ORIGINAL ARTICLE

Correlation between Lifestyle Factors and COVID-19 Indices: An Ecological Study

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Received: 08 January 2025
Revised: 04 February 2025
Accepted: 13 March 2025

Abstract

Background: Coronavirus disease of 2019 (COVID-19) became a public health threat to global public health in late 2019. This study aimed to investigate the correlation between lifestyle factors and the COVID-19 epidemiological indicators, including cumulative incidence rate, the cumulative rate of death, recovery rate, and case fatality rate.

Methods: In this ecological study, aggregate data were used. Information about COVID-19 for each country was retrieved from https://www.worldometers.info/ from the date of the first report until November 30th, 2020. The information on the prevalence of smoking, alcohol consumption, and obesity in 2019 was collected from https://www.indexmundi.com/. Moreover, the information on the prevalence of physical inactivity was obtained from the WHO website. We drew scatter plots of lifestyle factors based on COVID-19 indices.

Results: Results showed that the cumulative incidence rate and cumulative rate of death had significant direct correlations with the prevalence of obesity, physical inactivity, smoking, and alcohol consumption ($P<0.05$). This means that the countries with a high prevalence of obesity, physical inactivity, smoking, and alcohol consumption had increased indicators such as the cumulative incidence rate and cumulative rate of death ($P<0.05$). There were also significant inverse correlations between the recovery rate and the prevalence of smoking and alcohol consumption ($P<0.05$).

Conclusion: There are significant correlations between the cumulative incidence rate, the cumulative rate of death, and the recovery rate of COVID-19 with unhealthy lifestyle behaviors. Therefore, it is necessary to develop lifestyle modification strategies that can lead to reduction of the morbidity and mortality of this disease.

Please cite this article as: Rezaei F, Ghelichi-Ghojogh M, Mobasheri F, Amiri S, Piraee E, Dehghani SS, Hassani AH, Jokari K, Mirahmadizadeh AR. Correlation between Lifestyle Factors and COVID-19 Indices: An Ecological Study. J Health Sci Surveillance Sys. 2025;13(2):182-192.

Keywords: COVID-19, Lifestyle, Obesity, Physical inactivity, Smoking

Introduction

Several patients were admitted to hospitals with an initial diagnosis of pneumonia with an unknown cause in late December 2019. These patients were epidemiologically linked to a wholesale market for marine animals in Wuhan, Hubei Province, China.[1,2] Therefore, coronavirus disease of 2019 (COVID-19) became a global public health threat. The lower respiratory tract is the main target of this infection, and pneumonia is always present in patients with severe COVID-19.[3] Despite global efforts to prevent its spread, COVID-19 was eventually declared

a pandemic by the World Health Organization (WHO), affecting more than 70 million people worldwide as of December 15th, 2020, and having killed more than 1.6 million people.[4]

Various studies have shown that lifestyle may be effective in reducing coronavirus infection and death due to COVID-19. A study was done in California, stating that obesity plays an important role in the risk of death from coronavirus, especially in the young and male population.[5] In the United States, obesity was also recognized as an important risk factor for COVID-19.[6] There are different opinions about smoking and the risk of contracting the coronavirus. A study in 38 European countries found a negative association between coronavirus infection and smoking.[7] However, the results of a meta-analysis study revealed that smoking was a risk factor for the progression of COVID-19. Indeed, smokers are more likely to develop severe COVID-19 than non-smokers.[8] We did not find any specific study on alcohol consumption and the risk of COVID-19 infection in our literature. On the other hand, considering that alcoholics are more vulnerable to lung infections and alcohol consumption may lead to erroneous results of coronavirus diagnostic tests, resulting in delayed diagnosis, it can be a risk factor for COVID-19.[8, 9] Exercise and physical activity may have a lot of advantages concerning the risk of COVID-19 infection.

In a study, it was shown that physical activity can help to reduce the consequences of the COVID-19 epidemic in a variety of ways, including reducing the severity of COVID-19 infection, reducing obesity, thereby reducing the risk of death, reducing stress, enhancing overall immunity, and protecting effects on lung function.[10] However, the relationship between lifestyle factors and important epidemiological indicators of this disease is unknown. This study aimed to identify the correlation of four lifestyle factors, including obesity, smoking, alcohol consumption, and physical inactivity, with epidemiological indices of COVID-19, which included new cases, recovery rates, and death rates.

Methods

Setting

In this ecological study, all variables are aggregate ones. To collect the studied variables, a data set was provided that included the information of each country regarding the cumulative incidence rate, cumulative rate of deaths, case fatality rate, and recovery rate. Information about COVID-19 for each country was retrieved from https://www.worldometers.info/ from the date of the first report until November 30th, 2020. The formula for calculating COVID-19 indices is as follows. In this study, the correlation of COVID-19 indices, including cumulative incidence rate, cumulative rate of death, recovery rate, and case fatality rate, with lifestyle factors, including obesity, physical inactivity, smoking, and alcohol consumption, was investigated.

