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REGULAR PAPERS

PERSPECTIVE

Lifestyle factors in the prevention of COVID-19

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ABSTRACT

Confinement to the home and psychological distress due to the coronavirus disease 2019 (COVID-19) pandemic may lead to harmful health behaviors, such as overeating, sedentary behavior with reduced physical activity, elevated alcohol and tobacco use and increased screen time causing impaired sleep. All of these behaviors are associated with non-communicable diseases and can interfere with immunity. While no foods, single nutrients or dietary supplements are capable of preventing infection with COVID-19, a balanced diet containing sufficient amounts of macronutrients and diverse micronutrients is a prerequisite of an optimally functioning immune system. High-energy “Western” diets and obesity are major risk factors for a more severe course of COVID-19. Alcohol use and tobacco also have detrimental effects on the immune system. Therefore, population-wide body weight control, reduction of smoking rates and limitation of alcohol consumption are important preventive measures. Furthermore, sufficient restorative sleep is needed for adequate immune functioning. Appropriate lifestyle changes in regard to nutrition, exercise, sleep, smoking and alcohol intake may help shift the population distribution of infection risk and aid in preventing severe COVID-19 disease. Large-scale surveys should explore the effects of lifestyle changes, and the provision of reliable lifestyle information and effective interventions to individuals and communities during the pandemic is a pressing need.

1. Introduction

The novel infectious coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), poses a global threat, and its ultimate extent remains unknown.¹ Like the influenza pandemic of 1918, COVID-19 is likely to remain endemic and recur in waves.

The effects of the COVID-19 pandemic on both physical and mental health are significant.²⁻³ In addition to serious pathology in the respiratory tract, COVID-19 appears to cause extrapulmonary manifestations affecting the cardiovascular, gastrointestinal, urinary and nervous systems.⁴ Mental health problems associated with the pandemic include depression, anxiety, fatigue and post-traumatic stress disorder.³ The development of specific, effective and safe preventive measures and therapeutics against COVID-19, such as vaccines, antiviral agents and passive immunotherapy, is highly desirable. However, many problems remain to be solved, and comprehensive and effective prevention and therapy may remain elusive in the foreseeable future.²

Towards the beginning of the 20th century, the German physician and Nobel laureate Paul Ehrlich coined the expression “magic bullet” to describe precisely targeted medical treatments. The concept was based on the efficacy of arsenicals in the treatment of syphilis.⁵ Despite

widespread optimism that a vaccine will provide the magic bullet in the COVID-19 pandemic, the limited effectiveness of influenza vaccinations suggests that the development of vaccines against COVID-19 will face numerous obstacles, including possible mutations of SARS-CoV-2,⁶⁻⁷ and may see little success in the foreseeable future.⁴ Since a magic bullet against COVID-19 is unlikely to be discovered in the near future, the focus in the current pandemic should be on public education in respect to behaviors that can be influenced and modified.⁸ Behavioral risk factors related to disease are quantitative and not categorical phenomena and constitute a continuous distribution. The introduction of community-wide measures reducing these risk factors may be capable of shifting the population distribution of risk. This approach may be able to significantly reduce the burden of disease.⁹

Widespread and prolonged closures of schools and businesses lead to dramatic changes in daily routines and lifestyle behaviors.¹⁰ Harmful health behaviors, such as overeating, smoking and excessive alcohol consumption, may be more likely to be initiated by individuals affected by economic shutdowns, quarantines and curfews. Psychological distress due to SARS-CoV-2^{11,12} may be associated with an increase in energy intake¹³ and a decrease in physical exercise,¹⁴ resulting in weight gain and increased rates of overweight and obesity.

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At present, the most effective measure in halting the transmission of COVID-19 and preventing associated chronic complications is unarguably the avoidance of exposure to the virus through physical distancing, face masks and eye protection.¹⁵ In addition, changes in lifestyle factors, including nutrition, exercise, smoking, alcohol consumption, screen time and sleep, may be able to contribute to shifting the risk distribution for COVID-19.¹⁶ These factors also appear to play a role in the management of mental disorders,¹⁷⁻¹⁸ which are commonly observed in pandemics such as the current one.¹⁹⁻²¹ The present overview will discuss the potential role of lifestyle factors in regard to immune functioning and prevention of severe outcomes of COVID-19.

