.04	1		
4	Regular food consumption	0.01	0.00	0.06	1	
5	Source of Regular Medical Care	-0.03	0.04	0.02	0.22	1

Table 8 Spearman correlation. Lifestyle variables, Russia

Variable number	Lifestyle variables, RLMS	1	2	3	4	5
1	Alcohol consumption	1				
2	Smoking	0.14	1			
3	Involvement in agriculture activity	-0.01	-0.04	1		
4	Regular food consumption	0.08	0.14	-0.08	1	
5	Source of Regular Medical Care	0.10	0.06	-0.06	0.03	1

treat some independent variables of any groups. And we present some significant estimates of statistical models in Tables 9, 10, 11 and 12.

However, before we proceed to investigation of subset of variables it is important to answer the question on statistical closeness of independent variables. Analysis by VIF statistics is complicated in case of multinominal regression, therefore, we estimate Spearman correlations to approach a multicollinearity problem in our models. Two variables related to a lifestyle demonstrate high (values more than 0.3) correlation in case of South Africa (Table 7). Smoking and alcohol consumption are positively related, therefore, these independent variables shouldn't be included in the same regression.

As Table 8 witnesses, no lifestyle variables demonstrate statistical closeness in case of Russia. All the values of Spearmen pair correlation are below 0.3. Therefore, there are no objections for inclusion of any combination of these variables in a regression.

The number of variables for households' items is big enough to present full tables of Spearmen correlations here. Instead, we put the tables in Supplementary Materials (Appendix I and J). However, here we note the related variables. In case of Russia, a statistical closeness is observed in the following variables. Availability of a digital camera correlates with microwave oven, flat color television, computer (desktop and laptop), and high-speed internet connection (coefficients of pair correlations are above 0.3). Variables for a washing machine, microwave oven, flat color television, and high-speed internet connection are also close enough. And we should note pair correlation between variables of foreign car and GPS. There are not many variables with high enough Spearman correlation scores, however, we avoid analysing them in the same regressions.

The number of related variables in case of South Africa is bigger compared to the Russian sample. Almost every variable of households' item has a correlation score above 0.3 with some other variable (see Supplementary Materials for details). Therefore, every variable is a candidate for the proxy of a welfare. And we should use in regression only one factor at a time to investigate socio-economic determinants of risk groups.

Given the results on statistical closeness of variables within two groups (indicators of lifestyle and indicators of welfare) we are now ready to analyze the role of substance use (including smoking and alcohol consumption), nutrition (such as regularity of nutrition and growing vegetables and fruits), the source of medical care, and proxy of welfare in explaining the differences in anemia prevalence. We start with models that capture differences in the household ownership of assets. For South Africa, models S-1 and S-2 (Table 9) show that individuals have lower odds of being anemic if they belong to households with a washing machine (OR = 0.699, 95% CI: 0.564–0.866, $p \leq 0.01$) or an electric/gas oven (OR = 0.769, 95% CI: 0.613–0.967, $p \leq 0.05$). Other variables relating to property items are insignificant. This could likely be explained by the availability of additional time for housekeeping and cooking. The significant role of the electric/gas oven in reducing the risk of anemia supports this assumption. Other items, such as a personal computer, mobile phone, or satellite TV, do not have a significant effect. Thus, the problem of anemia in South Africa may not be a matter of prosperity, or these items may not serve as reliable proxy variables for wealth in the South African context.

In the case of Russia, statistical models also demonstrate the significance of household appliances (Table 10). The odds of being anemic decrease if a person has access to a fridge (OR = 0.773, 95% CI: 0.647–0.924, $p \leq 0.01$) or a microwave (OR = 0.832, 95% CI: 0.693–0.998, $p \leq 0.05$). However, we also note the significance of items that could be considered proxy variables for wealth. The odds of an individual being anemic are lower if their household has items unrelated to food preparation and storage,