Data on the prevalence of smoking in people over 15 years, the prevalence of physical inactivity in adults 18 years and older, alcohol consumption per person (liters) in people over 15 years, and the prevalence of obesity in adults were available in 103 countries. The data on the cumulative incidence rate and the cumulative rate of death were also available in 103 countries. Recovery rate data were available for 99 countries, and case fatality rate data were accessible for 103 countries. The information on smoking prevalence (aged 15+), total alcohol consumption per capita (liters of pure alcohol for 15+ years of age), and obesity prevalence in adults (%) all in 2019 were collected from https://www.indexmundi.com/.[11-13] Moreover, the information on the prevalence of physical inactivity (aged 18 and older) was obtained from the WHO website.[14]

In this study, smoking prevalence (aged 15+) is defined as the percentage of men and women aged 15 years and over who currently smoke any tobacco product on a daily or non-daily basis. It excluded smokeless tobacco use. The rates were age standardized. Also, total alcohol consumption per capita (liters of pure alcohol for 15+ years of age) is defined as the total (sum of recorded and unrecorded) amount of alcohol consumed per person (15 years of age or older) over a calendar year, in liters of pure alcohol, adjusted for tourist consumption.[12] Obesity prevalence in adults (%) is defined as the percentage of the population aged 20 and over who have a Body Mass Index (BMI) of 30 kg/m^2 or more. Also, the percentage of the population aged 18 and over who have less than 150 minutes of moderate-intensity physical activity per week or less than 75 minutes of vigorous-intensity physical activity per week or equivalent is set for the definition of the prevalence of physical inactivity.[15]

Statistical Analysis

Scatter plots of lifestyle factors were drawn based on the cumulative incidence rate, cumulative rate of death, recovery rate, and case fatality rate of COVID-19. Furthermore, the Spearman correlation coefficient was used to verify the correlation between lifestyle factors and COVID-19 indicators.

Results

The results of this ecological study revealed that among all surveyed countries, Luxembourg (54807.89 per million) and Belgium (49661.05 per million) had the highest cumulative incidence rates of COVID-19,

when Vietnam (78.13 per million) and Fiji (71.46 per million) had the lowest cumulative incidence rates. Also, it revealed that Belgium (1425.15 per million) followed by Spain (1118.96 per million) had the highest cumulative deaths due to COVID-19, while Vietnam (0.36 per million) and Thailand (0.86 per million) had the lowest cumulative rates of death as a result of COVID-19. The highest recovery rate was in Singapore (99.86%) and Qatar (97.99%), while the lowest rate was in Belgium (6.48%) and France (7.28%). In addition, the highest case fatality rate of COVID-19 was in Mexico (9.54%) followed by Ecuador (6.99%); on the other hand, the lowest case fatality rate of COVID-19 was in Singapore (0.05%) and Qatar (0.17%).

Table 1 shows the correlation coefficient between the COVID-19 indicators and the prevalence of obesity, physical inactivity, smoking, and alcohol consumption. This study revealed that the cumulative incidence rate and cumulative rate of death had significant direct correlations with the prevalence of obesity, physical inactivity, smoking, and alcohol consumption ($P<0.05$). This means that the countries with a high prevalence of obesity, physical inactivity, smoking, and alcohol consumption had increased indicators such as the cumulative incidence rate and cumulative rate of death. There were also significant inverse correlations between the recovery rate and the prevalence of smoking and alcohol consumption; therefore, the recovery rate decreases with an increasing prevalence of smoking and alcohol consumption ($P<0.05$). In countries with a population of less than 10 million, there were significant direct correlations between the cumulative incidence rate and the cumulative rate of death with the prevalence of obesity, physical inactivity, smoking, and alcohol consumption ($P<0.05$). Also, it was shown that the mortality rate has a significant correlation with obesity prevalence.

In Figures 1 to 4, scatter plots of the prevalence of smoking, alcohol consumption, obesity, and physical inactivity by the cumulative incidence rate, cumulative rate of death, recovery rate, and case fatality rate in all countries and countries with a population over 10 million are seen.

In all countries, the highest R^2 was related to the recovery rate for smoking and COVID-19 indices ($R^2=0.16$). Moreover, among countries with a population of 10 million or more, the highest R2 was related to the cumulative incidence rate (R2=0.16). The highest R^2 was related to the cumulative incidence rate for alcohol consumption and COVID-19 indices between all countries ($R^2=0.19$), similar to thecountries with a population of 10 million or more ($R^2=0.33$). The highest R^2 was related to the cumulative incidence rate for obesity and COVID-19 indices between all countries ($R^2=0.25$); however, the highest R2 was related to the cumulative rate of death among countries with a population of 10 million or more (R2=0.33). The highest R^2 was related to the cumulative incidence rate for physical inactivity and COVID-19 indices between all countries ($R^2=0.25$); also, the highest R^2 was related to the cumulative incidence rate among countries with a population of 10 million or more ($R^2=0.16$).