2. Food and nutrition

Adequate nutrition is critically important for an optimally functioning immune system, and both malnutrition and overnutrition can adversely affect immune responses. Nutritional deficits in energy, protein and micronutrients, caused by malnourishment and starvation, can impair the immune system and resistance to infection.²²⁻²³ Specific nutrients may exert effects on immune functions through alterations of gut microbiota composition, cell activation and modification of both gene expression and production of signaling molecules.²⁴⁻²⁵

Various functional food plants, such as garlic, ginger, turmeric, black pepper, blueberry, elderberry and others, have been suggested to have antiviral and immunomodulatory effects.²⁶ However, evidence of their efficacy in humans is weak or non-existent, and some of them may even produce toxic effects if administered in large amounts.²⁶ Food bioactives, such as polyphenols and carotenoids, are thought to have antiviral efficacy.¹⁶ Polyphenols have been shown to influence the regulation of immune cells, the synthesis of pro-inflammatory cytokines and the suppression of pro-inflammatory gene expression.²⁷ Another mechanism responsible for potential antiviral properties of resveratrol may be the upregulation of the functional SARS-CoV receptor angiotensin-converting enzyme 2, which is necessary for host cell entry and subsequent viral replication.²⁸⁻³¹ Hypotheses regarding antiviral benefits of polyphenols³² and carotenoids³³ are based mainly on research in cell cultures and animal models. However, beneficial effects of food bioactives on viral infections in humans are questionable, since controlled trials of these compounds have not yet been conducted.

Probiotics can activate multiple immune mechanisms, exert effects on host immunological networks,³⁴⁻³⁵ enhance immune responses³⁶ and modestly decrease the incidence and duration of viral respiratory tract infections.³⁷⁻³⁸ Microbial dysbiosis with a reduction in *Lactobacillus* and *Bifidobacterium* has been observed in some individuals with COVID-19,³⁹ and probiotics have been recommended in COVID-19 management guidelines.⁴⁰ However, the actual efficacy of conventional probiotics in the prevention or therapy of COVID-19 is unknown.⁴¹

Micronutrients, such as vitamins and trace elements, are known to play essential roles in both innate and adaptive immune responses, and micronutrient homeostasis is central to the maintenance of a healthy immune system.⁴² Deficiencies in micronutrients can decrease immunity to disease, while supplementation has been found to improve immunity to viral infections.⁴³ For example, vitamin D deficiency appears to be associated with impaired immune responses and an increased risk of systemic infections.⁴⁴ Supplementation of vitamin D may prevent respiratory infections through a decrease in the production of pro-inflammatory cytokines and a consequent reduction in the risk of a cytokine storm causing pneumonia.⁴⁵ The investigation of individual nutrients capable of promoting optimal immune system functioning reflects a belief in magic bullets and relies on an outdated model of disease pathophysiology. A research strategy attempting to understand the functions of single nutrients and to examine their therapeutic efficacy individually fails to take into account physiological processes, which require an intake of a wide range of nutrients in balance. This approach may provide an explanation for the limited success of the administration of single nutrients.⁴⁶

The efficacy of dietary interventions in infections can be affected by numerous factors, such as the type of pathogen, the dose and duration of administration and the age, genetics, lifestyle, immunological and nutritional status of the study participants.⁴⁶⁻⁴⁷ In particular, immunosenescence during aging changes the impact of nutrition on immune function.⁴⁸ Furthermore, prolonged supplementation of food bioactives and micronutrients at high doses may have adverse effects and may even aggravate infectious diseases.^{46,49-51}

Certain dietary patterns can produce detrimental effects on immune responses and may be involved in the development of various inflammatory diseases.⁵² For example, the consumption of a Western diet can generate exaggerated immune responses to exogenous and endogenous triggers of inflammation and could contribute to inflammatory disease.⁴⁶ In animals, Western-type energy-rich diets have been shown to induce enhanced cytokine production to stimulation with lipopolysaccharide.⁵³⁻⁵⁴ A Western diet has also been shown to trigger innate immune reprogramming and lead to long-term changes of immune responses in mice.⁵⁵