Table 9 Results of multinomial regression. Welfare, South Africa

Variable	Models for SANHANES (mild)	
Model number	S-1	S-2
Observations	4390	4340
Pseudo R -square	0.0013	0.0036
LR chi2	6.660*	17.890***
Degree of freedom	3	3
BIC	5104.829	5041.437
AIC	5066.506	5003.183
Log likelihood	-2527.253	-2495.591
	Exp B (95% CI)	Exp B (95% CI)
Anemia outcome = 1 (Base = 0)		
Constant	0.147*** (0.121–0.179)	0.137*** (0.121–0.154)
Availability of electric/ gas oven	0.769** (0.613–0.967)	
Availability of a washing machine		0.699*** (0.564–0.866)
Anemia outcome = 2 (Base = 0)		
Constant	0.078*** (0.060–0.102)	0.075*** (0.064–0.087)
Availability of electric/ gas oven	0.846 (0.626–1.142)	
Availability of a washing machine		0.780* (0.593–1.026)
Anemia outcome = 3 (Base = 0)		
Constant	0.010*** (0.005–0.021)	0.010*** (0.006–0.015)
Availability of electric/ gas oven	0.628 (0.274–1.439)	
Availability of a washing machine		0.366** (0.138–0.968)

Base: No anemia, ***Significant at 99%, **Significant at 95%, *Significant at 90%

S1 labels a model with constant and an oven as independent variable. S2 labels a model with constant and a washing machine as independent variable

Table 10 Results of multinomial regression. Welfare, Russia

Variable	Models for RLMS		
Model number	R-1	R-2	R-3
Observations	14,353	14,319	14,308
Pseudo R -square	0.0033	0.0062	0.0094
LR chi2	14.660***	27.880***	42.04***
Degree of freedom	2	3	5
BIC	4495.633	4492.52	4496.681
AIC	4518.348	4462.243	4451.270
Log likelihood	-2244.816	-2227.121	-2219.635
	Exp B (95% CI)	Exp B (95% CI)	Exp B (95% CI)
Anemia outcome = 1 (Base = 0)			
Constant	0.049*** (0.042–0.057)	0.051*** (0.044–0.058)	0.046*** (0.037–0.056)
The presence of a refrigerator	0.773*** (0.647–0.924)		0.758*** (0.631–0.911)
Availability of a washing machine			1.412*** (1.124–1.773)
Availability of a DVD player		0.819** (0.684–0.981)	0.822** (0.685-986)
Availability of a personal computer		0.754*** (0.629–0.905)	0.726*** (0.602–0.875)
The presence of a passenger car		0.757** (0.610–0.938)	0.745*** (0.600-0.924)
Availability of microwave	0.832** (0.693–0.998)		

Base– no anemia, ***Significant at 99%, **Significant at 95%, *Significant at 90%

R1 labels a model with constant, a refrigerator and a microwave as independent variables. R2 labels a model with constant, DVD, a computer and a car as independent variables. R3 labels a model with constant and the above property except a microwave as independent variables

such as a DVD player (OR = 0.819, 95% CI: 0.684–0.981, $p \le 0.05$), a personal computer (OR = 0.754, 95% CI: 0.629–0.905, $p \le 0.01$), or a passenger car (OR = 0.757, 95% CI: 0.610–0.938, $p \le 0.05$). These items retain their significance in Model R-3, which includes a refrigerator and washing machine. The odds maintain their qualitative relationship with anemia, except for the washing machine (OR = 1.412, 95% CI: 1.124–1.773, $p \le 0.01$). We currently have no explanation for the positive odds in this case.

