Clinical Nutrition xxx (xxxx) xxx

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Covid-19

Region-specific COVID-19 risk scores and nutritional status of a high-risk population based on individual vulnerability assessment in the national survey data

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ARTICLE INFO

Article history:
Received 15 December 2020
Accepted 12 February 2021

Keywords:
COVID-19
Risk assessment
Death
Nutritional status
National survey

SUMMARY

Background & aims: Coronavirus disease 2019 (COVID-19) is an ongoing pandemic outbreak leading to more than 1 million deaths worldwide as reported in 2020. Several risk assessment tools, including individual vulnerability to COVID-19, have been developed. The present study aimed to characterize a high-risk population using such a tool and examine risk factors and nutritional status in the national survey data and estimate the region-specific population size.
Methods: The study included 17,540 Korean adults who participated in the Korea National Health and Nutrition Examination Survey (KNHANES). The risk scores for individual vulnerability to COVID-19 were calculated based on age, sex, smoking status, and comorbidities, and a high-risk population was defined as having risk scores ≥11. Nutritional status was compared between the high-risk population and the remaining participants in the KNHANES data. The region-specific population size was estimated using national statistics.
Results: The proportion of the high-risk population was estimated to be 10.5%, which corresponds to approximately 4.6 million adults in South Korea. About 20% of them had inadequate intake of all of vitamins A, B1, B2, B3, and C below the estimated average requirement. The high-risk population showed 1.65 [95% confidence interval: 1.39, 1.96] higher odds of inadequate intake of multiple vitamins than the remaining participants. In the ecological analysis, the region-specific numbers of the high-risk population correlated significantly with the actual numbers of deaths due to COVID-19 (P value = 0.013).
Conclusions: These results suggest that individuals vulnerable to COVID-19, in particular those are living in densely populated regions, should pay particular attention to the protection against this pandemic and have adequate nutritional status, which may support optimal immune function.

1. Introduction

Since the outbreak of coronavirus disease 2019 (COVID-19) ten months ago, more than 1 million people worldwide have died due to this pandemic. According to the Central Disease Control Headquarters (http://ncov.mohw.go.kr, accessed on October 7, 2020), the numbers of cumulative cases and deaths of COVID-19 are 24,353 and 425, respectively, in South Korea. Although the mortality rate of COVID-19 is relatively low in South Korea compared with that in other countries (https://covid19.who.int/, accessed on October 7, 2020), an increase in the number of severe cases considered to be at high-risk of deaths is a concern intimidating the national capacity of hospital beds [1].

Global data regarding the risk factors for severity and mortality of COVID-19, so-called vulnerability to COVID-19, are accumulating and several studies have developed risk prediction models or risk assessment tools for COVID-19 [2–6]. Most studies have generated risk scores among patients with COVID-19 [2–5], while one study reported a risk assessment tool for a general population [6]. In these studies, demographic and health-related risk factors such as age, gender, smoking, comorbidities, symptoms, and clinical findings were considered [2–6]. Previous studies, but not all, have evaluated the diagnostic accuracy or validity for the developed risk scores [2–5]. However, risk assessment tools and its evaluation data for a general population are still lacking. In the clinical findings in

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https://doi.org/10.1016/j.clnu.2021.02.019
0261-5614/

Please cite this article as: I. Baik, Region-specific COVID-19 risk scores and nutritional status of a high-risk population based on individual vulnerability assessment in the national survey data, Clinical Nutrition, https://doi.org/10.1016/j.clnu.2021.02.019

COVID-19 patients, lower levels of serum albumin, which is commonly used to assess malnutrition, were observed in severe cases than in non-severe cases [2–4] although it is uncertain whether albumin is a significant factor in the risk prediction model [2,4]. Nonetheless, poor nutritional status was reportedly observed in hospitalized COVID-19 patients, particularly in severe cases [7–9], and associated with mortality [10,11]. The link between nutrition and COVID-19 infection may be explained by the role of specific nutrients in overall immune function [12] and the influence of infectious disease on dietary intake and nutrient requirement [13]. So far, data on nutritional status of individuals who are not yet exposed to the infection but potentially vulnerable to COVID-19 have not been reported.

