Chapter

Consequences of COVID-19 Pandemic Including Endocrine and Metabolic Impacts

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Abstract

A pandemic is an epidemic that spreads globally. Coronavirus disease 2019 (COVID-19) caused a major pandemic that affected human health and activities around the world since the beginning of 2020 and became a major international emergency. Through multiple paths, COVID-19 pandemic influenced life at individual, familial, societal, and environmental levels and led to a global economic recession. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus responsible for the disease. It invades the target cells by binding to angiotensin-converting enzyme 2 (ACE2). Endocrine and metabolic systems can be implicated in COVID-19 infection. Subjects with several comorbidities (e.g., hypertension, diabetes, and obesity) are more likely to be infected and are at a higher risk for complications and death from COVID-19. Wearing mask, social distancing, home confinement, and isolation have been recommended and implemented in several countries to curb the spread of the outbreak. Vaccination remains the best protective measure. Different vaccines are now available and have been used. The worldwide impact of COVID-19 pandemic may last several years.

Keywords: pandemic, COVID-19, consequences, endocrine and metabolic systems

1. Introduction

A pandemic is an epidemic that spreads globally, crosses international boundaries, and affects large number of people (**Figure 1**) [1, 2].

Through multiple mechanisms (e.g., infection and confinement/isolation), pandemics can influence life at individual, familial, societal, and environmental levels [3].

COVID-19 pandemic became a global health and economic crisis of the 21st century, representing one of the most profound medical, societal, and economic challenges in modern times [4–7]. Endocrine and metabolic systems can be involved in COVID-19 infection [8–48]. Diabetes and obesity negatively impact immune system and increase the risk of infection and morbidity/mortality due to COVID-19 [8–12, 14, 23–25, 31, 33–37].

Multiple COVID-19 vaccines are now available and have been used worldwide [49–53].

Figure 1.
Pandemics affect large number of people in multiple countries.

2. Pandemics

2.1 History of pandemics

Numerous pandemics have occurred throughout the history of mankind, the most recent being the COVID-19 pandemic [1, 2, 4–6].

Important pandemics that occurred over the last 1,500 years are reported in **Table 1** (non-exhaustive list). The deadliest pandemics were the Plague of Justinian, the Black Death, and the Spanish Flu.

Pandemic Name	Pathogen	Vector	Date	Mortality
Plague of Justinian	Yersinia pestis	Fleas	541–750	Up to 100,000,000
Black Death	Yersinia pestis	Fleas	1347–1351	Up to 200,000,000
Spanish Flu	H1N1 virus	Avian	1918–1919	Up to 100,000,000
Asian Flu	H2N2 virus	Avian	1957–1958	Up to 4,000,000
Hong Kong Flu	H3N2 virus	Avian	1968–1969	Up to 4,000,000
Swine Flu	H1N1 virus	Pigs	2009–2010	Up to 250,000
COVID-19	SARS-CoV-2	Unknown	2019-present	At least 4,362,000*

**As of August 17, 2021.*

Table 1.
Important pandemics over the last 1,500 years (non-exhaustive list).

2.2 Consequences of pandemics

Through multiple paths (e.g., infection and confinement/isolation), pandemics can influence life at individual, familial, societal, and environmental levels [3].

At the individual level, there are health consequences (e.g., infection caused by the pathogen, metabolic diseases, mental disorders, impact on pre-existing conditions, and eventually death), financial challenges (mainly due to unemployment), and educational consequences (due to remote learning).

At the familial level, the prolonged presence of parents and children at home can promote domestic violence.

At the societal level, the limitation of social life and activities will have major economic consequences for several businesses (e.g., agriculture, restaurant, hotel, store, airline, cruise, convention, concert, sport event, museum, movie, and theater).

At the environmental level, the confinement may have some health benefits, at least for short term, due to a reduction in air pollution mainly secondary to the decrease in circulating cars and flying planes. This can also positively impact the life of animals and plants.

3. COVID-19 pandemic

3.1 Virus

In January 2020, Chinese authorities announced the isolation of a new type of coronavirus, SARS-CoV-2, following the occurrence in December 2019 of several pneumonia cases of unknown etiology. On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic.

COVID-19 is caused by one of the coronaviruses in the family of Coronaviridae. The virus belongs to genera Betacoronavirus and is the seventh coronavirus known to cause human diseases. It is a spherical or pleomorphic enveloped, non-segmented, single-stranded, positive-sense RNA virus. The genome of the virus is composed of 29,903 nucleotides. The virus is made up of four main structural proteins: spike (S), membrane (M), envelope (E), and nucleocapsid (N) proteins (**Figure 2**) [4–6, 14, 25, 29, 38, 54, 55].

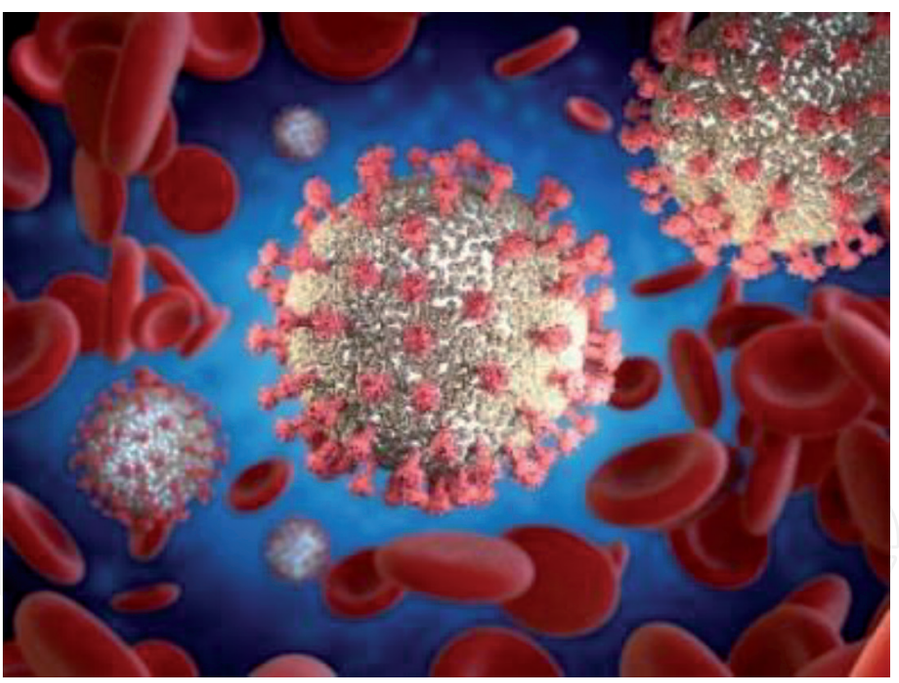

Figure 2.
SARS-CoV-2.

SARS-CoV-2 evolves over time and like other viruses is subject to mutations. The mutated virus is referred to as a variant of the original virus. Several variants of SARS-CoV-2 have been reported (e.g., Alpha, Beta, Delta, Epsilon, Eta, Gamma, Iota, Kappa, Lambda, Theta, and Zeta). They were initially detected in countries like the United Kingdom (UK), South Africa, Brazil, and India. Some variants are more transmissible and aggressive and may be more resistant to the current vaccines. The Delta variant has created serious concerns in several countries, especially in the USA where it became the dominant variant affecting adults, adolescents, and children, and causing spike in hospitalizations.