Substance use behaviors allow for the distinction between anemic and healthy states in both samples

(Table 11). However, the direction of the effect contradicts common intuition. A formal approach to the analysis of the statistical models leads to the following interpretation: smoking and alcohol consumption are associated with a lower chance of being anemic compared to healthy individuals. The statistically significant inverse relationship is evident. Model R-4 shows lower odds of being anemic in Russia for individuals who smoke (OR = 0.494, 95% CI: 0.378–0.645, $p \leq 0.01$) or consume alcohol (OR = 0.695, 95% CI: 0.554–0.871, $p \leq 0.01$). According to Model S-3, the same relationship holds for South Africa: alcohol consumption (OR = 0.598, 95% CI: 0.433–0.825, $p \leq 0.01$) and smoking (OR = 0.675, 95% CI: 0.503–0.907, $p \leq 0.01$) are associated with lower odds of being anemic. This relationship can likely be explained by the general state of health. It is more reasonable to assume that non-anemic individuals feel healthier and, as a result, on average, drink alcohol and smoke more often than those vulnerable to certain diseases. Anemic individuals, on the other hand, may have stronger motivations for maintaining a healthy lifestyle and are therefore more likely to give up smoking and alcohol use.

Two more variables proved to be less clear in explaining the differences within the samples. The " Involvement in agriculture activity" variable was not significant in the case of Russia. One reason for this is that this activity is widespread in Russia, and many respondents answered positively to the corresponding question. As a result, this common feature lacks the ability to distinguish between groups within the sample. On the other hand, in the case of South Africa, " Involvement in agriculture activity " was positively associated with anemia (OR = 1.333, 95% CI: 1.063–1.671, $p \leq 0.05$).

The second variable, which was significant only in one of the samples (RLMS in this case), is the source of medical care in case of illness — specifically, whether a person seeks help from a medical organization or relies on self-medication. The habit of visiting a doctor when ill is associated with a lower chance of being anemic. The relative risk of being anemic compared to being healthy is lower if a person seeks a doctor when they feel any health problems (OR = 0.774, 95% CI: 0.704–0.850, $p \leq 0.01$). It is reasonable to assume that a doctor would prescribe a patient a general blood test — one of the standard diagnostic methods during the first stage of medical care in

Table 11 Results of multinomial regression. Lifestyle

Variable	Models for SANHANES		Models for RLMS	
Model number	S-3	S-4	R-4	R-5
Observations	4176	4353	9462	7017
Pseudo R- square	0.012	0.0013	0.0163	0.0087
LR chi2	60.080***	6.360*	46.750***	27.600***
Degree of freedom	6	3	2	1
BIC	4880.95	5072.607	2843.991	3158.735
AIC	4823.916	5034.335	2822.526	3145.023
Log likelihood	-2402.958	-2511.168	-1408.263	-1570.511
	Exp B (95% CI)	Exp B (95% CI)	Exp B (95% CI)	Exp B (95% CI)
Anemia outcome = 1 (Base = 0)				
Constant	0.142*** (0.127–0.159)	0.113*** (0.101–0.127)	0.056*** (0.047–0.067)	0.142*** (0.105–0.193)
Alcohol consumption	0.598*** (0.433–0.825)		0.695*** (0.554–0.871)	
Smoking	0.675*** (0.503–0.907)		0.494*** (0.378–0.645)	
Source of Regular Medical Care				0.774*** (0.704–0.850)
Involvement in agriculture activity		1.333**(1.063–1.671)		
Anemia outcome = 2 (Base = 0)				
Constant	0.0.86*** (0.075–0.099)	0.069*** (0.060–0.080)		
Alcohol consumption	0.523*** (0.334–0.817)			
Smoking	0.525*** (0.345–0.797)			
Involvement in agriculture activity		0.966 (0.705–1.325)		
Anemia outcome = 3 (Base = 0)				
Constant	0.010*** (0.006–0.014)	0.008*** (0.005–0.012)		
Alcohol consumption	0.816 (0.238–2.793)			
Smoking	0.144* (0.019–1.104)			
Involvement in agriculture activity		0.836 (0.316–2.215)		

Base outcome: no anemia, ***Significant at 99%, **Significant at 95%, *Significant at 90%

S-3 and R-4 label models with constant, alcohol consumption and smoking as independent variables for South Africa and Russia respectively. S-4 labels a model with constant and "Involvement in agriculture activity" as an independent variable for South Africa. R-5 labels a model with constant and source of medical care as an independent variable for Russia. Russian data don't have outcomes 2 and 3– only 0 and 1

