Cardiovascular risk factors among oil refinery workers: ecological study

Fatores de risco cardiovascular em trabalhadores de uma refinaria de petróleo e derivados: um estudo ecológico

Flavia Cortines Carvalho[1], Marluce Rodrigues Godinho[2], Aldo Pacheco Ferreira[3]

ABSTRACT | Background: Monitoring the health of workers is indispensable to develop indicators to identify potential risk factors and the workload impact on illness and characterize their morbidity profile. **Objective:** To identify modifiable and non-modifiable cardiovascular risk factors among employees of an oil refinery with fixed work schedule or allocated to shifts. **Methods:** Ecological, exploratory, descriptive and quantitative study with data retrieved from the company's record system. We performed time series analysis of the prevalence of risk factors in the period from 2008 through 2017. **Results:** We found an increasing trend in the prevalence of hypertension and diabetes and a decreasing trend for high cholesterol, high LDL, low HDL, smoking and coronary artery risk. The prevalence of hypertension increased, while that of all other risk factors, except for diabetes, decreased in 2017 by comparison to 2008. **Conclusion:** The analyzed sample is at medium risk for cardiovascular disease despite their young age, high educational level and available resources. We call attention to the need to systematize workplace health promotion programs.

Keywords | occupational health; cardiovascular diseases; oil and gas industry; workers; risk factors.

RESUMO | **Introdução:** O monitoramento da saúde do trabalhador é uma ferramenta indispensável, pois possibilita a construção de indicadores que permitem a identificação de fatores como potenciais riscos à saúde e impactos das cargas de trabalho envolvidas no processo de adoecimento e caracterização do perfil de morbidade do trabalhador. **Objetivo:** Identificar fatores de risco modificáveis e não modificáveis para doenças cardiovasculares em trabalhadores de turno e de jornada fixa de uma refinaria de petróleo e derivados. **Método:** Estudo ecológico, de caráter exploratório, descritivo e quantitativo. A coleta de dados foi realizada no módulo de indicadores do sistema corporativo do serviço de saúde da refinaria, tornando possível a realização de análises temporais sobre a prevalência dos fatores de risco à saúde dos trabalhadores, no período de 2008 a 2017. **Resultados:** Observaram-se tendência crescente na hipertensão e na diabetes nos trabalhadores ao longo do período analisado e tendência decrescente dos fatores de risco colesterol alto, lipoproteínas de baixa densidade (LDL) alto, lipoproteínas de alta densidade (HDL) baixo, tabagismo e risco coronariano. Ao comparar as prevalências de 2008 e 2017, foi possível também verificar aumento significativo na hipertensão e redução expressiva dos demais fatores de risco, exceto para diabetes. **Conclusão:** Pelos dados encontrados, pode-se inferir que os empregados apresentam risco moderado para o desenvolvimento de doenças cardiovasculares, apesar da baixa faixa etária, do nível de escolaridade elevado e dos recursos disponíveis na empresa. Aponta-se para sistematização de programas de promoção de saúde no ambiente de trabalho.

Palavras-chave | saúde do trabalhador; doenças cardiovasculares; indústria de petróleo e gás; trabalhadores; fatores de risco.

[1]Occupational Department, Duque de Caxias Refinery – Rio de Janeiro (RJ), Brazil.

[2]School of Nursing, Universidade Federal de Juiz de Fora – Juiz de Fora (MG), Brazil.

[3]Department of Human Rights, Health and Cultural Diversity, Sergio Arouca National School of Public Health – Rio de Janeiro (RJ), Brazil.

INTRODUCTION

Illness among workers has been a considerable topic of research as of lately. However, despite a broad scope of studies on this subject, there are still gaps in the knowledge needed to promote effective participation of workers in their health and work processes and emphasize the commitment and responsibility of employers[1].

Understanding how illness occurs is no easy task, because it goes beyond identifying diseases and risk factors to consider changes in the world of work, negative impacts of organizational patterns and new technologies, labor demands and social relations. All these factors influence the balance between health and disease and are determinants of physical and mental disorders among workers[2,3]. In addition, such complexity hinders the implementation of actions to minimize the associated morbidity.

Workers are exposed to the same health problems as the general population, and also to work-related diseases, which include job-specific problems and others derived from their working conditions. As a result, establishing a causal relationship between work and disease is often difficult, thus differing from typical occupational accidents[4].