The present study aimed to characterize a general population at a high risk of vulnerability to COVID-19 in the national survey data. In this study, risk scores were calculated with demographic and health-related risk factors, except symptoms and clinical findings, to define a high-risk population and used for nutritional evaluation. In addition, region-specific numbers of this population were estimated and applied for ecological correlations with the actual numbers of deaths due to COVID-19 in South Korea.

2. Subjects & methods

2.1. Study population

In this study, data from the 7th (year 2016–2018) Korea National Health and Nutrition Examination Survey (KNHANES) were used. The study population was 17,540 adults (8728 men and 8812 women) aged 19 years or older who had variables of interest in the KNHANES data. In these participants, dietary data were available in 15,249.

2.2. Definition of risk scores and a high-risk population

Risk scores were calculated using the information on demographic and health-related risk factors, including age, sex, smoking status, and the presence of comorbidities, such as obesity defined as a body mass index (BMI) $\geq$ 30 kg/m^2, hypertension, diabetes mellitus (DM), cardiovascular disease, renal diseases, respiratory diseases, and cancer. These variables were already reported as risk factors for COVID-19 [14] and used as predictors in previous studies [2–6]. Using health risk factors similar to those reported by Chatterjee et al. [6], the present study adopted their scoring system for health risk factors. As a difference from their study, however, the present study additionally considered obesity as a comorbid disease as other studies did [2–5,14]. After scoring for age groups (2 points for 19–39 years; 3, 40–49 years; 4, 50–59 years; 5, 60–69 years; 6, 70–79 years; and 7, 80 years or older), sex (1 and 2 points for female and male, respectively), smoking status (1 and 2 points for non-smoking and smoking, respectively), and the presence of comorbidities (1 point for no comorbidity; 2, presence of one comorbidity; 3, presence of two comorbidities; and 4, presence of three or more comorbidities), risk scores were calculated by summing all points. A high-risk population vulnerable to COVID-19 was defined as having risk scores $\geq$11.

2.3. Variables in the Korea National Health and Nutrition Examination Survey

The information of all variables needed was collected from the KNHANES data to calculate the risk scores. Hypertension was defined using information on systolic and diastolic blood pressure (BP), use of antihypertensive medications, or a physician diagnosis of hypertension (if data on BP and medications were unavailable), and DM was defined using information on fasting blood glucose levels, use of insulin or oral hypoglycemic medications, or a physician diagnosis of DM (if data on glucose levels and medications were unavailable). Based on the definition, all variables needed for hypertension and DM were collected. For other diseases, data on the prevalence of a specific disease were used.

The information of 17 regions (first-tier administrative divisions of South Korea) including Busan, Chungbuk, Chungnam, Daegu, Daejeon, Gangwon, Gwangju, Gyeongbuk, Gyeonggi, Gyeongnam, Incheon, Jeju, Jeonbuk, Jeonnam, Sejong, Seoul, and Ulsan and consumption of calories and nutrients available in the data (including protein; fat; monounsaturated fatty acid; polyunsaturated fatty acid; n-3 fatty acid; n-6 fatty acid; vitamins A, B1, B2, B3, and C; retinol; carotene; calcium; phosphorus; and iron) were collected.

2.4. Other information

The national statistics regarding the region-specific numbers of the population for 2019 were obtained from the Korean Statistical Information Service website (http://kosis.kr, accessed on October 7, 2020). Also, the region-specific numbers of cumulative deaths due to COVID-19 were obtained from the Central Disease Control Headquarters website (http://ncov.mohw.go.kr, accessed on October 7, 2020).