Obesity appears to have a substantial impact on pathogen defense and immunity, and a link has been demonstrated between obesity and various infectious diseases. A characteristic of obesity is low-grade chronic inflammation, which can impair innate and adaptive immune responses and render the immune system more vulnerable to infections.^{46,56} Obesity has been shown to have detrimental effects on host immunity, risk of susceptibility to infection, post-infection complications and mortality from severe infections.⁵⁷⁻⁵⁹

Non-communicable diseases seem to increase the risk for adverse outcomes and mortality in COVID-19,⁶⁰⁻⁶² and obesity is a key risk factor for COVID-19.⁶³ The impact of obesity on COVID-19 may be mediated by its effects on pulmonary function⁶⁴⁻⁶⁵ and the production of pro-inflammatory cytokines,⁶⁶ increased levels of which may cause immune hyperactivation, acute respiratory distress syndrome or multiple organ failure.⁶⁷ The increased risk of mortality from COVID 19 in obese people points to an important role of nutrition.^{46,68} Preventive interventions, such as weight reduction programs, may be considered during the present pandemic. For example, the British government has introduced a weight loss campaign to decrease body weight and to encourage healthier food choices.⁶⁹

In summary, overweight and obese people are at high risk for severe or fatal outcomes of COVID-19. These individuals need special attention, with an emphasis on avoidance of infection and reduction in body weight.⁴⁶

3. Exercise

While confinement to the home can be a safe measure against the spread of the coronavirus, it reduces people's physical activity and changes their exercise patterns.⁷⁰⁻⁷¹ In fact, the coronavirus pandemic is exacerbating the established pandemic of physical inactivity.⁷² A nationwide cross-sectional study from China, conducted during home quarantine in the initial phase of the outbreak of COVID-19, reported that nearly 60% of adults temporarily adopted a sedentary lifestyle, with the prevalence of insufficient physical activity being more than twice the global level.⁷³ In a South Korean survey conducted between March 27 and 31, 2020, over 90% of parents reported a decrease in their young children's use of play and sports facilities.⁷⁴ Restricted activity reduces energy expenditure and increases the risk of weight gain. An increase in body weight may also be a consequence of increased eating due to boredom, depressed mood and anxiety. Exercise during the pandemic is important in preventing the health risks associated with physical inactivity and,⁷⁵ more specifically, in increasing wellbeing and immunity and reducing stress and anxiety.^{73,76}

Exercise training of moderate intensity appears to be associated with a decrease in the occurrence, duration and severity of infections, particularly viral infections, of the upper respiratory tract.⁷⁷⁻⁷⁸ For example, epidemiological data suggests that regular physical activity is associ-

ated with a reduction in the incidence of and mortality from influenza and pneumonia.⁷⁹ However, physical exercise can have either positive or negative effects on immunity depending on the nature, duration and intensity of exercise.⁸⁰ This relationship has been described in terms of a “J-shaped curve”, which is the graphical appearance of risk of illness plotted against the characteristics of exercise. While people engaging in moderate physical activity show a lower risk of upper respiratory tract infection compared to sedentary individuals,⁸¹ excessively strenuous endurance exercise may suppress immune function and elevate the risk of illness.⁸² Regular bouts of short-lasting moderate intensity exercises (up to 45 min) have been suggested to be immuno-enhancing, while repeated bouts of long-lasting arduous intensity exercises (more than 1.5 h) can be immunosuppressive.^{83–84} Immunomodulation induced by low-to-moderate exercise might enhance immune responses playing a role in the spread of infection with COVID-19.⁸⁵

The effectiveness of aerobic exercise in regard to mental problems has been shown in individuals with raised anxiety and in those diagnosed with anxiety disorders, with high-intensity exercise being more effective than programs using lower intensity.⁸⁶ Exercise has been found to be moderately more effective in reducing symptoms of depression when compared to no exercise.⁸⁷