Laurel and Noriega[5] observe that occupational diseases and accidents result from unloaded adjustment of workers to their work environment — understanding loads as physical, chemical, biological, mechanical, physiological and mental aspects. Work is a means for people to achieve personal goals, earn a living and attain social status. As such, it is one of the main determinants of health for workers, their families and society at large.

According to the Brazilian Policy of Occupational Health[6], prevention and health promotion and protection actions cannot be separated from health care delivery, including individual and collective rehabilitation. This policy describes principles, guidelines and strategies for the national health system (Sistema Único de Saúde–SUS)[7] at its three management levels to provide integrated health care and thus promote and safeguard the health of workers and reduce work-related morbidity and mortality.

The goal of health surveillance in the present time is to overcome older disease- and hygiene-based paradigms to shift the focus to health promotion[1]. Health protection demands paying attention to occupational risks, while the aim of health recovery actions is to provide care to already sick workers[4]. Both goals point to the need to investigate different work processes and the consequences of uninterrupted production activities on the health of workers[8].

Cardiovascular disease (CVD) — including coronary artery disease (CAD), heart failure, angina, acute myocardial infarction, valve heart disease, arrhythmias and hypertension, among others — is considered a major public health problem[9]. It is associated with several modifiable or no risk factors[10], such as hyperlipidemia, smoking, drinking, high blood sugar, obesity, sedentary lifestyle, poor diet and oral contraception, and family history, age, sex and ethnicity respectively[11].

To safeguard the health of their employees organizations should implement systems to monitor preventive medicine programs[12]. In Brazil, workplace safety and occupational medicine Regulatory Standards (RS) describe disease prevention and health promotion actions to avert high-risk situations and harms to the health of workers. RS 4[13] establishes the creation of Safety Engineering and Occupational Medicine Specialized Services in organizations to meet the goals of health promotion and protection in the workplace. RS 7[14] establishes the formulation and implementation of a Medical Control and Occupational Health Program (MCOHP) to screen for occupational diseases and achieve early diagnosis[15].

According to Moreno and Louzada[16], one of the most significant discoveries ever is that the human is a diurnal species, therefore, upon interfering with the circadian rhythm, shift work has consequences for health. Yet, these authors further observe, a shift schedule including several teams is necessary to ensure the continuity of production/service delivery. Shifts may be fixed, rotational or variable, while changes in the work schedule and night work may behave as risk factors for several problems, including CVD, gastrointestinal and sleep disorders.

MCOHP at the oil refinery analyzed in the present study is formulated and implemented by the company department of occupational medicine. Actions include focused medical examinations according to intrinsic hazards and monitoring risk factors for noncommunicable diseases, as e.g. CVD, and their consequences for the quality of life of workers. In addition, the staff prepares clinical and epidemiological reports to ground

the planning and execution of health actions based on the actual prevalence of detected diseases to thus improve the employees' quality of life.

The aim of the present study was to identify risk factors for CVD among employees of an oil refinery.

METHODS

In the present ecological, exploratory, descriptive and quantitative study with time series analysis we sought to establish the prevalence of risk factors for the health of employees of an oil refinery in Rio de Janeiro, Brazil. Participants were workers under shift or fixed work schedule who complied with periodic medical occupational examinations on the premises from 2008 through 2017. We excluded outsourced workers and company employees who performed examinations in facilities other than the employer's. Data were obtained from the company's Health Management Computerized Corporate System (HMCCS).

Since the present study was based on de-identified data, there was no need for informed consent. Ethical approval was granted by Sérgio Arouca National School of Public Health, Oswaldo Cruz Foundation, ruling no. 2,512,157, on 26 February 2018, in compliance with the National Health Council Resolution no. 510/2016.

The analyzed company accounts for 80% of lubricant production, the largest amount of natural gas processing in Brazil, and the largest product portfolio (55 products processed in 43 units). At a strategical location, the company was the starting point for a strong regional industrial complex. Today the refinery operates linked to a wide network of industries, ensuring supply to market demands of fuel, lubricants, petrochemicals and gas. It participates intensively in the natural gas chain, both in the distribution and supply of input for the petrochemical industry in Rio de Janeiro, São Paulo, Espírito Santo, Minas Gerais, Bahia, Ceará, Paraná and Rio Grande do Sul.