Table 12 Results of multinomial regression. Welfare and lifestyle, SA

Variable	Model for SANHANES
Model number	S-5
Observations	4283
Pseudo R -square	0.0348
LR chi2	172.830***
Df	9
BIC	4887.32
AIC	4810.971
Log likelihood	-2393.486
	Exp B (95% CI)
Anemia outcome = 1 (Base = 0)	
Constant	0.058*** (0.039–0.088)
Involvement in agriculture activity	1.255* (0.996–1.581)
Gender	1.617*** (1.295–2.020)
Availability of a washing machine	0.702*** (0.563–0.873)
Anemia outcome = 2 (Base = 0)	
Constant	0.001*** (0.000-0.003)
Involvement in agriculture activity	0.959 (0.692–1.330)
Gender	9.81*** (5.695–16.899)
Availability of a washing machine	0.769* (0.580–1.019)
Anemia outcome = 3 (Base = 0)	
Constant	0.001*** (0.000-0.007)
Involvement in agriculture activity	0.730 (0.273–1.949)
Gender	4.750** (1.427–15.813)
Availability of a washing machine	0.343** (0.129–0.913)

Base: no anemia, ***Significant at 99%, **Significant at 95%, *Significant at 90%

Russia. This test, among other things, measures the level of hemoglobin and, therefore, allows for the timely detection of nutrient imbalances. This is true even if the symptoms that prompted the patient to seek medical care are unrelated to anemia.

Thus, our analysis demonstrates the significant role of factors related to unhealthy habits in both samples. Socioeconomic status has no explanatory power in the studied datasets. In South Africa, it seems that the high burden of farming is associated with a higher likelihood of anemia. This assumption is supported by the model, which includes the mentioned variables related to household management and the gender of the respondent (see Table 12). The model shows that the presence of a washing machine is negatively associated with the relative risk of anemia compared to being healthy (OR = 0.702, 95% CI: 0.563–0.873, $p \leq 0.01$), while involvement in agriculture activity (OR = 1.255, 95% CI: 0.996–1.581, $p \leq 0.10$) and being female (OR = 1.617, 95% CI: 1.295–2.020, $p \leq 0.01$) are associated with an increased likelihood of anemia.

Our results demonstrate a strong relationship between anemia status and substance use behaviors for both South Africa and Russia. We note a consistent qualitative pattern in this relationship. Statistical investigation of the two databases also reveals the significance of

Table 13 Co-occurrence of anemia status vs. locality in South Africa

	Rural	Urban
Anemia not detected	1546	2417
Mild anemia	202	275
Total	1748	2692

Table 14 Spearman correlations for selected factors in South Africa

	Anemia status	Locality	Involvement in agriculture activity
Anemia status	1.000		
Locality	-0.029	1.000	
Involvement in agriculture activity	-0.020	0.2830	1.000

household property in identifying risk groups. However, income levels and education show no statistical relationship with anemia in Russia and South Africa. In Russia, items related to household prosperity have explanatory power: the presence of a car, personal computer, DVD player, or refrigerator in the household is associated with a lower chance of being in the anemic group compared to the healthy group. On the other hand, South African families benefit from household items such as an electric/gas oven and washing machine. Other items — such as the availability of a telephone, computer, etc. — have no discriminatory power in the case of the SANHANES sample.

The significance of items related to food preparation supports the assumption that these items allow an individual to channel their efforts into a more attentive approach to nutrition within the family. Model S-5 also takes into account participation in agriculture activity. This model suggests that families engaged in agriculture but lacking household appliances are the most vulnerable to anemia. It is natural to assume that such a model highlights the difference between urban and rural residents. But SANHANES data do not reveal a statistically significant difference in the risk of being anemic between urban and rural residents (see Table 13). Indeed, for rural areas, the relative number of anemia cases is higher: 11.6% (202 out of 1748) compared to 10.2% (275 out of 2692) for urban areas. However, the multinomial regression model does not allow us to conclusively associate this difference specifically with the respondents' place of residence (p-value = 0.5).