2.5. Statistical analysis

According to the 17 regions, descriptive statistics for the scores of each component and total risk scores were calculated, and statistical tests were conducted when sample weights were considered in the analysis. *P* values were obtained from the chi-square and analysis of variance tests. The calorie and nutrient intakes were compared according to the three groups of risk scores (<8, 8–10, and $\geq$11) using the linear regression analysis considering sample weights. For nutritional evaluation, the estimated average requirement (EAR) for each nutrient, based on the 2015 Dietary Reference Intakes for Koreans [15], was used to calculate the proportion of participants with inadequate intake below the EAR. Using the logistic regression analysis and sample weights, odds ratios (ORs) of inadequate intake below the EAR and its 95% confidence interval (CI) were calculated for the high-risk population compared with the remaining participants with risk scores <11. In addition, the proportions of participants with inadequate intake were compared across the 17 regions. Furthermore, the ecological analysis was conducted to obtain a correlation coefficient for the association between the estimated region-specific numbers of the high-risk population and the actual region-specific numbers of deaths due to COVID-19. All statistical analyses were performed with SAS 9.1.3 (2008, SAS Institute, Cary, NC, USA), and statistical significance was set at 0.05 for a two-tailed test.

3. Results

3.1. Risk factors of the study population according to regions

Participants in Jeonnam were older than those in other regions, and the proportions of males and smokers were higher in Sejong and Ulsan, respectively. In comorbidities, the prevalence rates of hypertension and DM were higher in Gangwon and Jeonbuk, respectively, than in other regions ($P < 0.01$) (Table 1).

3.2. Risk scores according to regions

Table 2 shows total risk scores and scores for each component according to the 17 regions with the proportion of the high-risk

Table 1
Region-specific descriptive statistics regarding risk factors for individual vulnerability to COVID-19 in 17,540 adult participants from the Korea National Health and Nutrition Examination Survey 2016–2018.

Regions	Number of participants	Age, years	Male sex, %	BMI, kg/m^2	Smoker, %	Prevalence of disease, %				
						Obesity[a]	Hypertension	DM	CVD	Others[b]
All	17,540	47.20 ± 0.24	49.76	23.95 ± 0.04	21.60	5.62	27.76	10.54	3.20	3.73
Busan	1173	48.43 ± 0.86	47.71	23.72 ± 0.14	20.51	4.39	27.99	11.57	4.03	3.83
Chungbuk	512	49.40 ± 1.44	49.46	23.96 ± 0.23	17.51	4.39	31.58	13.84	3.75	5.09
Chungnam	577	48.21 ± 1.38	50.06	24.38 ± 0.20	24.56	7.90	32.07	12.35	4.06	3.93
Daegu	783	47.17 ± 1.03	49.05	23.64 ± 0.15	23.05	4.81	23.33	9.58	2.56	4.38
Daejeon	611	44.71 ± 1.04	52.68	23.92 ± 0.23	22.44	6.36	27.03	7.31	2.69	3.12
Gangwon	587	50.30 ± 1.38	51.81	24.46 ± 0.28	20.21	7.37	36.86	12.95	4.70	4.51
Gwangju	538	45.57 ± 1.28	52.56	23.77 ± 0.22	20.41	5.96	21.43	8.98	4.30	4.08
Gyeongbuk	868	49.69 ± 1.64	49.27	24.11 ± 0.17	24.57	6.69	28.02	11.48	4.16	3.41
Gyeonggi	4198	45.94 ± 0.44	50.45	23.94 ± 0.07	23.10	5.64	27.71	9.67	2.83	3.84
Gyeongnam	1025	47.62 ± 1.19	50.21	23.96 ± 0.15	21.28	5.26	24.93	10.27	2.86	2.52
Incheon	1007	46.27 ± 0.93	50.25	24.16 ± 0.16	23.44	6.62	28.59	9.78	3.00	2.30
Jeju	347	48.07 ± 2.19	47.99	24.34 ± 0.25	23.87	6.56	30.39	13.37	2.72	5.09
Jeonbuk	570	50.59 ± 1.17	48.00	24.15 ± 0.19	15.36	6.84	30.15	15.79	3.90	4.13
Jeonnam	570	52.94 ± 1.78	46.63	24.46 ± 0.23	22.14	7.35	33.83	14.66	4.17	4.51
Sejong	361	44.73 ± 1.86	54.72	23.88 ± 0.34	16.21	7.48	25.99	10.91	3.92	4.38
Seoul	3454	46.34 ± 0.47	48.71	23.76 ± 0.08	19.46	4.59	26.58	9.53	2.60	3.48
Ulsan	359	47.97 ± 2.36	50.93	24.02 ± 0.14	24.63	4.87	30.09	13.02	3.63	5.73
P value		0.088	0.582	0.687	0.058	0.205	0.004	0.002	0.195	0.213