3.2 COVID-19 origin, mode of transmission, and action

The exact origin of SARS-CoV-2 has been subject of multiple debates and speculations (bats to humans through Huanan Seafood Market or release from a research laboratory, in Wuhan, Hubei Province, China). According to the former director of Centers for Disease Control and Prevention in the United States of America (USA), the virus most likely originated from the Wuhan research laboratory. The accidental or intentional release of the virus remains to be established.

Human-to-human transmission occurs mainly by direct contact or by droplets spread by infected subjects through cough or sneeze. The virus can survive in the environment from a few hours to a few days, depending on the conditions. The nose, mouth, and ocular mucosa are the major way of transmission (**Figure 3**).

Figure 3.
Mode of transmission of SARS-CoV-2.

The virus uses the host cell membrane protein receptors to enter and infect the cell. The most well-described cell membrane protein receptor is ACE2 (a zinc metalloprotease). First, the virus spike protein binds to ACE2. Then, there is an internalization of ACE2 with a subsequent reduction of cell surface ACE2 enzymatic activity [14, 25, 29, 38, 55]. ACE2 is expressed in several organs including endocrine glands. It is abundant in the epithelia of the lung and intestine. Infected cells undergo apoptosis or necrosis and trigger inflammatory responses.

3.3 COVID-19 diagnostic tests

The Food and Drug Administration in the USA has approved two tests for diagnosing COVID-19 infection. The antigen test detects certain proteins in the virus. The polymerase chain reaction test detects genetic material of the virus. For both tests, the fluid sample is collected using a nasal swab (**Figure 4**).

Figure 4.
COVID-19 diagnostic tests use a nasal swab to collect fluid sample.

3.4 COVID-19 consequences

Through infection and confinement/isolation, COVID-19 can influence life at individual, familial, societal, and environmental levels (**Figure 5**) [3].

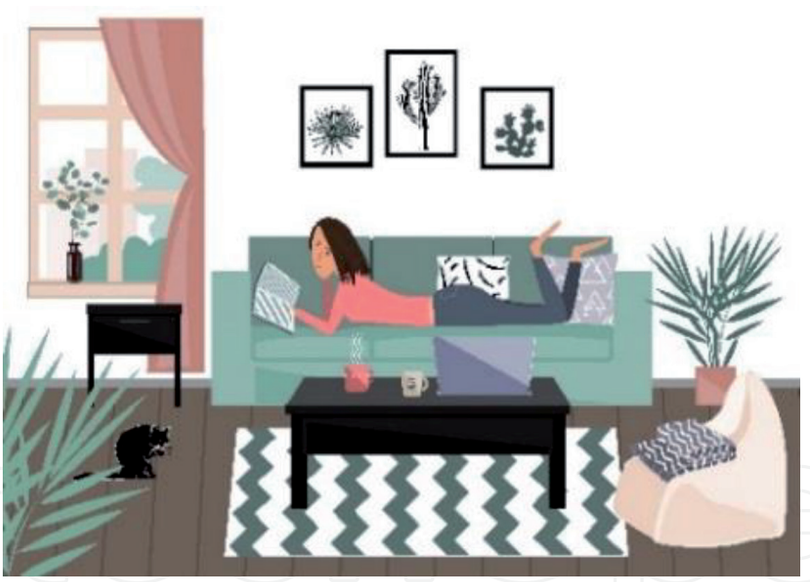

Figure 5.
COVID-19 pandemic led to confinement/isolation.

3.4.1 Individual

3.4.1.1 Health consequences

3.4.1.1.1 Global health

COVID-19 has placed a significant burden upon healthcare worldwide. COVID-19 can target different systems that express ACE2 (respiratory, cardiovascular, neurological, gastrointestinal, endocrine, others). Although lung has been reported to be one of the most affected organs, the contribution of intestinal involvement to the clinical

course of the disease and its treatment (through gut microbiota) has been highly speculated [54]. All age groups may be affected. The disease is more severe in men [11, 12].

COVID-19 is associated with alterations in the host immunological status including an increase in pro-inflammatory cytokines. The surge of pro-inflammatory factors ("cytokine storm") may cause host organ damage such as lung damage resulting in severe respiratory failure [8, 38]. Subjects infected with COVID-19 can be asymptomatic, have mild symptoms recovering within 1 to 2 weeks, or be severely affected (e.g., severe pneumonia and cardiogenic shock) with the ultimate risk of death. Common symptoms include fever, dry cough, dyspnea, arthralgia, myalgia, ageusia (loss of taste), and anosmia (loss of smell). COVID-19 symptoms can sometimes last several months. The damage to the lungs, heart, and brain can increase the risk of long-term symptoms (long haulers). Older subjects (> 65 years), black subjects, smokers, and subjects with immunodeficiency, cardiac and respiratory diseases, cancer, hypertension, diabetes, obesity, and dyslipidemia are considered high-risk populations [8–12, 14, 23–25, 31, 33–37, 39]. Among COVID-19 mortality cases in Wuhan, China, the main associated comorbidities were hypertension (54%), diabetes (42%), and cardiac disease (19%) [9].

The public health recommendations during the COVID-19 pandemic resulted in social distancing and home confinement/isolation. More than 4 billion people worldwide have experienced the COVID-19 mobility restriction. The life in home confinement and self-isolation for a long period has significant negative health consequences due to alterations in lifestyle (eating behavior and physical activity) and mental status, and the impact on pre-existing diseases [3, 21, 22, 31, 32, 40, 42, 56–58].

The changes in lifestyle (e.g., unhealthy diet and reduced physical activity) which affect both adults and children, can lead to weight gain (overweight or obesity). Sedentarism can cause a very rapid loss of muscle mass (up to 10% after 30 days) with degenerative changes of the neuromuscular system and reduced cardiorespiratory fitness [21]. The confinement and isolation, especially if associated with unemployment and financial challenges, can negatively influence psychological health, and promote anxiety and depression, especially in women [3, 40, 57, 58]. It may also impact access to health care (e.g., medications, physicians, and hospital beds) for the management of pre-existing medical conditions (e.g., heart disease, cancer, and diabetes) [3].

Death can result from direct consequences of the viral infection, mental complications of confinement/isolation with the risk of suicide, or aggravation of pre-existing diseases (**Figure 6**).

Figure 6.
Death from COVID-19 pandemic affected millions of people worldwide.

The extent of death from COVID-19 pandemic as of August 17, 2021 is reported in **Table 2**. African countries had a low mortality rate, at least at the beginning of the pandemic, that can be explained in part by the existence of less indoor activities (less exposure to the virus) and younger population.

Country	Total Population	Infected Subject	Mortality
World	**Around 7,900,000,000**	**At least 207,173,000**	**At least 4,362,000**
USA	Around 333,000,000	At least 36,385,000	At least 615,000
Brazil	Around 214,000,000	At least 20,350,000	At least 568,000
India	Around 1,395,000,000	At least 32,225,000	At least 431,000
Mexico	Around 130,000,000	At least 3,091,000	At least 248,000
Peru	Around 33,000,000	At least 2,132,000	At least 197,000
Russia	Around 146,000,000	At least 6,621,000	At least 171,000
UK	Around 68,000,000	At least 6,267,000	At least 130,000
Italy	Around 60,000,000	At least 4,440,000	At least 128,000
Colombia	Around 51,000,000	At least 4,864,000	At least 123,000
Indonesia	Around 277,000,000	At least 3,871,000	At least 118,000
France	Around 65,000,000	At least 6,311,000	At least 111,000
Argentina	Around 46,000,000	At least 5,080,000	At least 108,000

Table 2.
Extent of infection and death from COVID-19 pandemic in 12 countries ranked by descending order of death (WHO data, as of August 17, 2021).