At the same time, it appears that the cultivation of vegetables and fruits barely correlates with the place of residence. The Spearman correlation matrix for ranked variables is displayed in Table 14.

In this context, SANHANES data do not consistently characterize locality as a determining factor in ensuring households have access to high-quality and balanced nutrition.

The assumption regarding the relief from time-consuming duties and its role in anemia prevention in South Africa is not dismissed but requires further meticulous testing.

Discussion

Returning to the identification of risk groups using RLMS for agent-based modeling, we observe that self-reports yield results similar to surveys involving medical investigations. The findings for Russia align with the widely accepted notion that higher levels of welfare are associated with a reduced risk of anemia: the possession of certain assets is linked to a decreased risk of the disease. In households equipped with a refrigerator, a DVD player, a personal computer, or a car, individuals are statistically less likely to be anemic. A prior Russian population survey, which included medical investigations to detect anemia, highlighted the presence of a personal computer and a car, along with income level and second home ownership [38]. Among the identified assets, only the refrigerator directly contributes to enhanced nutrition opportunities, while the other possessions primarily indicate the general level of welfare. Previous studies based on the initial four RLMS waves (August-October 1992, December 1992-March 1993, July-September 1993, and October 1993-February 1994), despite using a different methodology compared to our research, revealed that poverty and low meat consumption significantly impact nutritional deficiencies and, consequently, the development of anemia [39]. Analysis of RLMS data from 1996 to 2008 indicated an increase in the consumption of vitamins- and minerals-rich supplements alongside individual income growth [40]. However, during the same period, fiber consumption exhibited a decrease.

The next significant factor in Russia is the practice of seeking medical help instead of self-medicating. Individuals who adhere to this practice have a lower risk of anemia. This association is linked to the detection of the disease irrespective of the initial reason for the hospital visit. Anemia can be identified through a blood test, which is a standard component of primary care in Russia.

Common to the Russian and South African samples are the associations of anemia with smoking and alcohol consumption. Furthermore, both factors exhibit an inverse relationship with anemia: statistically, individuals who smoke and consume alcohol are at a lower risk of anemia. We attribute this correlation to overall health. Individuals with poor health and susceptibility to various risks tend to abandon unhealthy habits in favor of a healthier lifestyle. A similar relationship was previously observed in Indian men [24], where smoking was also negatively correlated with the risk of anemia. However, this relationship was not further elaborated upon in the cited study.

Involvement in agriculture activity appeared to be significant factor of mild anemia in the case of South Africa. Indeed, the previous studies has noted differences in the prevalence of anemia between urban and rural areas [24, 41], and rural residents are also known to have poorer access to diets of high quality with a variety of food [42]. However, our analysis doesn't recognize locality as a factor of anemia. There are several possible reasons for this. Firstly, an urban agriculture policy has been implemented in South Africa [43]. Secondly, a recent study indicates that in the South African context, the cost of the diet is not the primary concern regarding anemia; rather, it is the nutrient-density-to-price ratio [44]. This suggests that individuals who are health-conscious opt for a diet with higher nutritional value at the same cost. However, nutritionists observe that the cost of a balanced diet is often prohibitive for a large portion of the population [45]. Personal preference likely influences dietary choices. Interviews, while not fully representative, suggest that individuals tend to prepare and consume foods according to their preferences, regardless of whether the menu is perceived as healthy [46]. Nevertheless, cereals and legumes are staples in the typical diet [47], and these foods are known to contain phytates, which are inhibitors of iron absorption.

At the outset of our study, we hypothesized that questionnaires could yield results as valuable as medical measurements. Both the medically investigated (SANHANES) and self-reported (RLMS) samples exhibit commonalities in healthy lifestyle factors, while socio-economic factors show variation between the samples. We attribute this variation to the cultural specifics of South Africa and Russia. Previous medical surveys have reported divergent conclusions on similar factors, with some studies emphasizing the role of socio-economic factors and others not [48]. Therefore, we acknowledge the validity of self-assessments in modeling disease prevalence, considering the cultural nuances of the population being modeled.