Employees with fixed schedule work Monday to Friday from 7:30 to 16:30, being off duty on weekends and holidays to a total of 40 hours/week. Shiftwork was implemented to ensure uninterrupted operation, through five rotational teams under three 8-hour shifts — 7:00 to 15:00, 15:00 to 23:00 and 23:00 to 7:00 — all seven days of the week,

including holidays, with rest between shifts, to a total working time of 32 hours/week. These workers receive additional pay. The work/rest schedule was approved by the corresponding trade union and complies with the labor laws in force.

Shiftwork has both advantages and disadvantages, and health surveillance studies might contribute to the identification of health problems among the involved population of workers to enable early interventions as per need.

Data analyzed in the present study were health indicators obtained from the records of periodic medical examinations to grant occupational health certificates. These examinations also include some diagnostic tests as established in MCOHP, which are requested by the physician who chairs the program as a function of environmental hazards detected through the company's Environmental Hazard Prevention Program. We selected the HMCCS health indicators module for information to calculate the prevalence of CAD risk in 10 years[17]. Variables considered were age, sex, diabetes, blood pressure, total cholesterol (desirable <190 mg/dL), high-density lipoprotein (HDL, desirable ≥60 mg/dL), low-density lipoprotein (LDL, desirable <130 mg/dL) and smoking.

We performed statistical analysis with software Statistical Package for the Social Sciences (IBM SPSS Statistics Base 22.0). Descriptive analysis included calculation of absolute (n) and relative (%) frequencies of qualitative variables. Annual prevalence rates of risk factors were calculated for the period from 2008 to 2017. The results are presented as frequency tables and line plots. Job position was defined as unit of analysis, with consideration of the actual weight of each. We estimated trends in the prevalence of risk factors by means of χ^2 for linear trend statistic of ordinal variables (linear-by-linear association test). Binary logistic regression analysis was performed to test shiftwork as risk factor for health outcomes with control for sex and age. We set cut-off points for categorization based on the prevalence of each analyzed outcome. The goodness-of-fit of the logistic regression model was assessed by means of the χ^2 test, Nagelkerke's pseudo R^2 and the Hosmer-Lemeshow test and the model's predictive ability based on the categorization table. The significance level was set to 5% in all the analyses.

RESULTS AND DISCUSSION

The highest odds of hypertension and high LDL corresponded to men above 40 and shift workers. The highest odds of diabetes were exhibited by workers above 40 and those with fixed work schedule independently from sex. Risk of CVD was moderate, despite young age, high educational level and available resources at the company. The results further indicated a high rate of employees exposed to three or more risk factors, whence one may infer a need for multiple interventions.

Overall, our findings demonstrate the relevance of the present study by providing relevant and/or alarming information essential for the follow-up of the analyzed population of workers.

In the calculation of prevalence rates for trend analysis we considered the total number of employees in each analyzed year to a total of 16,710. Figure 1 depicts linear trends in the prevalence of the analyzed risk factors from 2008 to 2019: increasing trend for high blood pressure (χ^2=44.883, p<0.001) and diabetes (χ^2=9.138, p=0.003) and decreasing trend for high cholesterol (χ^2=39.133, p<0.001), high LDL (χ^2=70.862, p<0.001), low HDL (χ^2=532.042, p<0.001), smoking (χ^2=61.808, p<0.001) and CAD risk (χ^2=22.809, p<0.001).