Between March and October 2020, COVID-19 became the third leading cause of death in the USA (after heart disease and cancer) for persons aged 45 to 84 years [7].

For several months and mainly due to political reasons, the magnitude and gravity of COVID-19 pandemic were not taken seriously in the USA at federal and some state levels. According to the former COVID-19 task force coordinator, with an appropriate management and policy, hundreds of thousands of lives could have been saved.

3.4.1.1.2 Endocrine and metabolic systems

Several endocrine and metabolic systems can be impacted by COVID-19 infection (**Figure 7**) [8–48]. Findings in this area are evolving and long-term effects of COVID-19 infection remain unknown.

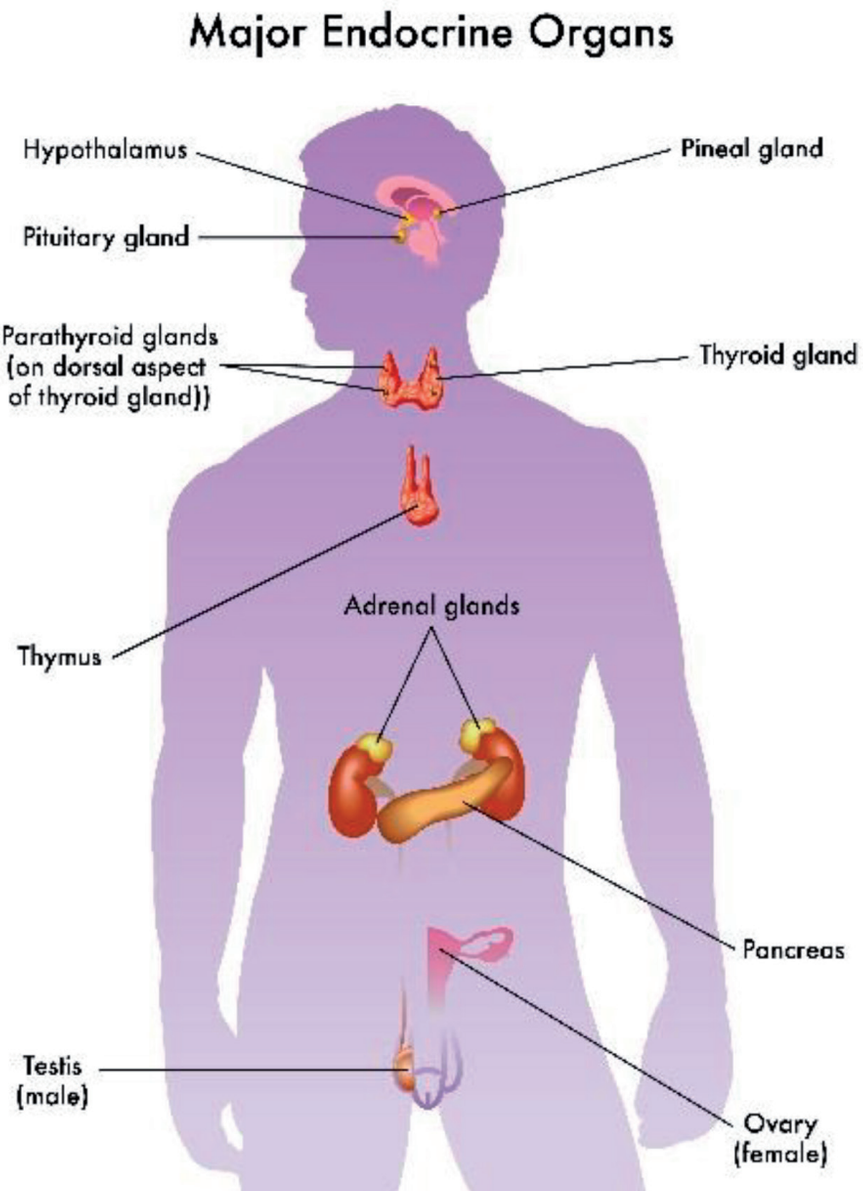

Figure 7.
Different endocrine systems can be impacted by COVID-19 infection.

3.4.1.1.2.1 Hypothalamus, pituitary

The hypothalamus and pituitary tissues do express ACE2 and can theoretically be targeted by SARS-CoV-2. However, there are no solid data on hypothalamic–pituitary dysfunction in subjects affected by COVID-19 [8, 10, 12, 14].

In subjects with treated diabetes insipidus, the priority should be to avoid hyponatremia [8].

Management of pituitary tumors without signs of emergency (e.g., visual deterioration and apoplexy) can be differed for several months [16].

3.4.1.1.2.2 Thyroid

ACE2 receptors have been located in the thyroid. Data on thyroid involvement during COVID-19 infection are relatively limited [8, 10, 12, 14, 17, 18].

In severe cases of COVID-19, subjects may present with nonthyroidal illness syndrome [17]. Several cases of onset of subacute thyroiditis have been reported in subjects with COVID-19 infection [12, 14]. COVID-19 can be a precipitating factor for the initiation or relapse of Graves' disease [8, 10]. In subjects receiving antithyroid drugs, because symptoms of agranulocytosis (a rare side effect of antithyroid drugs) can overlap with COVID-19, special attention is needed [12].

Diagnostic procedures and surgery for thyroid nodules can be postponed in most cases [8, 30]. The timing of surgery should be carefully decided for subjects with thyroid cancer [19, 30].

3.4.1.1.2.3 Parathyroid

Data on parathyroid disorders and COVID-19 infection are relatively rare. In case of hyperparathyroidism, surgery can be postponed without major clinical impact [20].

3.4.1.1.2.4 Adrenal

ACE2 is expressed in the adrenal gland. Impaired adrenocortical response has been reported in subjects with COVID-19 infection consistent with central adrenal insufficiency [15].

Subjects with Cushing's disease or syndrome may be at higher risk of COVID-19 infection since excess cortisol production has immunosuppressive effect [8, 12]. Medical treatment is recommended as first-line therapy for most of these subjects during the COVID-19 pandemic.

Adrenal insufficiency may create a potentially increased risk of acquiring COVID-19 infection as this condition is associated with impaired immunity. Subjects with adrenal insufficiency may be at higher risk of medical complications and increased mortality in case of COVID-19 infection. If COVID-19 infection is suspected in subjects with adrenal insufficiency, a prompt increase in dose of the replacement therapy is indicated to avoid adrenal crisis [8, 10, 12–14]. Subjects with known adrenal insufficiency and COVID-19 may require parenteral glucocorticoid treatment with careful monitoring of serum potassium [12, 13].

3.4.1.1.2.5 Pancreas

ACE2 is expressed in pancreas (both exocrine and endocrine pancreas). Physical inactivity leads to insulin resistance and systemic inflammation with subsequent metabolic consequences [21, 22]. COVID-19 infection, through multiple mechanisms, may impair the function of the endocrine pancreas and promote or aggravate diabetes [10, 14, 23].