Abbreviation: BMI, body mass index; DM, diabetes mellitus; CVD, cardiovascular disease.
Data are presented as mean ± standard error or a proportion estimated using sample weights.
P value in the chi-square test or analysis of variance.
[a] Defined as 30 kg/m^2 or greater.
[b] Includes respiratory diseases, tuberculosis, and cancer.

Table 2
Region-specific risk scores for individual vulnerability to COVID-19 and high-risk population size.

Regions	Risk scores for individual vulnerability to COVID-19					High-risk population[a], %	No of high-risk population[b] (in thousands)
	Age	Sex	Smoking	Disease	Total		
All	3.47 ± 0.02	1.50 ± 0.01	1.22 ± 0.01	1.51 ± 0.01	7.69 ± 0.03	10.49	4551.4
Busan	3.59 ± 0.07	1.48 ± 0.01	1.21 ± 0.02	1.52 ± 0.03	7.79 ± 0.10	11.82	341.7
Chungbuk	3.72 ± 0.12	1.49 ± 0.03	1.18 ± 0.03	1.59 ± 0.06	7.98 ± 0.18	15.06	205.6
Chungnam	3.54 ± 0.12	1.50 ± 0.03	1.25 ± 0.03	1.60 ± 0.06	7.89 ± 0.18	13.43	244.4
Daegu	3.48 ± 0.09	1.49 ± 0.02	1.23 ± 0.02	1.45 ± 0.03	7.65 ± 0.11	10.00	203.9
Daejeon	3.25 ± 0.09	1.53 ± 0.02	1.22 ± 0.02	1.47 ± 0.04	7.46 ± 0.10	8.00	99.4
Gangwon	3.71 ± 0.13	1.52 ± 0.01	1.20 ± 0.03	1.66 ± 0.06	8.09 ± 0.19	14.93	192.5
Gwangju	3.36 ± 0.10	1.53 ± 0.02	1.20 ± 0.02	1.45 ± 0.05	7.54 ± 0.14	9.00	110.0
Gyeongbuk	3.72 ± 0.14	1.49 ± 0.02	1.25 ± 0.03	1.54 ± 0.04	8.00 ± 0.15	12.90	291.9
Gyeonggi	3.35 ± 0.04	1.50 ± 0.01	1.23 ± 0.01	1.50 ± 0.02	7.58 ± 0.05	9.20	1008.3
Gyeongnam	3.47 ± 0.11	1.50 ± 0.01	1.21 ± 0.02	1.46 ± 0.04	7.65 ± 0.15	9.35	259.3
Incheon	3.38 ± 0.08	1.50 ± 0.01	1.23 ± 0.02	1.50 ± 0.03	7.62 ± 0.09	8.94	220.2
Jeju	3.53 ± 0.16	1.48 ± 0.03	1.24 ± 0.04	1.58 ± 0.05	7.83 ± 0.20	10.61	57.3
Jeonbuk	3.80 ± 0.10	1.48 ± 0.01	1.15 ± 0.02	1.61 ± 0.04	8.05 ± 0.12	14.88	225.4
Jeonnam	3.95 ± 0.17	1.47 ± 0.02	1.22 ± 0.03	1.64 ± 0.06	8.28 ± 0.19	17.38	261.4
Sejong	3.28 ± 0.16	1.55 ± 0.01	1.16 ± 0.02	1.52 ± 0.08	7.51 ± 0.19	9.97	25.6
Seoul	3.39 ± 0.04	1.49 ± 0.01	1.19 ± 0.01	1.47 ± 0.02	7.54 ± 0.05	9.36	777.4
Ulsan	3.55 ± 0.20	1.51 ± 0.01	1.25 ± 0.02	1.57 ± 0.07	7.87 ± 0.26	10.07	94.5
P value	0.034	0.539	0.107	0.131	0.008	0.0001	