Conclusion

We conducted a comparison of the roles of socio-economic factors in the prevalence of anemia across two distinct samples. The first sample was derived from the SANHANES survey in South Africa, which categorizes health status based on medical observations. The second sample was sourced from the RLMS survey in Russia, which tracks respondents' self-reports regarding whether a doctor diagnosed them with anemia in the past 12 months before the interview. The variables of interest in our study encompassed indicators of education, well-being, lifestyle, regular access to food, cultivation of fruits and vegetables, and sources of medical care. These variables are commonly acknowledged as socio-economic factors affecting anemia. Through the analysis of representative samples using the multinomial regression method, we uncovered the shared significance of healthy lifestyle factors - particularly smoking and alcohol avoidance - in both samples. We attribute the negative correlation of these factors with anemia to the inclination of individuals with poor health to relinquish unhealthy habits.

Educational level did not emerge as a determinant of anemia, nor did income level or locality. However, the proxy of household welfare variables — such as property ownership — was found to be statistically significant. In the context of South Africa, the presence of an electric or gas oven, washing machine, and a lack of participation in growing fruits and vegetables showed positive significance for health. We attribute the absence of anemia to reduced efforts in household chores, indicating a greater focus on making mindful dietary choices. In the Russian sample, the presence of a personal computer, a DVD player, and a car demonstrated significant impacts. Studies have linked income growth in Russia to an increased demand for supplements containing vitamins and minerals. We find no reason to refute this finding, and we tend to associate the decline in anemia among wealthier individuals with their access to higher-quality products and nutritional supplements.

As the literature on anemia in Russia is limited, our results contribute to expanding the available information sources for investigating the disease in this region. The resemblance of risk factors in Russia to those in other countries enables us, with caution, to suggest using the RLMS dataset, which includes nearly 2500 questions, as a source for generating hypotheses related to anemia. These hypotheses could then be subjected to more rigorous testing through medical examinations. Furthermore, our findings could prove valuable for developing computer models of anemia prevalence in Russia, potentially leading to more accurate simulations and scenario analyses.

We should also acknowledge the limitations of our study. Firstly, we compared the South African survey, which included three stages of anemia, with the Russian survey that focused on only one stage. Secondly, we analyzed outdated data as SANHANES data pertains to 2012. Thirdly, since our analysis relies on questionnaires, the results regarding risk factors are applicable primarily to studies with similar question formulations or are unaffected by variations in question wording. Fourthly, our study does not account for regional and national nuances, which are crucial for a large and diverse country like Russia. This limitation arises from the fact that RLMS is a nationally representative study and does not provide regional-level data.

Recommendations

To combat anemia prevalence, public health initiatives should prioritize promoting healthy lifestyle practices, including abstaining from smoking and excessive alcohol consumption, both of which exhibited negative associations with anemia in South Africa and Russia. Nutritional awareness campaigns should underscore the significance of balanced diets and the utilization of nutritional supplements, emphasizing a shift away from labor-intensive food production in South Africa and enhancing access to high-quality products in Russia. Policies aimed at enhancing household welfare, such as improving access to essential appliances in South Africa and digital tools in Russia, can indirectly bolster healthier lifestyles. Regional strategies should also target systemic inequalities and harness economic growth to sustain anemia prevention endeavors. Additionally, delving into unexplored determinants like the roles of education, income, and cultural dietary patterns is crucial for crafting more impactful interventions.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22363-6.

Supplementary Material 1

Author contributions

Maria A. Burilina– RLMS data processing, literature review. Natisha Dukhi– design of the general methodology of the research, literature review. Aleksandra L. Mashkova– design of the general methodology of the research. Ivan V. Nevolin– RLMS data processing and interpretation, literature review. Ronel Sewpaul– SANHANES data processing and interpretation.

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Data availability

Raw RLMS data are available at the project website https://www.hse.ru/en/rlms/data. Raw SANHANES data are available upon request.

Declarations

Ethical approval and informed consent statements

No ethical approval was required.

Competing interests

The authors declare no competing interests.

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