Chronic hyperglycemia in subjects with diabetes negatively impacts immune system and increases the risk of infection and morbidity/mortality due to COVID-19 (**Figure 8**) [8–12, 14, 23–25]. It is important to maintain a good glycemic control in subjects with diabetes to reduce the risk of COVID-19 infection. In case of COVID-19 infection, the outpatient plasma glucose goal is 72–144 mg/dL with a hemoglobin A1c goal less than 7%. Plasma glucose should be monitored at least twice a day. Insulin is the preferred treatment in hospitalized subjects with the use of continuous glucose monitoring [12].

Figure 8.
COVID-19 pandemic can promote diabetes or be aggravated by diabetes.

3.4.1.1.2.6 Testis

There is a high level of ACE2 expression in the testis (e.g., Sertoli cells, Leydig cells, and spermatogonia). COVID-19 infection may cause Sertoli cells, Leydig cells, and seminiferous tubules damages resulting in low serum testosterone levels and altered sperm quality [10, 12, 14, 26–28].

Men with COVID-19 are exposed to worse outcome than women, possibly due to sex differences in immune response [11, 12].

3.4.1.1.2.7 Ovary

ACE2 is expressed in the ovary. However, data on ovarian function and COVID-19 infection are limited [12, 14]. COVID-19 infection may disturb the female reproductive system and cause menstrual disorder, infertility, and fetal distress [29].

3.4.1.1.2.8 Adipose tissue

Adipose tissue expresses ACE2. The unhealthy diet and reduced physical activity promoted by confinement can lead to overweight or obesity, especially in high-income countries/families [31, 32]. Low-income countries/families are exposed to food insecurity, malnutrition, and weight loss [31].

With higher adipose tissue mass, more receptors (ACE2) would be available for SARS-CoV-2, exposing subjects to COVID-19 [10]. Subjects with overweight/obesity may experience a more serious COVID-19 infection through several mechanisms (e.g., inflammation, impaired immunity, mechanical lung dysfunction, impact of comorbidities, and vitamin D deficiency) (**Figure 9**) [8–11, 14, 31, 33–37]. These subjects require weight reduction using the appropriate tools as indicated (e.g., diet, exercise, drug, medical device, and bariatric surgery) [36, 37, 59–62]. All precautions should be taken to avoid infection. Subjects with obesity and COVID-19 who require treatment in intensive care units present challenges in their management (e.g., difficulty for moving, for intubating, and for obtaining diagnostic imaging) [8].

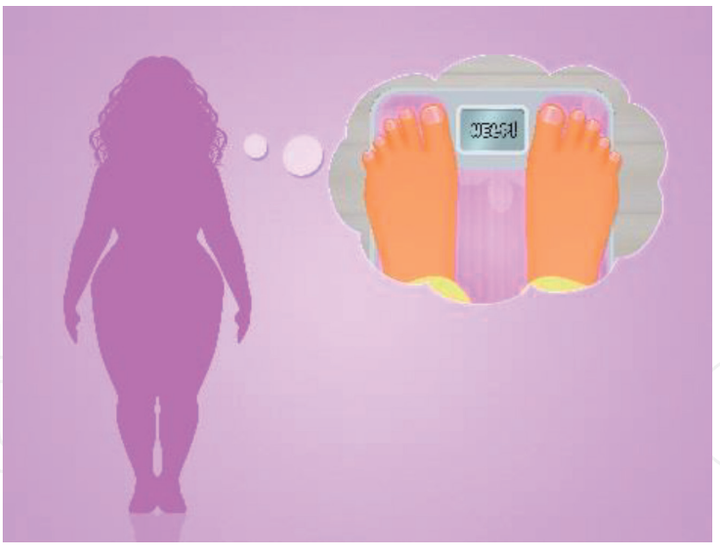

Figure 9.
COVID-19 pandemic can promote overweight/obesity or be aggravated by overweight/obesity.

3.4.1.1.2.9 Lipids

The "cytokine storm" caused by COVID-19 produces an immune-mediated inflammatory dyslipidemia (e.g., decreased high-density lipoprotein cholesterol and low-density lipoprotein cholesterol, increased triglycerides, and increased lipoprotein oxidation) [38].

Dyslipidemia is one of the most common comorbidities in the general population and in subjects with COVID-19. It can potentially increase the severity and mortality of COVID-19. This increased risk is more pronounced with older age, male gender, and presence of hypertension [39].

3.4.1.1.2.10 Nutrition (calories, macronutrients, electrolytes, vitamins) and exercise

During COVID-19 confinement, a healthy lifestyle is essential (**Figure 10**). An optimal nutrition (e.g., calories, macronutrients, electrolytes, and vitamins) is

Figure 10.
Healthy lifestyle is essential during COVID-19 pandemic.

important, especially for boosting the immune system [21, 31, 33, 40–44, 47, 48]. It is recommended to reduce the daily energy intake by 15–25% with more energy during breakfast and less energy during lunch and dinner.

Diet should be balanced and contain fruits, vegetables, whole grains, low-fat dairy products, and olive oil, with adequate hydration. The consumption of sugar, saturated fat, and salt should be reduced. COVID-19 infected-subjects, especially those who are hospitalized, are at risk of malnutrition and need adequate nutritional support [8].

Electrolytes and trace elements play an important role in the management of COVID-19. The severity of COVID-19 is associated with lower serum concentrations of sodium, potassium, and calcium. It is important to assess the levels of electrolytes and trace elements throughout the course of the disease to establish appropriate corrective actions [45, 46].

Vitamins are important in the prevention of viral infection. Subjects at risk of or with respiratory viral infection should receive vitamin C and vitamin D. Particular attention should be paid to the treatment of subjects with hypovitaminosis D [8, 11, 12].

Safe handling of food, from production to consumption, is critical to reduce the risk of viral dissemination.

Daily exercise (e.g., low to medium-intensity exercise) is essential for preventing the negative impact of inactivity and improving health [21, 40].

COVID-19 has caused a major disruption in the management of subjects with endocrine and metabolic disorders. The services offered by healthcare systems must adapt rapidly. Outpatient management with remote advice and support services need to be organized [23, 30]. Routine in-person appointments are not recommended in order to avoid crowds in waiting rooms [9]. Elective surgical procedures should be postponed when possible.

3.4.1.2 Financial consequences

Unemployment may cause financial challenges at the individual level and this can affect both physical and mental health (**Figure 11**) [31, 40]. Between February and May 2020, the number of unemployed Americans rose by more than 14 million.

Figure 11.
Unemployment caused by COVID-19 pandemic may lead to individual financial challenges.

3.4.1.3 Educational consequences

For the current generation of young people (children and adolescents), the disrupted education due to remote learning and lack of in-person classes during an extensive period of confinement and social distancing can negatively impact the quality of education and social skills (**Figure 12**).