More than 4500 participants of a Canadian survey were requested to report their exercise habits between March 29 and April 3, 2020. Engaging in exercise, particularly outdoors, was found to be associated with better perceived general and mental health during the COVID-19 pandemic,⁸⁸ suggesting that outdoor exercise may be important in the promotion of better health during periods of confinement. Exercising at home is well suited to maintaining physical fitness while avoiding infection with SARS-CoV-2,⁷⁰ and daily moderate-intensity physical activity is advisable.⁸⁹ Active videogames (exergames) may be an easy-to-use mode of home-based exercise and also a useful tool for reducing social isolation and coping with anxiety during quarantine periods.⁹⁰ Exergames have been shown to improve anxiety levels across various clinical populations.⁹¹

In summary, during times of confinement, a physically active lifestyle is essential for mental and physical health. Regular physical exercise during the COVID-19 pandemic may have benefits regarding infection risk, mental problems such as anxiety and depression, maintenance of body weight and the prevention and management of chronic disease. In view of the adverse impact of the COVID-19 pandemic on children’s movement and play behaviors,⁹² promoting physical exercise in children deserves special attention.⁷⁴

4. Alcohol

Prolonged periods of home quarantine can lead to boredom, stress and mental problems, which may result in increased alcohol consumption.⁹³

No amount of alcohol produces positive health effects,⁹⁴ and alcohol is a major risk factor for chronic disease and injury.⁹⁵ The risk of all-cause mortality rises with increasing amounts of alcohol consumed, and only complete abstinence minimizes the risk of health loss.⁹⁶ In particular, chronic alcohol use has disruptive effects on the innate and adaptive immune systems and has been shown to reduce ability to overcome infections such as tuberculosis and pneumonia.^{97–100} Alcohol can affect immunity through a wide range of mechanisms and is likely to have detrimental effects in regard to infection with the novel coronavirus.¹⁰¹ Chronic high alcohol consumption has been found to significantly elevate the risk of acute respiratory distress syndrome, which is one of the most severe complications of COVID-19.^{102–103}

In addition to the well-established health consequences of alcohol consumption, social and psychological aspects should be considered. During the current pandemic, an increase in domestic violence has been reported as a consequence of quarantines and other physical distancing measures.¹⁰⁴ Alcohol plays a causal contributing role in aggression¹⁰⁵ and is closely linked to the risk and severity of interpersonal violence,

such as intimate partner violence, sexual violence and violence against children.^{106–107} During the COVID-19 lockdown, with families at home, children are more likely to observe their parents’ alcohol consumption. Parental alcohol use or misuse can influence current and future drinking behaviors of children and adolescents^{108–109} and is associated with subsequent alcohol intake and misuse in adolescence through adulthood.^{110–111} This may ultimately lead to an increase in alcohol harm for a generation or more.¹¹²

5. Smoking

The risk of respiratory tract infections in smokers may be increased through various mechanisms.¹¹³ Smoking impairs immune function and has been shown to almost double the risk of infection with tuberculosis¹¹⁴ and to increase the risk of several types of pneumonia infection 3–5 fold¹¹⁵ and of influenza approximately five fold.¹¹⁶

Despite early correlational evidence suggesting that smoking could have a protective effect against COVID-19,^{117–118} it is becoming increasingly clear that smoking may have negative effects. For example, the percentages of current and former smokers were higher in severe as compared to non-severe COVID-19 cases.^{119–120} While a short meta-analysis found no association between smoking status and severity of COVID-19,¹¹⁷ the findings of a systematic review of five studies suggested an association of smoking with negative progression and adverse outcomes of the disease.¹²¹ The number of cases in most studies is small, and firm conclusions cannot be drawn at present. However, smoking is a major risk factor for lung disease¹²² as well as for bacterial and viral infections.¹²³ Furthermore, an association between fatality rate and smoking status has also been reported for the Middle East respiratory syndrome (MERS) epidemic in 2015.¹²⁴

The angiotensin-converting enzyme 2 (ACE2) has been demonstrated to be a functional SARS-CoV receptor necessary for host cell entry and subsequent viral replication.^{29,125} ACE2 gene expression was shown to be higher in small and large airway epithelia of healthy ever smokers compared with never smokers, with current smokers having the highest expression.¹²⁶ An elevated expression of the ACE2 gene in the airways of current smokers has also been reported in another study.¹²⁷