Data are presented as mean ± standard error or a proportion estimated using sample weights.
P value in the chi-square test or analysis of variance.
[a] Defined as risk scores ≥11.
[b] Calculated using the 2019 population data obtained from the Korean Statistical Information Service.

population. The overall proportion was 10.5% and the proportions across the regions differed significantly ($P < 0.001$). A higher mean of total risk score and a greater proportion of the high-risk population were observed in Jeonnam compared with those in other regions. However, greater numbers of the high-risk population were examined in Seoul and Gyeonggi areas because of population density.

Figure 1 demonstrates the size of the high-risk population in the map of South Korea. Fewer than 100,000 adults vulnerable to COVID-19 were observed in Daejeon, Jeju, Sejong, and Ulsan indicated as green color. Besides Seoul and Gyeonggi areas displaying the greatest numbers, Busan, Gyeongbuk, Gyeongnam, and Jeonnam showed large numbers of the high-risk population more than 250,000 indicated as orange color. Other areas, including Daegu, were classified as having a medium size between 100,000 and 250,000.

3.3. Nutritional evaluation for the high-risk population

Table 3 presents the calorie and nutrient intakes across the three groups of risk scores. The high-risk population with risk scores ≥11 were more likely to have lower consumption of calorie, protein, fat,

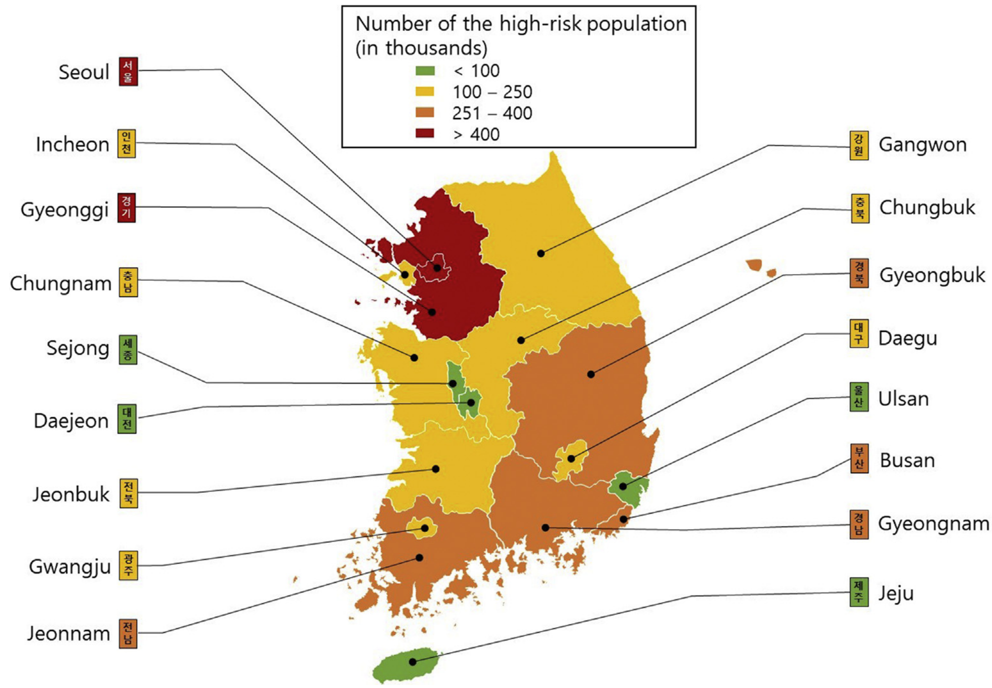

Fig. 1. Region-specific estimates of the number of population at high risk of individual vulnerability to COVID-19.

Table 3
Comparison of dietary intake from 1-day 24-h recall data according to risk score groups and odds ratios of inadequate intakes for high-risk participants who are vulnerable to COVID-19.