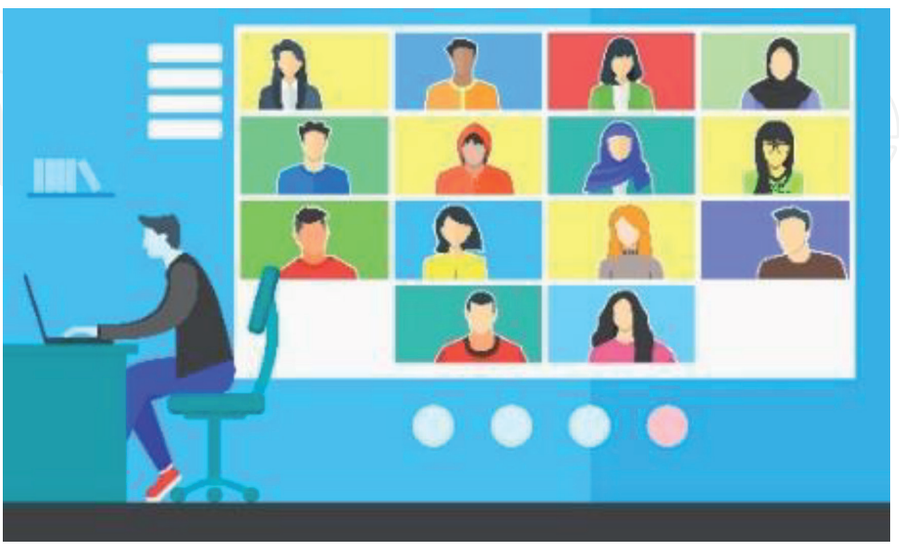

Figure 12.
The switch to remote learning during COVID-19 pandemic may impact the quality of education and social skills of the current generation of students.

3.4.2 Familial

During the enforced COVID-19 home confinement, there is an important decrease in the amount of familial/social activities (e.g., interactions with other individuals and entertainment), associated with a lower life satisfaction [63].

Confinement, isolation, and prolonged presence of parents and children expose to the risk of domestic violence. Children and their mothers are particularly vulnerable (**Figure 13**) [64].

Figure 13.
The confinement following COVID-19 pandemic can promote domestic violence.

3.4.3 Societal

COVID-19 pandemic led to a global economic recession [40]. According to a report released by the World Bank, in 2020, the world economy probably shrank by 4.3% (equivalent of $3.9 trillion).

The financial burden of COVID-19 is mainly due to confinement and limitation of social life. These restrictions lead to the limitation or closing of several businesses (with the subsequent increase of unemployment) affecting the income from agriculture, restaurant, hotel, store, airline, cruise, convention, concert, sport event, museum, movie, and theater (non-exhaustive list) and causing health issues, all contributing to a decrease in productivity and an increase in national debt.

Reducing social inequalities should become a priority for all countries to build resilience during the pandemic.

The pandemic also impacted medical research for hospitals and pharmaceutical companies by creating limitations in implementation and conduct of clinical trials in different countries, especially when in-person visits are necessary.

3.4.4 Environmental

The lockdown measures of COVID-19 pandemic caused a temporary reduction in global air pollution secondary to the decrease of anthropogenic activities (e.g., less circulating cars and flying planes) (**Figure 14**) [65–67].

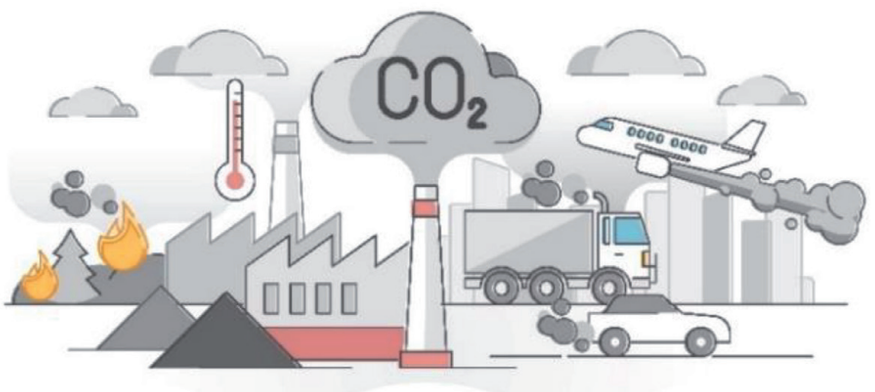

Figure 14.
The confinement due to COVID-19 pandemic temporarily reduced air pollution by decreasing the anthropogenic activities.

Most polluted cities are located in Asia, especially in India, China, and Pakistan. Results of a study using satellite observations at the continental scale from January to May 2020 showed a substantial decrease in the concentrations of nitrogen dioxide (maximum reduction of 33% in East Asia), sulfur dioxide (maximum reduction of 41% in East Asia), and aerosol optical depth (maximum reduction of 37% in South Asia) during the lockdown period of 2020 compared to their averages for the baseline period (2015–2019) over all continents [65].

According to WHO, ambient air pollution was responsible for 4.2 million deaths worldwide in 2016 (mainly from respiratory infection, chronic obstructive ulmonary disease, ischemic heart disease, stroke, and lung cancer).
Any reduction in global air pollution, even for a short period of time, may

theoretically have some health and financial benefits for humans. It can also be beneficial for animals and plants.

3.5 COVID-19 prevention

3.5.1 General precautions

In many locations affected by COVID-19 infection, wearing mask, social distancing, and lockdown (with the possibility to work from home) became mandatory to prevent the expansion of the disease in the general population and the subsequent medical challenges for the healthcare system (**Figure 15**). In addition, subjects were encouraged to wear gloves when appropriate and do careful hand washing, especially before eating and drinking.

Figure 15.
Wearing mask is a simple but very efficient way to protect against COVID-19 infection.

Politicization of wearing mask in some countries (e.g., USA) created medical challenges in the control of the pandemic.

3.5.2 Vaccination

Vaccination is the cheapest and most effective way to protect against COVID-19 infection. Vaccine development is a lengthy process that usually takes 10–15 years, but development of COVID-19 vaccines followed a very fast pace mainly due to collaborative efforts of research institutions and active engagement of regulatory agencies.

Several vaccine candidates have been investigated by various companies in different countries using multiple vaccine platforms (e.g., live-attenuated, inactivated, protein subunit, virus-like particle, replicating viral vector, non-replicating viral vector, DNA, and mRNA) [49–53]. Several vaccines were designed to use the SARS-CoV-2 spike protein or part of it as the immunogen. As of August 17, 2021, 21 COVID-19 vaccines have been approved or authorized for emergency use by at least 1 country. In the USA, Pfizer/BioNTech vaccine was first authorized for emergency use in subjects aged 16 years and older and later for adolescents aged 12 to 15 years. A partial list of the approved/authorized vaccines is reported in **Table 3**. Several clinical trials of additional COVID-19 vaccines are currently ongoing (44 trials in Phase 1, 59 trials in Phase 2, and 29 trials in Phase 3).

Company	Type of Vaccine	Number of Country Approval/Authorization
Oxford/AstraZeneca (UK)	Non-replicating viral vector	121
Pfizer/BioNTech (USA/Germany)	mRNA	97
Gamaleya (1) (Russia)	Non-replicating viral vector	71
Moderna (USA)	mRNA	68
Sinopharm Beijing (China)	Inactivated	60
Janssen (USA)	Non-replicating viral vector	59
Serum Institute of India (India)	Non-replicating viral vector	45
Sinovac (China)	Inactivated	39
Gamaleya (2) (Russia)	Non-replicating viral vector	12
Bharat Biotech (India)	Inactivated	9
CanSino (China)	Non-replicating viral vector	8

Table 3.
Top 11 COVID-19 vaccines approved/authorized by at least 1 country ranked by descending order of number of country approval/authorization (as of August 17, 2021).