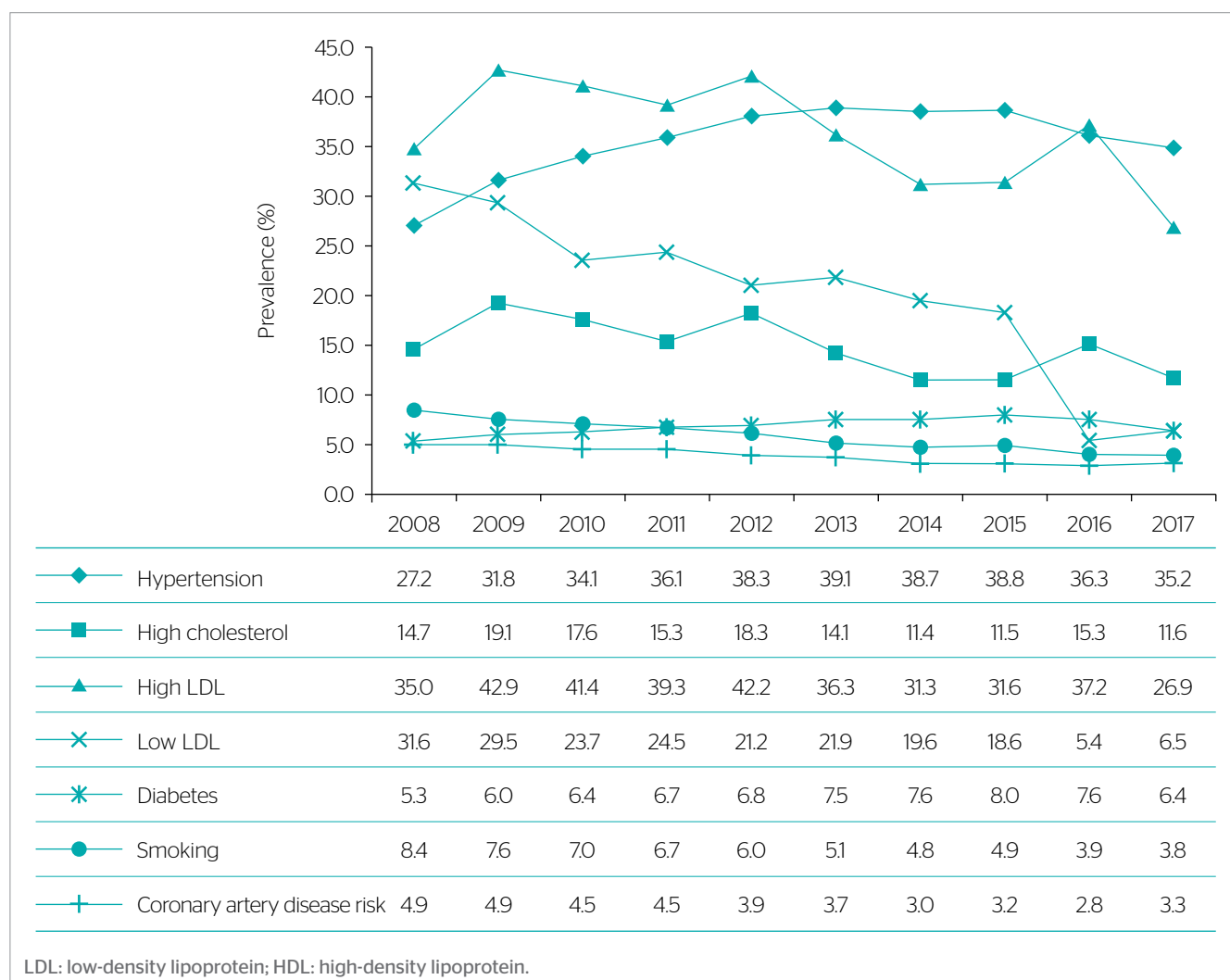The prevalence of hypertension significantly increased in 2017 compared to 2008, while that of high cholesterol,

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hypertension	27.2	31.8	34.1	36.1	38.3	39.1	38.7	38.8	36.3	35.2
High cholesterol	14.7	19.1	17.6	15.3	18.3	14.1	11.4	11.5	15.3	11.6
High LDL	35.0	42.9	41.4	39.3	42.2	36.3	31.3	31.6	37.2	26.9
Low LDL	31.6	29.5	23.7	24.5	21.2	21.9	19.6	18.6	5.4	6.5
Diabetes	5.3	6.0	6.4	6.7	6.8	7.5	7.6	8.0	7.6	6.4
Smoking	8.4	7.6	7.0	6.7	6.0	5.1	4.8	4.9	3.9	3.8
Coronary artery disease risk	4.9	4.9	4.5	4.5	3.9	3.7	3.0	3.2	2.8	3.3

LDL: low-density lipoprotein; HDL: high-density lipoprotein.

Figure 1. Prevalence of risk factors among employees of an oil refinery, 2008–2017. Rio de Janeiro, Brazil (n=16,710).

high LDL, smoking, CAD risk and especially low HDL decreased (Table 1).