Table 1: The correlation of lifestyle factors and COVID-19 indices

Variable	All countries				Countries with ≥10 million population			
	N	Correlation coefficient	P value	Comment*	N	Correlation coefficient	P value	Comment
Cumulative Incidence rate (per million)								
Smoking prevalence (ages 15+)	103	0.48	<0.001	Moderate	62	0.43	<0.001	Moderate
Alcohol consumption prevalence (ages 15+)	103	0.44	<0.001	Moderate	62	0.44	<0.001	Moderate
Obesity prevalence (ages 15+)	103	0.51	<0.001	Moderate	62	0.60	<0.001	Strong
Physical inactivity prevalence (aged 18+)	103	0.38	<0.001	Weak	62	0.49	<0.001	Moderate
Cumulative rate of death (per million)								
Smoking prevalence (ages 15+)	103	0.41	<0.001	Moderate	62	0.37	0.003	Weak
Alcohol consumption prevalence (ages 15+)	103	0.42	<0.001	Moderate	62	0.38	0.002	Weak
Obesity prevalence (ages 15+)	103	0.53	<0.001	Moderate	62	0.66	<0.001	Strong
Physical inactivity prevalence (aged 18+)	103	0.36	0.006	Weak	62	0.50	<0.001	Moderate
Recovery Rate (%)								
Smoking prevalence (ages 15+)	99	-0.38	<0.001	Weak	58	-0.23	0.07	NS
Alcohol consumption prevalence (ages 15+)	99	-0.35	<0.001	Weak	58	-0.14	0.29	NS
Obesity prevalence (ages 15+)	99	-0.19	0.05	Very weak	58	-0.11	0.39	NS
Physical inactivity prevalence (aged 18+)	99	-0.09	0.36	NS**	58	-0.14	0.28	NS
Case Fatality Rate (%)								
Smoking prevalence (ages 15+)	103	-0.05	0.60	NS	62	0.08	0.50	NS
Alcohol consumption prevalence (ages 15+)	103	-0.06	0.51	NS	62	-0.002	0.98	NS
Obesity prevalence (ages 15+)	103	0.10	0.29	NS	62	0.40	0.001	Moderate
Physical inactivity prevalence (aged 18+)	103	0.002	0.98	NS	62	0.19	0.13	NS