As of August 17, 2021, the number of COVID-19 vaccine doses administered was more than 4,452,000,000. In most locations, the vaccination prioritized the healthcare workers, old subjects, and subjects with comorbidities. The mRNA vaccines need to be stored and transported at very low temperatures. This requirement may prevent effective distribution of these vaccines to areas with limited availability of specialized freezers. Viral spread will continue to cause significant health and economic issues until a sufficient number of subjects are vaccinated and herd immunity is achieved (**Figure 16**).

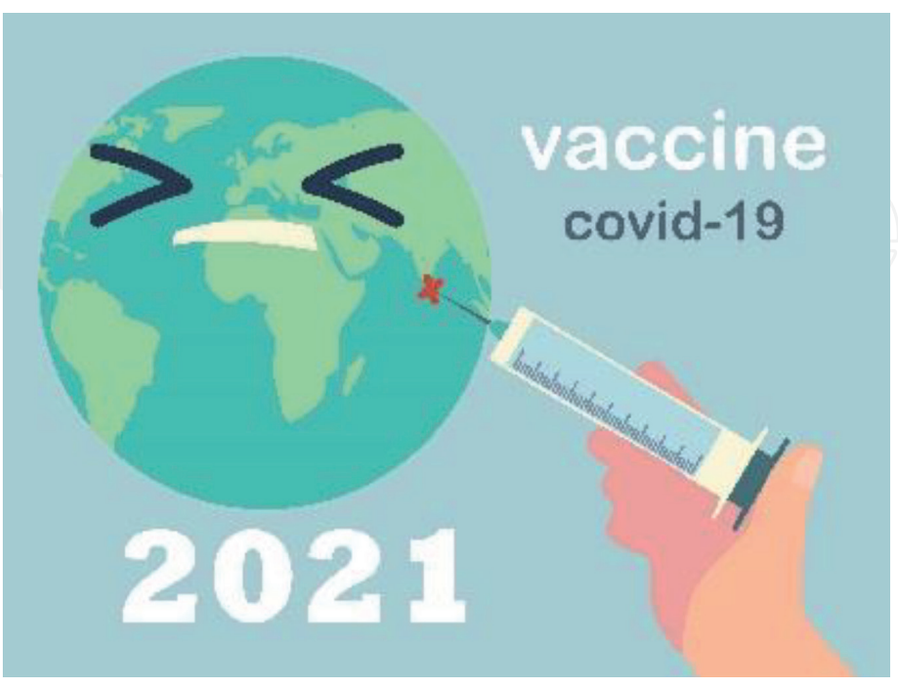

Figure 16.
There is a need to vaccinate a minimum number of subjects worldwide against COVID-19 to reach herd immunity.

COVID-19 vaccines have a high efficacy (up to 95%) by providing significant protection against severe disease, hospitalization, and death. The duration of immunity after the first full vaccination is unknown. COVID-19 vaccine boosters are most likely necessary for all vaccinated subjects. In the USA, very recently, Pfizer/BioNTech and Moderna received authorization for an extra dose of vaccine in immunocompromised subjects. Some of the currently available vaccines provide partial to complete protection against SARS-CoV-2 variants.

COVID-19 vaccines are overall safe and well tolerated. Subjects may develop minor side effects (e.g., swelling, redness, and pain at injection site, fever, headache, tiredness, muscle pain, chills, and nausea) lasting usually 1 or 2 days after the injection. In rare cases, subjects may develop anaphylaxis, myocarditis/pericarditis, and thrombosis. Long-term side effects of COVID-19 vaccines are currently unknown. Limited data are available regarding vaccine safety in pregnancy.

There are a significant number of subjects with vaccine hesitancy for a variety of reasons including concerns about the unknown or undisclosed side effects of the vaccines, absence of full vaccine approval, ignorance, misinformation, selfishness, and political influence (mainly in the USA).

3.6 COVID-19 treatment

The standard management of COVID-19 infection is based on supportive treatment with lung-protective ventilation and dexamethasone. Several drugs have also been investigated and used for the treatment of COVID-19 infection. They include antiviral agents (e.g., remdesivir) and monoclonal antibodies (e.g., casirivimab + imdevimab and sotrovimab) (**Figure 17**) [68].

Figure 17.
Several drugs to treat COVID-19 infection are currently used or under investigation.

4. Life with COVID-19 pandemic

The COVID-19 pandemic may last several years and can cause dramatic changes in society, affecting our lives for generations to come. The precautions necessary to avoid infection or transmission of the virus may stay in effect for a long period. This has significant impact on life at different levels (e.g., family, profession, gathering, traveling, hand shaking, hugging, kissing, and love making). The new normal, even at a very personal level, may be very different and somehow odd (**Figure 18**).

Figure 18.
The new normal after COVID-19 pandemic may look odd but necessary.

5. Conclusions

COVID-19 pandemic became a global health and economic crisis of the 21st century. It represents one of the most profound medical, societal, and economic challenges in modern times.

The pandemic caused substantial morbidity and mortality. Almost all organs and biological systems are directly or indirectly impacted by COVID-19. The presence of diabetes and obesity contributes to a worse prognosis of COVID-19 infection due to impaired immune function.

Wearing mask, social distancing, home confinement, and isolation have been recommended and implemented in most countries to curb the spread of the outbreak. Mass quarantine leads to major health and social consequences.

Several efficient and safe vaccines are now available and have been used worldwide.

Conflict of interest

The author declares no conflict of interest.

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References

[1] Samal J. A historical exploration of pandemics of some selected diseases in the world. International Journal of Health Sciences and Research. 2014;**4**:165-169.

[2] Piret J, Boivin G. Pandemics throughout history. Frontiers in Microbiology. 2021;**11**:631736. DOI: 10.3389/fmicb.2020.631736

[3] Yen-Hao Chu I, Alam P, Larson HJ, Lin L. Social consequences of mass quarantine during epidemics: A systematic review with implications for the COVID-19 response. Journal of Travel Medicine. 2020;**27**:1-14. DOI: 10.1093/jtm/taaa192

[4] Sahin AR, Erdogan A, Mutlu Agaoglu P, et al. 2019 Novel coronavirus (COVID-19) outbreak: A review of the current literature. Eurasian Journal of Medicine and Oncology. 2020;**4**:1-7. DOI: 10.14744/ejmo.2020.12220

[5] Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. Journal of Autoimmunity. DOI: 10.1016/j.jaut.2020.102433

[6] Phelan AL, Katz R, Gostin LO. The novel coronavirus originating in Wuhan, China. Challenges for global health governance. Journal of the American Medical Association. DOI: 10.1001/jama.2020.1097

[7] Woolf SH, Chapman DA, Lee JH. COVID-19 as the leading cause of death in the United States. Journal of the American Medical Association. 2021;**325**:123-124. DOI: 10.1001/jama.2020.24865

[8] Marazuela M, Giustina A, Puig-Domingo M. Endocrine and metabolic aspects of the COVID-19 pandemic. Reviews in Endocrine and Metabolic Disorders. 2020;**21**:495-507. DOI: 10.1007/s11154-020-09569-2

[9] Puig-Domingo M, Marazuela M, Giustina A. COVID-19 and endocrine diseases. A statement from the European Society of Endocrinology. Endocrine. 2020;**68**:2-5. DOI: 10.1007/s12020-020-02294-5