	Risk scores (n = 15,249)						
	<8 (n = 6819)		8 – 10 (n = 6016)		≥11 (n = 2414)		
	Mean ± SE	%, < EAR	Mean ± SE	%, < EAR	Mean ± SE	%, < EAR	OR[a] (95% CI)
Calorie, kcal	2040.58 ± 15.09	61.83	2068.70 ± 16.70	55.69	1729.84 ± 21.50*	66.35	1.36 (1.20, 1.53)
Protein, g	76.17 ± 0.69	19.73	72.50 ± 0.79*	23.88	56.95 ± 0.86*	38.46	1.88 (1.62, 2.17)
Fat, g	53.54 ± 0.58		42.90 ± 0.59*		28.16 ± 0.59*		
MUFA, g	17.52 ± 0.21		13.69 ± 0.22*		8.49 ± 0.22*		
PUFA, g	12.98 ± 0.14		11.19 ± 0.15*		8.03 ± 0.18*		
n-3 fatty acid, g	1.82 ± 0.03		1.89 ± 0.03		1.48 ± 0.04		
n-6 fatty acid, g	11.17 ± 0.12		9.31 ± 0.13*		6.56 ± 0.15*		
Vitamin A, μgRE	655.04 ± 13.72	50.23	667.89 ± 12.73	49.04	524.62 ± 14.05*	61.54	1.30 (1.17, 1.45)
Retinol, μg	166.30 ± 4.70		131.64 ± 7.13*		70.09 ± 2.94*		
Carotene, μg	2875.86 ± 75.12		3179.91 ± 53.72*		2708.62 ± 80.15		
Vitamin B1, mg	1.56 ± 0.02	25.51	1.62 ± 0.02*	22.25	1.35 ± 0.02	33.54	1.07 (0.94, 1.22)
Vitamin B2, mg	1.62 ± 0.02	30.83	1.53 ± 0.02*	39.90	1.15 ± 0.02*	60.40	2.50 (2.21, 2.83)
Vitamin B3, mg	15.30 ± 0.16	38.08	14.70 ± 0.17*	42.57	11.38 ± 0.18*	62.18	2.04 (1.79, 2.33)
Vitamin C, mg	73.12 ± 1.57	69.60	82.57 ± 2.08*	64.72	63.92 ± 2.20	73.27	1.14 (1.01, 1.29)
Calcium, mg	504.39 ± 4.79	67.21	525.72 ± 5.69*	68.33	435.38 ± 7.53*	76.43	1.16 (1.03, 1.31)
Phosphorus, mg	1089.22 ± 8.00	12.75	1104.73 ± 9.90	13.20	905.74 ± 12.54*	25.18	1.82 (1.53, 2.15)
Iron, mg	13.40 ± 0.17	35.53	14.64 ± 0.19*	12.85	12.65 ± 0.27*	15.26	0.27 (0.23, 0.31)
Vitamins[b]		10.08		11.59		21.11	1.65 (1.39, 1.96)
Vitamins and protein[c]		8.01		9.73		17.36	1.59 (1.31, 1.93)
Vitamins, protein, and minerals[d]		5.98		5.65		9.79	1.06 (0.85, 1.33)

Abbreviation: SE, standard error; EAR, estimated average requirement for adults based on the 2015 Dietary Reference Intakes for Koreans; OR, odds ratio; CI, confidence interval; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.
Mean ± SE was estimated using sample weights.
**P* value < 0.05 compared with the group with risk scores <8 in the linear regression analysis considering sample weights and calorie intake.
[a] OR of having nutrient intake < EAR for the high-risk population with risk scores ≥11 compared with the remaining participants with risk scores <11 in the logistic regression analysis considering sample weights and calorie intake.
[b] Consumption of all vitamins listed < EAR.
[c] Consumption of all vitamins listed and protein < EAR.
[d] Consumption of all nutrients listed including vitamins, protein, and minerals < EAR.

vitamins, and minerals than the groups with <8 or 8–10. Among the high-risk population, the proportion of participants with inadequate intake below the EAR was greater than 70% for vitamin C and calcium, 60%–66% for calorie and vitamins A, B2 and B3, and less than 40% for protein, vitamin B1, phosphorus, and iron. Among the high-risk population, 21% which corresponds to about 900