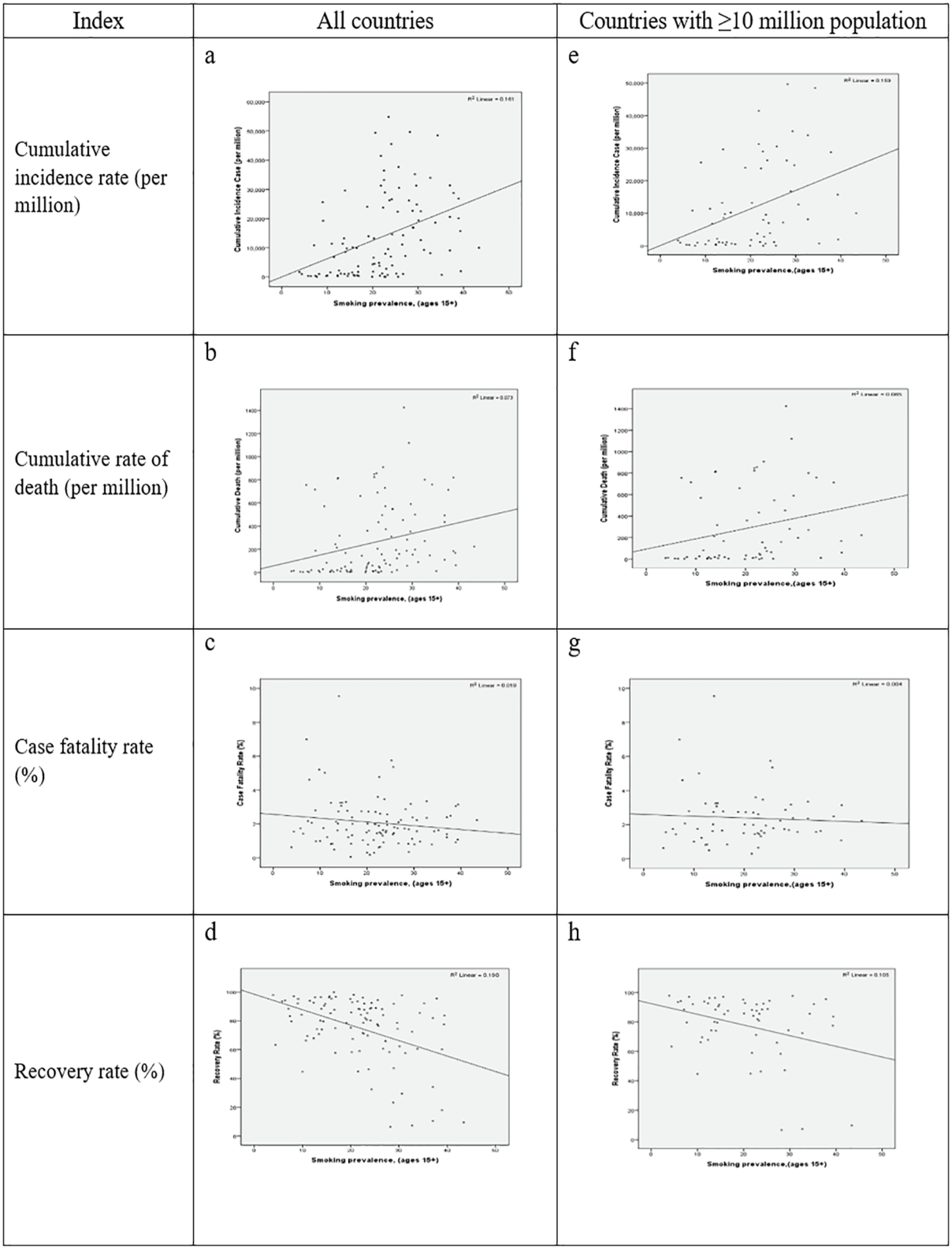


Figure 1: Scatter plot of the correlation between smoking and COVID-19 indices. a, b, c: Singapore, Qatar, Malaysia, Botswana, United Arab Emirates, Sri Lanka, Kuwait, Ghana, Nepal, Norway, Lebanon, Slovak Republic, Rwanda, Lithuania, Mozambique, Uzbekistan, Belarus, Luxembourg, Serbia, Estonia, Cabo Verde, Uganda, Denmark, Namibia, Russia, Austria, Latvia, New Zealand, India, Korean Republic, Uruguay, Malta, Croatia, Benin, Bangladesh, Japan, Switzerland, Thailand, Portugal, Kazakhstan, Ethiopia, Germany, Czech Republic, Armenia, Finland, Dominican Republic, Cuba, Morocco, Saudi Arabia, Ukraine, Poland, Nigeria, Kyrgyz Republic, Kenya, the Netherlands, Slovenia, Philippines, United States, Mauritius, Brunei Darussalam, Pakistan, Zambia, Senegal, Lesotho, Paraguay, Moldova, Togo, Hungary, Greece, Turkey, France, Romania, Jamaica, Bulgaria, Chile, Ireland, Vietnam, Argentina, South Africa, Brazil, Sweden, Zimbabwe, Colombia, Belgium, Bosnia and Herzegovina, Malawi, Indonesia, Spain, Mali, Canada, Australia, the Gambia, Tunisia, Italy, United Kingdom, Niger, Fiji, Iran, Liberia, China, Egypt, Ecuador, Mexico; d: all countries in (a) except Spain, United Kingdom, Sweden, and the Netherlands. e, f, g, h: all countries in (a) except the countries with <10 million population.