[10] Pal R, Banerjee M. COVID-19 and the endocrine system: Exploring the unexplored. Journal of Endocrinological Investigation. 2020;**43**:1027-1031. DOI: 10.1007/s40618-020-01276-8

[11] dos Santos LR, Filho RB, Alves TAFdA, Jardine MB, Durate ML. Covid-19 and endocrinology-intersections: A review of current knowledge on physiopathological associations. Endocrinology & Metabolism International Journal. 2020;**8**:90-95. DOI: 10.15406/emij.2020.08.00286

[12] Lundholm MD, Poku C, Emanuele N, Emanuele MA, Lopez N. SARS-CoV-2 (COVID-19) and the endocrine system. Journal of the Endocrine Society. 2020;**4**:1-13. DOI: 10.1210/jendso/bvaa144

[13] Arlt W, Baldeweg SE, Pearce SHS, Simpson HL. Endocrinology in the time of COVID-19: Management of adrenal insufficiency. 2020;**183**:G25-G32. DOI: 10.1530/EJE-20-0361

[14] Kothandaraman N, Rengaraj A, Xue B, et al. COVID-19 endocrinopathy with hindsight from SARS. American Journal of Physiology Endocrinology and Metabolism. 2021;**320**:E139-E150. DOI: 10.1152/ajpendo.00480.2020

[15] Alzahrani AS, Mukhtar N, Aljomaiah A, et al. The impact of COVID-19 viral infection on the hypothalamic–pituitary–adrenal axis. Endocrine Practice. 2021;**27**:83-89. DOI: 10.1016/j.eprac.2020.10.014

[16] Fleseriu M, Buchfelder M, Cetas JS, et al. Pituitary society guidance:

Pituitary disease management and patient care recommendations during the COVID-19 pandemic - An international prospective. Pituitary. 2020;**23**:327-337. DOI: 10.1007/s11102-020-01059-7

[17] Wang W, Su X, Ding Y, et al. Thyroid function abnormalities in COVID-19 patients. Frontiers in Endocrinology. 2021;**11**:623792. DOI: 10.3389/fendo.2020.623792

[18] Dworakowska D, Grossman AB. Thyroid disease in the time of COVID-19. Endocrine. 2020;**68**:471-474. DOI: 10.1007/s12020-020-02364-8

[19] Shaha AR. Thyroid surgery during COVID-19 pandemic: Principles and philosophies. Head & Neck. 2020;**42**:1322-1324. DOI: 10.1002/hed.26198

[20] Aojula N, Ready A, Gittoes N, Hassan-Smith Z. Management of parathyroid disease during the COVID-19 pandemic. Journal of Clinical Medicine. 2021;**10**:920. DOI: 10.3390/jcm10050920

[21] Narici M, De Vito G, Franchi M, et al. Impact of sedentarism due to the COVID-19 home confinement on neuromuscular, cardiovascular and metabolic health: Physiological and pathophysiological implications and recommendations for physical and nutritional countermeasures. European Journal of Sport Science. DOI: 10.1080/17461391.2020.1761076

[22] Martinez-Ferran M, de la Guía-Galipienso F, Sanchis-Gomar F, Pareja-Galeano H. Metabolic impacts of confinement during the COVID-19 pandemic due to modified diet and physical activity habits. Nutrients. 2020;**12**:1549. DOI: 10.3390/nu12061549

[23] Wake DJ, Gibb FW, Kar P, et al. Endocrinology in the time of COVID-19: Remodelling diabetes services and emerging innovation. 2020;**183**:G67-G77. DOI: 10.1530/EJE-20-0377

[24] Guo W, Li M, Dong Y, et al. Diabetes is a risk factor for the progression and prognosis of COVID-19. Diabetes Metabolism Research and Reviews. 2020;**36**:e3319. DOI: 10.1002/dmrr.3319

[25] Muniyappa R, Gubbi S. COVID-19 pandemic, coronaviruses, and diabetes mellitus. American Journal of Physiology Endocrinology and Metabolism. 2020;**318**:E736-E741. DOI: 10.1152/ajpendo.00124.2020

[26] Yang M, Chen S, Huang B, et al. Pathological findings in the testes of COVID-19 patients: Clinical implications. European Urology Focus. 2020;**6**:1124-1129. DOI: 10.1016/j.euf.2020.05.009

[27] Li H, Xiao X, Zhang J, et al. Impaired spermatogenesis in COVID-19 patients. EClinicalMedicine. 2020;**28**:100604. DOI: 10.1016/j.eclinm.2020.100604

[28] Achua JK, Chu KY, Ibrahim E, et al. Histopathology and ultrastructural findings of fatal COVID-19 infections on testis. The World Journal of Men's Health. 2021;**39**:65-74. DOI: 10.5534/wjmh.200170

[29] Jing Y, Run-Qian L, Hao-Ran C, et al. Potential influence of COVID-19/ACE2 on the female reproductive system. Molecular Human Reproduction. 2020;**26**:367-373. DOI: 10.1093/molehr/gaaa030

[30] Raghavan D, Tan AR, Story ES, et al. Management changes for patients with endocrine-related cancers in the COVID-19 pandemic. Endocrine-Related Cancer. 2020;**27**:R357-R374. DOI: 10.1530/ERC-20-0229

[31] Popkin BM, Du S, Green WD, et al. Individuals with obesity and COVID-19: A global perspective on the

epidemiology and biological relationships. Obesity Reviews. 2020;**21**:e13128. DOI: 10.1111/obr.13128

[32] Clemmensen C, Peterson MB, Sørensen TIA. Will the COVID-19 pandemic worsen the obesity epidemic? Nature Reviews. Endocrinology. 2020;**16**:469-470. DOI: 10.1038/s41574-020-0387-z

[33] Rychter AM, Zawada A, Ratajczak AE, Dobrowolska A, Krela-Kaźmierczak I. Should patients with obesity be more afraid of COVID-19? Obesity Reviews. 2020;**21**:e13083. DOI: 10.1111/obr.13083

[34] Alberca RW, Oliveira LdM, Branco ACCC, Pereira NZ, Sato MN. Obesity as a risk factor for COVID-19: An overview. Critical Reviews in Food Science and Nutrition. DOI: 10.1080/10408398.2020.1775546

[35] Gao F, Zheng KI, Wang XB, et al. Obesity is a risk factor for greater COVID-19 severity. Diabetes Care. 2020;**43**:e72-e74. DOI: 10.2337/dc20-0682

[36] Kwok S, Adam S, Ho JH, et al. Obesity: A critical risk factor in the COVID-19 pandemic. Clinical Obesity. 2020;**10**:e12403. DOI: 10.1111/cob.12403

[37] Greenway FL, Look M, Golden A, et al. COVID-19 and the urgent need for new therapies for obesity. Population Health Management. DOI: 10.1089/pop.2020.0307

[38] Sorokin AV, Karathanasis SK, Yang ZH, Freeman L, Kotani K, Remaley AT. COVID-19-associated dyslipidemia: Implications for mechanism of impaired resolution and novel therapeutic approaches. The FASEB Journal. 2020;**34**:9843-9853. DOI: 10.1096/fj.202001451