Electronic cigarettes and other alternative devices are unlikely to be a safer option in regard to COVID-19-related risks. Since they use tobacco and produce smoke or vapor, they may cause the infectious lung damage observed with traditional cigarettes.^{128–130}

6. Screen time and sleep

The coronavirus prevention and lockdown measures adopted in many countries in the spring of 2020 led to an increased reliance on screens due to homeschooling, telework and online socializing. During the quarantine in the initial phase of the COVID-19 outbreak in China, adults engaged in increased screen times of more than 4 h per day.⁷³ In a survey conducted in South Korea between March 27 and 31, 2020, 80% of parents reported that their children’s screen time had increased.⁷⁴ Marked increases in total and gaming-related Internet traffic, mobile game downloading and gaming were also observed in Europe and America.^{131–134} Approximately two thirds of adult participants of a survey conducted in Canada from March 29 to April 3, 2020 reported an increase in time spent watching television and using the internet in comparison with their screen habits before the COVID-19 crisis; less than a quarter of participants reported an increase in video gaming.⁸⁸

The increase in screen time during the present pandemic is partly due to the transition of school and university curricula to online or virtual courses and will therefore have educational benefits. Social media may provide the means to stay connected with relatives and friends during phases of social distancing. In times of physical and social distancing, online gaming may be an alternative to more usual social activities and may be a means of escape, alleviating COVID-19-related stress, anxiety and depressed mood and thus offering a short-term adaptive

coping strategy.¹³⁵⁻¹³⁶ Gaming may be less harmful than many other stress-alleviating behaviors, such as overeating¹³⁷ or use of alcohol, psychoactive substances or illicit drugs.¹³⁸ However, gaming and other technology-based activities may develop into habitualized coping strategies for stress, which may be maladaptive since they can interfere with physical activity and sleep patterns and may help entrench unhealthy behaviors. Gaming may decrease engagement in normal social interactions and impair educational or occupational functioning.¹³⁹ Negative effects of excessive gaming include harm to physical health, sleep patterns and mental health.¹⁴⁰ Video gaming could also cause vulnerabilities that could be exploited by industries attempting to promote their products.¹⁴¹

Health risks associated with excessive screen time include an elevated risk for cardiovascular disease, poor sleep and an increase in time spent engaged in sedentary behavior.¹⁴² Excessive screen time has been found to be associated with negative mental health outcomes, such as anxiety and depression.¹⁴³⁻¹⁴⁵ The results of a cross-sectional epidemiological online survey in the United Kingdom, conducted during the COVID-19 pandemic, have also suggested a positive association between daily screen time and poor mental health.¹⁴⁶ Elevated screen time may also exacerbate risks for inattention, anxiety, depression and suicide in children and adolescents.¹⁴²

Individuals with massively increased screen time should be monitored for the extent of social isolation, sleep patterns and gaming behavior¹⁴⁷⁻¹⁴⁸ as well as negative consequences of excessive gaming.¹⁴⁹ Educational video games or active games with an emphasis on real-world social interaction or physical exercise may be better for the player's physical and mental health than mainstream video games, such as shooter games and multiplayer online role-playing games.¹⁵⁰ Furthermore, digital interventions including education, self-monitoring and parental involvement have been shown to significantly increase physical activity in adolescents.¹⁵¹ Findings of the Canadian survey conducted in spring 2020 with over 4500 participants suggested that limiting the time of television, internet and video game use may promote better mental and general health during periods of confinement.⁸⁸

A major problem associated with the increase in recreational screen time during the pandemic is changes in sleep patterns. For example, it has been shown that children are more sedentary and less active and have less consistent sleep patterns on non-school or unstructured days compared to school days.¹⁵² Several mechanisms may mediate the association between excessive screen time and poor sleep. Screen-related activities may displace physical activity, which is beneficial for sleep.¹⁴² Furthermore, chronic exposure to artificial light in the late evening produces a marked suppressive effect on melatonin levels, shortens the body's internal representation of night duration and can thereby impair sleep and related physiological measures.¹⁵³ In particular, the short wavelength-enriched light emitted by electronic devices may negatively impact sleep. In comparison with reading a printed book, reading a light-emitting eBook before bedtime was found to decrease evening sleepiness, reduce melatonin secretion, induce later timing of the circadian clock and impair next-morning alertness.¹⁵⁴