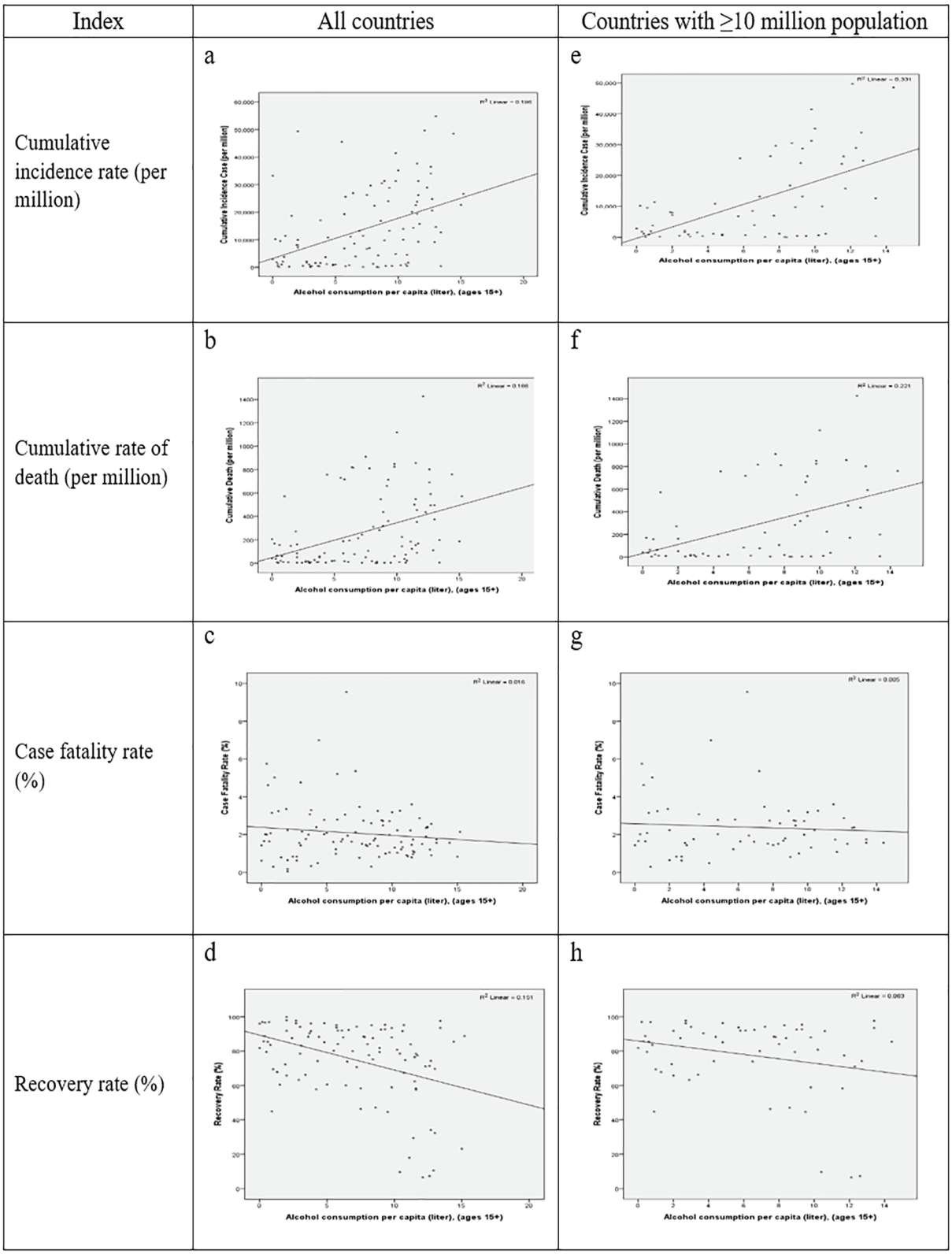


Figure 2: Scatter plot of the correlation between alcohol and COVID-19 indices. a, b, c: Singapore, Qatar, Malaysia, Botswana, United Arab Emirates, Sri Lanka, Kuwait, Ghana, Nepal, Norway, Lebanon, Slovak Republic, Rwanda, Lithuania, Mozambique, Uzbekistan, Belarus, Luxembourg, Serbia, Estonia, Cabo Verde, Uganda, Denmark, Namibia, Russia, Austria, Latvia, New Zealand, India, Korean Republic, Uruguay, Malta, Croatia, Benin, Bangladesh, Japan, Switzerland, Thailand, Portugal, Kazakhstan, Ethiopia, Germany, Czech Republic, Armenia, Finland, Dominican Republic, Cuba, Morocco, Saudi Arabia, Ukraine, Poland, Nigeria, Kyrgyz Republic, Kenya, the Netherlands, Slovenia, Philippines, United States, Mauritius, Brunei Darussalam, Pakistan, Zambia, Senegal, Lesotho, Paraguay, Moldova, Togo, Hungary, Greece, Turkey, France, Romania, Jamaica, Bulgaria, Chile, Ireland, Vietnam, Argentina, South Africa, Brazil, Sweden, Zimbabwe, Colombia, Belgium, Bosnia and Herzegovina, Malawi, Indonesia, Spain, Mali, Canada, Australia, the Gambia, Tunisia, Italy, United Kingdom, Niger, Fiji, Iran, Liberia, China, Egypt, Ecuador, Mexico; d: all countries in (a) except Spain, United Kingdom, Sweden, and the Netherlands. e, f, g, h: all countries in (a) except the countries with <10 million population.

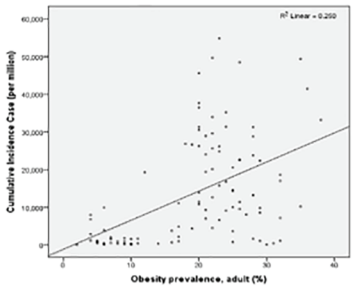
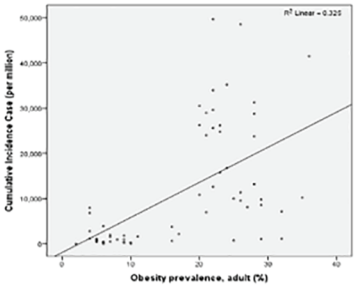
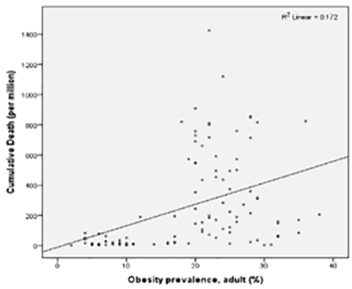
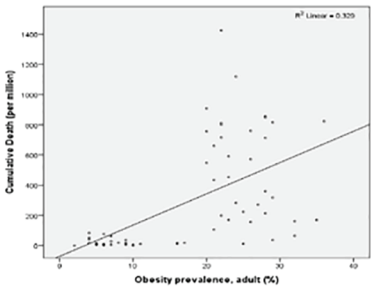
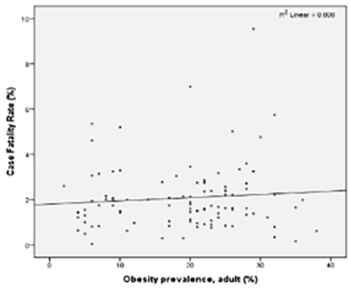
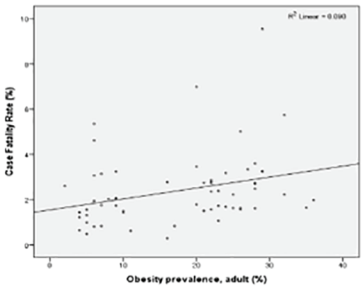
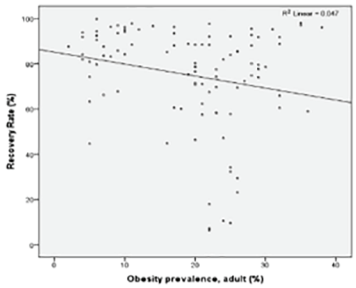
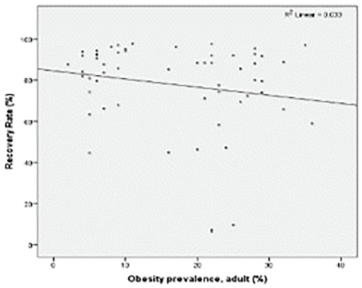
Index	All countries	Countries with ≥10 million population
Cumulative incidence rate (per million)	a 	e 
Cumulative rate of death (per million)	b 	f 
Case fatality rate (%)	c 	g 
Recovery rate (%)	d 	h 