[39] Atmosudigdo IS, Lim MA, Radi B, et al. Dyslipidemia increases the risk of severe COVID-19: A systematic review, meta-analysis, and meta-regression. Clinical Medicine Insights: Endocrinology and Diabetes. 2021;**14**:1-7. DOI: 10.1177/1179551421990675

[40] Clemente-Suárez VJ, Dalamitros AA, Beltran-Velasco AI, Mielgo-Ayuso J, Tornero-Aguilera JF. Social and psychophysiological consequences of the COVID-19 pandemic: An extensive literature review. Frontiers in Psychology. 2020;**11**:580225. DOI: 10.3389/fpsyg.2020.580225

[41] Coelho-Ravagnani CdF, Corgosinho FC, Sanches FLFZ, Prado CMM, Laviano A, Mota JF. Dietary recommendations during the COVID-19 pandemic. Nutrition Reviews. 2020;**79**:382-393. DOI: 10.1093/nutrit/nuaa067

[42] Muscogiuri G, Barrea L, Savastano S, Colao A. Nutritional recommendations for CoVID-19 quarantine. European Journal of Clinical Nutrition. 2020;**74**:850-851. DOI: 10.1038/s41430-020-0635-2

[43] Galanakis CM. The food systems in the era of the coronavirus (COVID-19) pandemic crisis. Foods. 2020;**9**:523. DOI: 10.3390/foods9040523

[44] Gasmi A, Chirumbolo S, Peana M, et al. The role of diet and supplementation of natural products in COVID-19 prevention. Biological Trace Element Research. DOI: 10.1007/s12011-021-02623-3

[45] Lippi G, South AM, Henry BM. Electrolyte imbalances in patients with severe coronavirus disease 2019 (COVID-19). Annals of Clinical Biochemistry. 2020;**57**:262-265. DOI: 10.1177/0004563220922255

[46] Taheri M, Bahrami A, Habibi P, Nouri F. A review on the serum electrolytes and trace elements role in

the pathophysiology of COVID-19. Biological Trace Element Research. DOI: 10.1007/s12011-020-02377-4

[47] Dehghani-Samani A, Kamali M, Hoseinzadeh-Chahkandak F. The role of vitamins on the prevention and/or treatment of COVID-19 infection; A systematic review. Modern Care Journal. 2020;**17**:e104740. DOI: 10.5812/modernc.104740

[48] Jovic TH, Ali SR, Ibrahim N, et al. Could vitamins help in the fight against COVID-19? Nutrients. 2020;**12**:2550. DOI: 10.3390/nu12092550

[49] Belete TM. Review on up-to-date status of candidate vaccines for COVID-19 disease. Infection and Drug Resistance. 2021;**14**:151-161. DOI: 10.2147/IDR.S288877

[50] Xing K, Tu XY, Liu M, et al. Efficacy and safety of COVID-19 vaccines: A systematic review. Chinese Journal of Contemporary Pediatrics. 2021;**23**:221-228. DOI: 10.7499/j.issn.1008-8830.2101133

[51] Doroftei B, Ciobica A, Ilie OD, Maftei R, Ilea C. Mini-review discussing the reliability and efficiency of COVID-19 vaccines. Diagnostics. 2021;**11**:579. DOI: 10.3390/diagnostics11040579

[52] Li Y, Tenchov R, Smoot J, Liu C, Watkins S, Zhou Q. A comprehensive review of the global efforts on COVID-19 vaccine development. ACS Central Science. 2021;**7**:512-533. DOI: 10.1021/acscentsci.1c00120

[53] Kumar A, Dowling WE, Román RG, et al. Status report on COVID-19 vaccines development. Current Infectious Disease Reports. 2021;**23**:9. DOI: 10.1007/s11908-021-00752-3

[54] Gao QY, Chen YX, Fang JY. 2019 novel coronavirus infection and gastrointestinal tract. Journal of Digestive Diseases. DOI: 10.1111/1751-2980.12851

[55] Mousavizadeh L, Ghasemi S. Genotype and phenotype of COVID-19: Their role in pathogenesis. Journal of Microbiology, Immunology and Infection. 2021;**54**:159-163. DOI: 10.1016/j.jmii.2020.03.022

[56] Ammar A, Brach M, Trabelsi K, et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: Results of the ECLB-COVID19 international online survey. Nutrients. 2020;**12**:1583. DOI: 10.3390/nu12061583

[57] Garre-Olmo J, Turró-Garriga O, Martí-Lluch R, et al. Changes in lifestyle resulting from confinement due to COVID-19 and depressive symptomatology: A cross-sectional a population-based study. Comprehensive Psychiatry. 2021;**104**:152214. DOI: 10.1016/j.comppsych.2020.152214

[58] León-Zarceño E, Moreno-Tenas A, Boix Vilella S, García-Naveira A, Serrano-Rosa MA. Habits and psychological factors associated with changes in physical activity due to COVID-19 confinement. Frontiers in Psychology. 2021;**12**:620745. DOI: 10.3389/fpsyg.2021.620745

[59] Gadde KM, Martin CK, Berthoud HR, Heymsfield SB. Obesity. Pathophysiology and management. Journal of the American College of Cardiology. 2018;**71**:69-84. DOI: 10.1016/j.jacc.2017.11.011

[60] Saxon DR, Iwamoto SJ, Mettenbrink CJ, et al. Antiobesity medication use in 2.2 million adults across eight large health care organizations: 2009-2015. Obesity. 2019;**27**:1975-1981. DOI: 10.1002/oby.22581

[61] Heshmati HM. Anti-obesity medical devices. In: Himmerich H, editor.

Weight Management. London: IntechOpen; 2020. p. 239-253. DOI: 10.5772/intechopen.91697

[62] Radvinsky D, Iskandar M, Ferzli G. Bariatric surgery today: The good, the bad, and the ugly. Annals of Laparoscopic and Endoscopic Surgery. 2017;**2**:52. DOI: 10.21037/ales.2017.02.26

[63] Ammar A, Chtourou H, Boukhris O, et al. COVID-19 home confinement negatively impacts social participation and life satisfaction: A worldwide multicenter study. International Journal of Environmental Research and Public Health. 2020;**17**:6237. DOI: 10.3390/ijerph17176237

[64] Bradbury-Jones C, Isham L. The pandemic paradox: The consequences of COVID-19 on domestic violence. Journal of Clinical Nursing. 2020;**29**: 2047-2049. DOI: 10.1111/jocn.15296

[65] Zhang Z, Arshad A, Zhang C, Hussain S, Li W. Unprecedented temporary reduction in global air pollution associated with COVID-19 forced confinement: A continental and city scale analysis. Remote Sensing. 2020;**12**:2420. DOI: 10.3390/rs12152420

[66] Venter ZS, Aunan K, Chowdhury S, Lelieveld J. COVID-19 lockdowns cause global air pollution declines. Proceedings of the National Academy of Sciences. 2020;**117**:18984-18990. DOI: 10.1073/pnas.2006853117

[67] Barua S, Nath SD. The impact of COVID-19 on air pollution: Evidence from global data. Journal of Cleaner Production. 2021;**298**:126755. DOI: 10.1016/j.jclepro.2021.126755

[68] Delang L, Neyts J. Medical treatment options for COVID-19. European Heart Journal: Acute Cardiovascular Care. 2020;**9**:209-214. DOI: 10.1177/2048872620922790