Sleep appears to be a crucial element of the immune system. Sleep and immunity are linked bidirectionally: while activation of the immune system can affect sleep, sleep has an influence on the innate and adaptive immune systems.¹⁵⁵⁻¹⁵⁶ The increase in sleep duration observed during infections is thought to promote host defense via the immune system, since sleep has been found to affect a variety of immune parameters, to be associated with a decrease in infection risk and to improve responses to vaccination and outcome of infections.¹⁵⁵ In particular, a large body of evidence suggests that sleep deprivation has detrimental effects on the immune response and increases susceptibility to infection.¹⁵⁷ Insomnia, insufficient sleep and poor sleep quality have been shown to contribute to the risk of inflammatory disorders.¹⁵⁸ Shorter sleep durations have been shown to be associated with an increased likelihood of developing the common cold after a challenge with intranasal rhinovirus,¹⁵⁹ and sleep deprivation has been found to produce a negative impact on the

development of antibody titers following immunization. Compared to well-rested individuals, partial sleep deprivation reduced titers by half in response to influenza vaccination,¹⁶⁰ and a single night's total sleep deprivation had an early, though not lasting, negative effect after H1N1 immunization in males.¹⁶¹

In summary, sleep and immunity are closely interrelated, and sleep deprivation and altered sleep patterns may increase susceptibility to infection with SARS-CoV-2. Sleep quality during the pandemic may be poorer due to anxiety and stressors related to COVID-19,¹⁶² and can be further impaired by excessive screen-related activities, such as watching television, using computers and mobile devices and playing games. Screen times should therefore be carefully monitored and sufficient sleep and regular sleep patterns encouraged to aid in the prevention of COVID-19.

7. Conclusion

Home confinement due to the COVID-19-related restrictions may lead to a variety of unhealthy behaviors, such as the adoption of unbalanced high-calorie diets, an increase in sedentary behavior with a reduction in physical activity, an elevated use of alcohol and tobacco as well as an increase in screen time causing impaired sleep patterns. All of these behaviors are related to non-communicable diseases and can interfere with immunity.

Miracle foods or diets capable of preventing or curing COVID-19 do not exist. However, a balanced and healthy diet is an important building block of a strong immune system. While malnourishment and starvation are associated with impaired immune responses and poor resistance to infectious disease, Western-type energy-rich diets, overweight and obesity can also have a significant negative impact on pathogen defense and immunity. Food and nutrition can therefore play a beneficial role in maintaining a healthy body weight and preventing non-communicable conditions.⁴⁶ A physically active lifestyle may counteract the negative impact of prolonged phases of social distancing on physical and mental health during the COVID-19 pandemic. The changes in physical activity and sleep patterns resulting from the increased recreational screen time observed during isolation and psychological distress give cause for concern. Given the reciprocal relationship between sleep and immunity, sufficient restorative sleep is needed for adequate immune functioning. Reducing smoking rates and limiting alcohol intake are important in decreasing disruptive effects on the immune systems and improving the ability to cope with infection. The urgent challenge currently facing governments and health care providers requires a focus on scientific strategies offering the most promising outcomes.⁴⁶ Providing individuals and communities with reliable lifestyle information and effective interventions during the pandemic is a pressing need. Observational studies of lifestyle behaviors are needed for the development of effective and evidence-based public policies.

At present, physical distancing and face masks are undoubtedly the best preventive measures to avoid exposure to the novel coronavirus. However, appropriate lifestyle changes in regard to nutrition, exercise, sleep, smoking and alcohol intake may contribute to shifting the population distribution of infection risk and preventing severe outcomes of COVID-19.

Authors' contributions

Klaus W. Lange conceptualized and wrote the original draft preparation. Yukiko Nakamura conceptualized, reviewed and edited this paper.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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