Figure 3: Scatter plot of the correlation between obesity and COVID-19 indices. a, b, c: Singapore, Qatar, Malaysia, Botswana, United Arab Emirates, Sri Lanka, Kuwait, Ghana, Nepal, Norway, Lebanon, Slovak Republic, Rwanda, Lithuania, Mozambique, Uzbekistan, Belarus, Luxembourg, Serbia, Estonia, Cabo Verde, Uganda, Denmark, Namibia, Russia, Austria, Latvia, New Zealand, India, Korean Republic, Uruguay, Malta, Croatia, Benin, Bangladesh, Japan, Switzerland, Thailand, Portugal, Kazakhstan, Ethiopia, Germany, Czech Republic, Armenia, Finland, Dominican Republic, Cuba, Morocco, Saudi Arabia, Ukraine, Poland, Nigeria, Kyrgyz Republic, Kenya, the Netherlands, Slovenia, Philippines, United States, Mauritius, Brunei Darussalam, Pakistan, Zambia, Senegal, Lesotho, Paraguay, Moldova, Togo, Hungary, Greece, Turkey, France, Romania, Jamaica, Bulgaria, Chile, Ireland, Vietnam, Argentina, South Africa, Brazil, Sweden, Zimbabwe, Colombia, Belgium, Bosnia and Herzegovina, Malawi, Indonesia, Spain, Mali, Canada, Australia, the Gambia, Tunisia, Italy, United Kingdom, Niger, Fiji, Iran, Liberia, China, Egypt, Ecuador, Mexico; d: all countries in (a) except Spain, United Kingdom, Sweden, and the Netherlands. e, f, g, h: all countries in (a) except the countries with <10 million population.