Figure 2 depicts the prevalence of the analyzed risk factors according to work schedule (shift vs. fixed). For the entire period (n=16,170) shift workers exhibited higher rates of hypertension (37.5 vs. 31.9%, χ^2=52.257, p<0.001) and high LDL (37.8 vs. 34.6%, χ^2=17.316, p<0.001). In turn, employees with fixed work schedule exhibited high prevalence of diabetes (7.8 vs. 6.3%, χ^2=14.470, p<0.001), smoking (6.6 vs. 5.5%, χ^2=9.240, p=0.002) and CAD risk (4.5 vs. 3.6%, χ^2=8.835, p=0.003). We did not find significant difference in the prevalence of high cholesterol (15.1 vs. 14.4%, χ^2=2.803, p=0.09) or low HDL (20.3 vs. 21.4%, χ^2=2.787, p=0.09) between both groups.

The identification of risk factors relevant for the prevention and change of the course of CVD challenged the idea that these diseases are genetically determined and thus little could be done, resulting in collective fatalism[16,17]. Several studies sought to identify such factors in different groups of people[10,18-21], and shiftwork was found to contribute to serious physical, mental and/or social problems.

Although our sample had a definite profile, the prevalence rates we found are quite similar to those reported

for other populations independently from socioeconomic and cultural aspects. Fischer and Lieber[22] reported CVD as the main problem associated with shiftwork, as in the present study. Also other authors, such as Olsen and Kristensen[23] and Tüchsen[24], found higher CAD risk among shift workers; Ely and Mostardi[25] detected higher serum norepinephrine levels.

Shiftwork may increase the relative risk of CAD by interfering with the possibility of a healthy lifestyle and modifying the natural history of risk factors. For this reason, it deserves special attention in the organization of work, CVD prevention and health promotion actions.

All the analyzed risk factors were significantly associated with age and sex, with higher prevalence among male and younger workers. To verify this relationship we fitted a multivariate model with control for these variables. Tables 2–4 describe the regression coefficients obtained with their significance within the model. Reference categories were: female sex, age 20–29 and fixed worked schedule. Tested risk factors were hypertension, high LDL and diabetes, because on bivariate analysis high cholesterol, low HDL and job position did not exhibit a significant relationship and the models fitted for smoking and CAD risk were invalid.

The model fitted proved to be valid to categorize works with hypertension and accounted for 15% of the variability. The odds of hypertension were higher for men (1.3 times), employees aged above 40 (3.4 to 6.4 times) and shift workers (1.3 times). The model had 65% of accuracy in the categorization of workers with hypertension, 52.5% of sensitivity (accurate identification of individuals with high blood pressure) and 72.5% of specificity ((accurate identification of individuals without high blood pressure) (Table 2).

The model was also valid to categorize workers with high LDL, but variables sex, age and job position accounted only for 3% of the variability. Shiftwork did not exhibit a statistically significant relationship with this outcome. The odds of high LDL were higher for men (1.4 times) and workers aged over 40 (1.8 and 2.1 times). Accuracy was 60%, sensitivity 36.6% and specificity 73.8% (Table 3).

Finally, the model proved to be also valid to categorize workers with diabetes and accounted for about 10% of the variability. Odds of diabetes were higher for workers above

Table 1. Prevalence of risk factors among employees of an oil refinery along 10 years (2008 vs. 2017), Rio de Janeiro, Brazil (n=3,040).

Outcome	Prevalence		χ^2	p-value
	2008	2017		
Hypertension	27.2%	35.2%	22.160	<0.001*
High cholesterol	14.7%	11.6%	6.276	0.01*
High LDL	35.0%	26.9%	22.751	<0.001*
Low HDL	31.6%	6.5%	285.696	<0.001*
Diabetes	5.3%	6.4%	1.410	0.23
Smoking	8.4%	3.8%	26.271	<0.001*
Coronary artery disease risk	4.9%	3.3%	5.253	0.02*

LDL: low-density lipoprotein; HDL: high-density lipoprotein; *statistically significant difference, p<0.05; t χ^2.

Figure 2. Prevalence of hypertension, high cholesterol, high HDL, low HDL, diabetes, smoking and coronary artery disease risk among employees of an oil refinery, 2008–2017. Rio de Janeiro, Brazil (n=16,710).

LDL: low-density lipoprotein; HDL: high-density lipoprotein.

Table 2. Logistic regression model to calculate odds of hypertension among employees of an oil refinery, 2008–2017. Rio de Janeiro, Brazil (n=16,710).