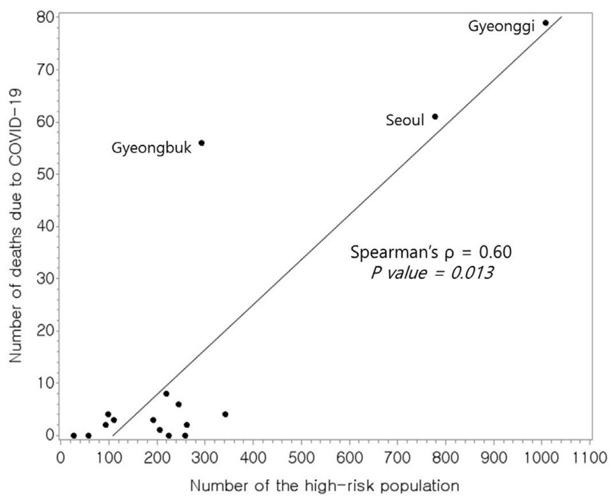

Fig. 2. Ecological correlation between the estimated numbers of the high-risk population and region-specific deaths (reported on October 7, 2020) due to COVID-19.

thousand adults in South Korea showed inadequate intake of multiple vitamins and approximately 10% inadequately consumed all nutrients listed including vitamins, protein, and minerals. In the results of logistic regression analysis, the high-risk population had significantly higher odds of having inadequate intake of calorie, protein, vitamins A, B2, B3, and C, calcium, and phosphorus compared with the remaining participants with risk scores <11 ($P < 0.05$). The high-risk population showed 1.65 [95% CI: 1.39, 1.96] higher odds of inadequate intake of multiple vitamins than the remaining participants (Table 3). When the proportions of those with inadequate intake of vitamins, protein, and minerals in the high-risk population were compared across the regions, significant differences were not examined (data available upon request).

3.4. Ecological analysis for the actual region-specific numbers of deaths due to COVID-19

A region-specific correlation was analyzed between the estimated numbers of the high-risk population and the actual numbers of deaths due to COVID-19 in the ecological analysis (Fig. 2). Data of the 16 regions were included in the analysis after excluding those of Daegu because the exceptionally high incidence rate of COVID-19 was observed in Daegu, a pivotal area of the initial outbreak in South Korea. The correlation was statistically significant (Spearman's $\rho = 0.60$ and $P < 0.05$). When considering the region-specific proportions of individuals with inadequate nutrient intake in the high-risk population, this high correlation has not changed much (Spearman's $\rho = 0.58$ and $P < 0.05$).

4. Discussion

The present study characterized a Korean adult population at high risk of vulnerability to COVID-19 and estimated its region-specific size using a risk assessment tool. Overall, approximately 4.6 million adult Koreans were estimated as the high-risk population, and approximately 20% of them were assessed to have inadequate intake of multiple vitamins. This high-risk population showed 1.65 higher odds of inadequate intake of all vitamins examined including A, B1, B2, B3, and C compared with the remaining individuals. The ecological analysis showed a significant correlation between the region-specific estimates of the high-risk population and the actual numbers of deaths due to COVID-19.

COVID-19 is caused by a novel coronavirus named severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) [16]. Since the outbreak of COVID-19 began in Wuhan, China, it has spread rapidly and globally in less than a year. It is still uncertain how this infectious disease started and when it will be eradicated. As reported by the World Health Organization, the numbers of confirmed cases and deaths due to SARS-CoV-2 have surpassed 35 million and 1 million, respectively, worldwide (https://covid19.who.int/, accessed on October 7, 2020). Such a huge and deadly consequence is a challenge to the public health and the national healthcare system, raising serious concerns about the shortage of hospital beds, medical facilities, equipment (in particular, intensive care unit facilities and extracorporeal membrane oxygenation equipment for severe cases), and healthcare workers [1]. Thus, information on who is clinically vulnerable or at high risk of acquiring a severe illness from COVID-19 and how many people at high risk potentially reside in a specific region may be useful for individual prevention and health policy decisions.