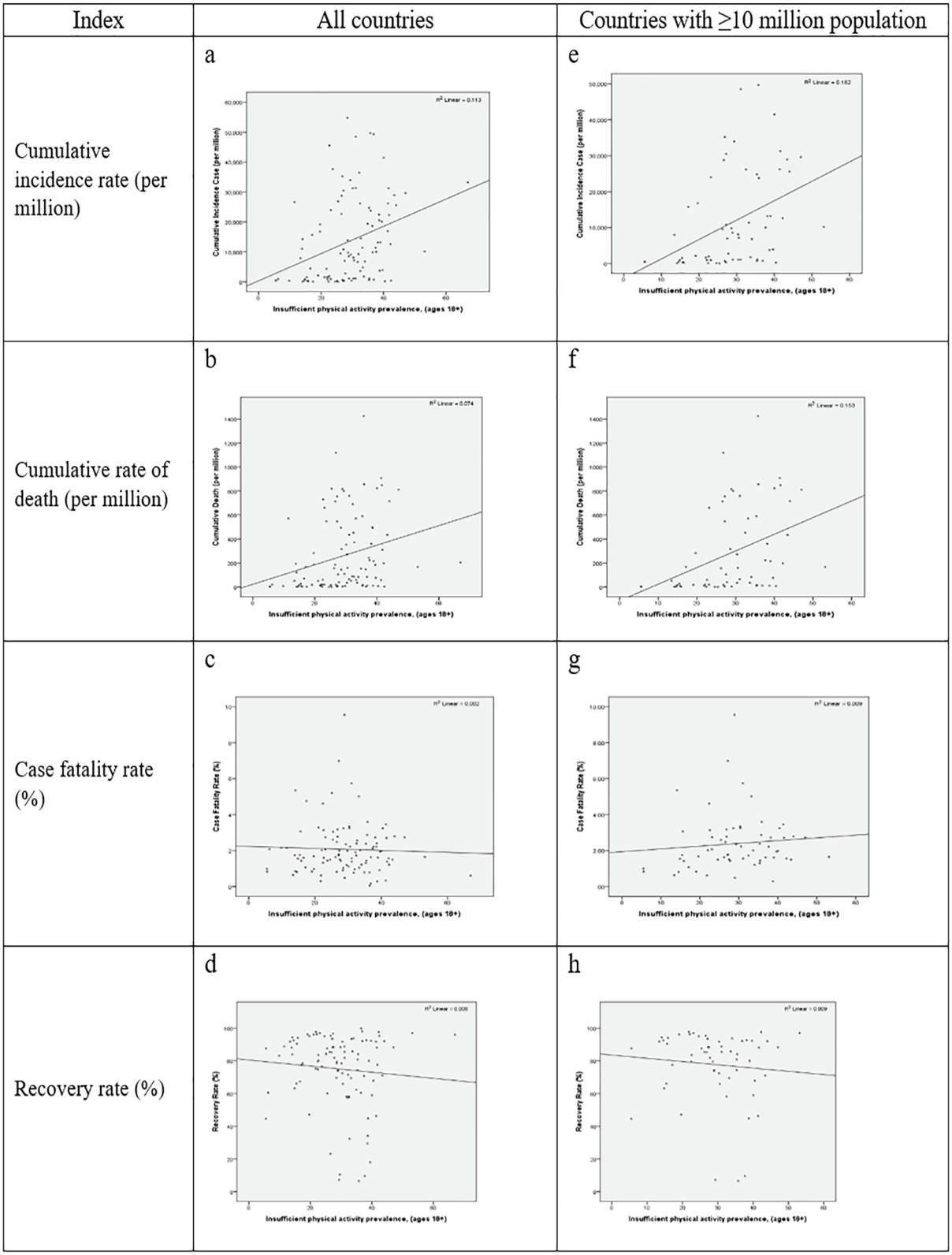


Figure 4: Scatter plot of the correlation between physical inactivity and COVID-19 indices. a, b, c: Singapore, Qatar, Malaysia, Botswana, United Arab Emirates, Sri Lanka, Kuwait, Ghana, Nepal, Norway, Lebanon, Slovak Republic, Rwanda, Lithuania, Mozambique, Uzbekistan, Belarus, Luxembourg, Serbia, Estonia, Cabo Verde, Uganda, Denmark, Namibia, Russia, Austria, Latvia, New Zealand, India, Korean Republic, Uruguay, Malta, Croatia, Benin, Bangladesh, Japan, Switzerland, Thailand, Portugal, Kazakhstan, Ethiopia, Germany, Czech Republic, Armenia, Finland, Dominican Republic, Cuba, Morocco, Saudi Arabia, Ukraine, Poland, Nigeria, Kyrgyz Republic, Kenya, the Netherlands, Slovenia, Philippines, United States, Mauritius, Brunei Darussalam, Pakistan, Zambia, Senegal, Lesotho, Paraguay, Moldova, Togo, Hungary, Greece, Turkey, France, Romania, Jamaica, Bulgaria, Chile, Ireland, Vietnam, Argentina, South Africa, Brazil, Sweden, Zimbabwe, Colombia, Belgium, Bosnia and Herzegovina, Malawi, Indonesia, Spain, Mali, Canada, Australia, the Gambia, Tunisia, Italy, United Kingdom, Niger, Fiji, Iran, Liberia, China, Egypt, Ecuador, Mexico; d: all countries in (a) except Spain, United Kingdom, Sweden, and the Netherlands. e, f, g, h: all countries in (a) except the countries with <10 million population.

Discussion

This ecological study aimed to assess the correlation between lifestyle factors and COVID-19 indices. The findings of the study revealed that there are significant direct correlations between the cumulative incidence rate and the cumulative rate of death with the prevalence of obesity. In other words, the incidence rate and cumulative rate of death were higher in the countries with a higher prevalence of obesity. Also, a weak, significant inverse correlation between the recovery rate and the prevalence of obesity was found in all countries. As the prevalence of obesity increased, the recovery rate decreased by about 19%, which was consistent with the reported results.[5, 16] Overweight and obesity increased the risk of some diseases, such as cardiovascular disease, diabetes, and bladder cancer.[17] It also increased the severity and mortality of COVID-19. Previous research has also shown that obesity could exacerbate COVID-19 by limiting the function of the lungs. Since the coronavirus also affects the lungs, it is more likely to develop severe symptoms. Some research already revealed that obese patients needed more artificial ventilation after hospitalization; also, overweight and obese men had a higher risk of COVID-19 mortality than women. This difference is probably due to the ability of obese women to produce estrogen and its effect on their immune systems.[5] Moreover, obesity can also limit air conditioning, and it can impair the body's immune response to viral infection.[18]