Variable	Parameter estimate	Standard error	*p*-value	Odds ratio (95%CI)
Sex (male)	0.292	0.070	<0.001	1.34 (1.17–1.54)
Age (years)			<0.001	
40–49	1.237	0.050	<0.001	3.44 (3.12–3.80)
50–69	1.841	0.048	<0.001	6.30 (5.73–6.92)
Work schedule (shift)	0.282	0.037	<0.001	1.33 (1.23–1.43)
Intercept	-2.247	0.075	<0.0001	0.11

χ^2=1,901.126; p<0,001; Nagelkerke's R^2=0.15; Hosmer-Lemeshow: p=0.01; Predictive accuracy=65.4%

Table 4. Logistic regression model to calculate odds of diabetes among employees of an oil refinery, 2008–2017. Rio de Janeiro, Brazil (n=16,710).

Variable	Parameter estimate	Standard error	*p*-value	Odds ratio (95%CI)
Sex (male)	0.119	0.132	0.368	1.13 (0.87–1.46)
Age (years)			<0.001	
40–49	1.448	0.138	<0.001	4.26 (3.25–5.58)
50–69	2.330	0.129	<0.001	10.27 (7.98–13.23)
Work schedule (shift)	-0.166	0.066	0.012	0.85 (0.74–0.96)
Intercept	-4.308	0.167	<0.0001	0.01

χ^2=626,354; p<0,001; Nagelkerke's R^2=0.09; Hosmer-Lemeshow: p=0.004; predictive accuracy=64.2%

Table 3. Logistic regression model to calculate odds of high LDL among employees of an oil refinery, 2008–2017. Rio de Janeiro, Brazil (n=16,710).

Variable	Parameter estimate	Standard error	*p*-value	Odds ratio (95%CI)
Sex (male)	0.306	0.064	<0.001	1.36 (1.20–1.54)
Age (years)			<0.001	
40–49	0.765	0.043	<0.001	2.15 (1.98–2.34)
50–69	0.566	0.041	<0.001	1.76 (1.62–1.91)
Work schedule (shift)	0.058	0.035	0.096	1.06 (0.99–1.14)
Intercept	-1.339	0.065	<0.0001	0.26

χ^2=419.882; p<0,001; Nagelkerke's R^2=0.03; Hosmer-Lemeshow: p<0.001; predictive accuracy=60.1%

age 40 (4.2 to 10.3 times) and those with fixed work schedule (1.2 times) independently from sex. Accuracy was 64.2%, sensitivity 69.4% and specificity 63.9% (Table 4).

CONCLUSION

The aim of the present study was to detect modifiable and non-modifiable CVD risk factors among employees of an oil refinery with fixed work schedule or allocated to shifts. We found a linear trend in the prevalence of the analyzed risk factors along the period from 2008 to 2017 (n=16,710).

The analyzed oil refinery is one of the largest in Brazil in regard to installed oil refining capacity. Shiftwork was introduced to ensure an uninterrupted operation. We investigated shiftwork as risk factor for health outcomes with control for sex and age on multivariate analysis. Thus we found higher prevalence of hypertension and high LDL among shift workers compared to employees with fixed work schedule. In turn, the prevalence of diabetes, smoking and CAD risk

was higher among the latter. The prevalence of high cholesterol and low HDL did not differ between the groups.

The results revealed an increasing trend for hypertension and diabetes and a decreasing trend for high cholesterol, high LDL, low HDL, smoking and CAD risk. Upon comparing the rates corresponding to 2008 and 2017, that of hypertension exhibited significant growth, with substantial reduction of all other analyzed risk factors, except for diabetes.

Since presenting one or more of the analyzed risk factors increases the odd of disease—while absence does not result in the opposite outcome—promoting behavior changes among the target population to influence modifiable risk factors might contribute to reduce the morbidity and mortality by CVD.

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Correspondence address: Aldo Pacheco Ferreira – Departamento de Direitos Humanos e Saúde – Escola Nacional de Saúde Pública Sergio Arouca – Fundação Oswaldo Cruz – Prédio da Expansão – Avenida Brasil, 4,036 – Manguinhos – CEP: 21040-361 – Rio de Janeiro (RJ), Brazil – E-mail: aldopachecoferreira@gmail.com