Several studies have characterized the risk factors for a severe illness and mortality of COVID-19 and have developed clinical risk scores [2–5]. Although significant risk factors for COVID-19 mortality and severity differed slightly in these studies, the common risk factors were older age, male sex, smoking, and the presence of comorbidities [2–5,14,17,18]. One study has suggested a risk assessment tool for a general population and constructed risk scores with four components including health-related risk factors, behavioral elements, exposures, and social policies [6]. The health-related risk factors were almost the same as the aforementioned common risk factors. The social and behavioral factors included physical distancing in the community, wearing masks, and hand hygiene practices. The health-related risk factors appear to predict the risks of severity and mortality of COVID-19, whereas the social and behavioral factors are related to the chances of exposure to the coronavirus [6].

In the present study, the proportion of the high-risk population was estimated as 10% approximately using only health-related risk factors because individual-level data regarding social and behavioral factors were unavailable. In South Korea, wearing a mask is mandatory. The Central Disease Control Headquarters strongly advocate physical distancing and hand hygiene practices, which the general public appreciates. One more difference in the risk assessment from a previous study [6] included obesity in comorbidities because some studies considered obesity as a common feature and a risk factor of mortality among patients with COVID-19 [17–19]. Obesity was reported to be a risk factor for community-acquired pneumonia in the general population [20]. In the results regarding comorbidities, the prevalence of hypertension and DM significantly differed across the 17 regions. Gangwon and Jeonnam showed higher prevalence than other regions partly because of a greater proportion of elders in the regional population. Accordingly, these regions showed a greater proportion of the high-risk population than other regions did. Because Jeonnam has a greater population size than Gangwon, it showed a larger high-risk population. Similarly, Seoul and Gyeonggi regions showed a larger size of the high-risk population than other regions did. Furthermore, these two regions showed a greater number of deaths due to COVID-19 and appeared to lead to the significant ecological correlation. Since these regions have a high population density and several crowded places, social and physical distancing practices should be strongly advocated for high-risk individuals who reside or stay in these regions. In southern rural areas with a higher proportion of the high-risk population, local hospitals may need more effort and support in preparing facilities and equipment for winter surge of COVID-19 cases.

The present study found that roughly one-in-five individuals with high-risk scores have inadequate intake of several vitamins including vitamins A and C, which are essential to maintain immune function [12,21,22]. These high-risk individuals are expected to be more vulnerable to coronavirus infection and likely to have severe illness if they acquire the infection. It is well known that patients with malnutrition have longer lengths of hospital stay and an increased risk of mortality [23]. Recent reports have demonstrated the similar results in patients with COVID-19 [10,24] and found that this viral infection leads to severe weight loss [25,26]. Upholding the nutritional management guidance for COVID-19 patients [27], preemptive nutritional strategies including aggressive early nutritional assessment and support are suggested in the serious situation of hospital bed shortage. In fact, it has been suggested that vitamin C may play a therapeutic role in the management of COVID-19 [28].

Some limitations should be considered when interpreting the findings of this study. Generally, the ecological correlation analysis generates a hypothesis regarding a potential association rather than inferring a causal relationship. As mentioned earlier, the present study considered the health-related risk factors only because individual-level data on other factors related to COVID-19 were unavailable. Epidemiological studies in COVID-19 patients are warranted to examine behavioral and clinical data including nutritional status assessment. Unfortunately, such studies are unlikely to be approved in current crisis and individual data of COVID-19 patients are unattainable at this time. Finally, limited generalizability is another weakness of the study; both survey data and COVID-19 mortality data were generated in South Korea. The present study's strength is the momentary evaluation to characterize and estimate individuals at high risk of vulnerability to COVID-19 using the general population survey data. Above all, characterization of their nutritional status may be useful information for the general public as well as for dietitians.

The study results suggest that individuals vulnerable to COVID-19 living in densely populated regions should pay particular attention to the protection against SARS-CoV-2 infection and have an adequate nutritional status, which may support optimal immune function.

Funding statement

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2019R1A2C2084000). The funders have no role in the study.

Conflict of interest

The author declares no potential conflicts of interests.

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