Our results revealed significant direct correlations between smoking and the cumulative rate of death and a significant inverse correlation between smoking and the recovery rate among all studied countries. However, there was no significant correlation between smoking and the recovery rate in countries with a population of 10 million or more. The results of a meta-analysis study showed that there was a significant relationship between smoking and the negative progression of COVID-19, so that smokers were 1.91 times more likely than non-smokers to develop severe COVID-19,[8] which was not consistent with the results of another recent meta-analysis study. Two studies, by Berlin et al. and Lippi et al., both reported an association between smoking and severe COVID-19.[4, 19] The admission to Intensive Care Units (ICUs), the need for artificial ventilation, and the rate of death were more prevalent among COVID-19 patients who were smokers, compared to non-smokers.[20] In one study, the only modifiable variable associated with the progression of COVID-19 pneumonia was patients' current smoking history.[21] In those who died due to COVID-19, the percentage of smokers was higher than in those who recovered.[22] In a study conducted by Vardavas and Nikitara, it was found that smoking was likely to be associated with negative disease progression and adverse outcomes.[23] Exposure to secondhand smoke is a risk factor for lung disease; also, smoking is a significant risk factor for bacterial and viral infections.[24, 25] In addition, there was a significant relationship between smoking and disease mortality in patients with MERS, which was common during 2012-2015.[26]

In this study, significant direct correlations were observed between the prevalence of physical inactivity and the cumulative rate of death. Moreover, a weak inverse correlation was observed between the recovery rate and physical inactivity, which was not significant. Furthermore, no significant correlation was shown between the case fatality rate and physical inactivity. The results of the study by Woods and colleagues showed that physical activity reduced respiratory problems in patients with COVID-19.[27] In a study by Zhang et al., it was found that physical activity had a protective effect on the complications of COVID-19 among all patients; however, no relationship was observed between vigorous and moderate physical activity and the consequences of COVID-19.[28] Published evidence suggests that physical activity is associated with physical health through immune system regulation, and it can be beneficial for mental health.[29] Also, physical activity can increase respiratory muscle endurance and improve the immune response to respiratory antigens.[30] A review of studies on exercise and viral infections revealed that regular moderate-intensity aerobic exercise (65-80% VO_2 max) increased the titer of the antibodies, lymphocyte proliferation, interferon-gamma production, NK cells, and immunoglobulins G and M. It also modulates inflammatory cytokines and cocaine. According to research, moderate-intensity sports activities can improve the immune system function due to their physiological effects. On the other hand, it is believed that vigorous-intensity exercise has negative effects on the immune system, which can lead to a reduction in the function of the immune system, leading to susceptibility to infectious diseases.[28]

Also, in this study, significant direct correlations were observed between total alcohol consumption and the cumulative incidence rate and the cumulative rate of death. A weak inverse correlation was observed between total alcohol consumption and the recovery rate among all studied countries; however, no association was seen between total alcohol consumption and the recovery rate among countries with a population of over 10 million. In another study, it was found that a correlation between alcohol consumption and viral infections exists.[31] In a study by Hamer et al., people who did not drink alcohol were at higher risk for COVID-19.[32] Li and colleagues showed in their study that there was no relationship between alcohol consumption and COVID-19.[33] Chronic alcohol consumption affects all components of the immune system.[34] Recent studies emphasized that excessive alcohol consumption is

associated with excessive production of inflammatory cytokines by liver cells, leading to inflammatory markers.[35] In particular, it has been observed that levels of interleukin-8 and Tumor Necrosis Factor Alpha (TNF-α) increase significantly in alcoholics.[36] Two separate studies by Parri and Casillo showed a similar trend in elevated interleukin-8 and TNF-α in patients with COVID-19.[37, 38] Alcohol consumption affects the body's immune response, which leads to a person being prone to acute respiratory syndrome.[39]

It should be kept in mind that aggregate data were used in our study. Thus, we should not forget that in all the findings of the study, ecological fallacy is one of the more important limitations of our study. For instance, all individuals living in countries with a high prevalence of obesity, physical inactivity, smoking, or alcohol consumption may not be at risk of COVID-19 morbidity and mortality indices. In addition, we evaluated the prevalence of obesity, smoking, and alcohol consumption among individuals aged 15 years and above and the prevalence of physical inactivity in the ≥20 years age group. Therefore, inequalities of age groups regarding these variables may have affected their correlation with COVID-19 indices.

Conclusion

As the results of our study revealed, there are significant direct correlations between the cumulative incidence rate and the cumulative rate of death with the prevalence of physical inactivity, obesity, smoking, and alcohol consumption. Also, there were significant inverse correlations between the recovery rate and the prevalence of obesity, smoking, and alcohol consumption. Therefore, it is necessary to develop lifestyle modification strategies that can lead to reduction of morbidity and mortality of this disease.

Authors' Contribution

Conceptualization: AMA, FR. Data curation: MGG, FM, KJ, SA, EP, SSD, AHH, HG, MJM, AJ. Formal analysis: MGG, FM, KJ, SA. Funding acquisition: None. Methodology: AMA, FR, MGG, FM, KJ, SA. Project administration: FR. Visualization: AMA. Writing–original draft: AMA, FR, MGG, FM, KJ, SA, EP, SSD, AHH, HG, MJM, AJ.

Acknowledgment

The authors would like to thank the vice chancellor for research and technology for financial support.

Ethical Consideration

This study was approved by the research ethics committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1399.174)

Funding

This study was approved and financially supported by Shiraz University of Medical Sciences (Grant number: 99-01-106-19536).

Conflict of Interest: None declared.

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