Lifestyle, psychological, socioeconomic and environmental factors and their impact on hypertension during the coronavirus disease 2019 pandemic

Reinhold Kreutz\textsuperscript{a,}*, Piotr Dobrowolski\textsuperscript{b,}*, Aleksander Prejbisz\textsuperscript{b}, Engi A.E.H Algharably\textsuperscript{a}, Grzegorz Biło\textsuperscript{c,}d, Felix Creutzig\textsuperscript{e,f}, Guido Grassi\textsuperscript{b}, Vasilios Kotsis\textsuperscript{b}, Dragan Lović\textsuperscript{c}, Eman Lurba\textsuperscript{h,i}, Pietro A. Modesti\textsuperscript{i}, Marco Pappacogli\textsuperscript{m,n}, Gianfranco Parati\textsuperscript{c,}d, Alexandra Persu\textsuperscript{u}, Jorge Polonia\textsuperscript{o}, Marek Rajzer\textsuperscript{b}, Philippe de Timany\textsuperscript{q}, Thomas Weber\textsuperscript{r}, Burkhard Weisser\textsuperscript{s}, Konstantinos Tsiofis\textsuperscript{t}, Giuseppe Mancia\textsuperscript{u,v}, Andrzej Januszewicz\textsuperscript{b}, European Society of Hypertension COVID-19 Task Force Review

Summary: The coronavirus disease 2019 (COVID-19) pandemic considerably affects health, wellbeing, social, economic and other aspects of daily life. The impact of COVID-19 on blood pressure (BP) control and hypertension remains insufficiently explored. We therefore provide a comprehensive review of the potential changes in lifestyle factors and behaviours as well as environmental changes likely to influence BP control and cardiovascular risk during the pandemic. This includes the impact on physical activity, dietary patterns, alcohol consumption and the resulting consequences, for example increases in body weight. Other risk factors for increases in BP and cardiovascular risk such as smoking, emotional/psychologic stress, changes in sleep patterns and diurnal rhythms may also exhibit significant changes in addition to novel factors such as air pollution and environmental noise. We also highlight potential preventive measures to improve BP control because hypertension is the leading preventable risk factor for worldwide health during and beyond the COVID-19 pandemic.

Keywords: cardiovascular risk, coronavirus disease 2019, diet, environmental, hypertension, life style, psychological, salt, severe acute respiratory syndrome coronavirus 2, smoking

Abbreviations: BP, blood pressure; COVID-19, coronavirus disease 2019; NCD, noncommunicable disease; PTSD, posttraumatic stress disorders; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2

INTRODUCTION

The declaration of the coronavirus disease 2019 (COVID-19) as a pandemic by the WHO on 1 March 2020 has led to unprecedented measures to combat this challenging disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1,2].

Emergency lockdowns have been initiated in countries across the globe, considerably affecting health, wellbeing, social, economic and other aspects of daily life. At the time of writing this review, the global pandemic of COVID-19 continues to cause considerable morbidity and mortality worldwide and the number of confirmed COVID-19 cases is still increasing. As of 5 October 2020, SARS-CoV-2 has...
infected more than 35 million individuals worldwide and caused more than one million deaths.

The COVID-19 pandemic continues to have a profound effect on societies worldwide, it altered everyday life and the effects will remain longer than anticipated, possibly beyond its control, for example by the availability of efficient vaccinations [3].

In addition to its direct clinical impact, COVID-19 also induced changes in people’s daily routines and lifestyles influencing their health and well being during the pandemic. For example, virtual meetings are substituting for travel and physical meetings and in many countries social distancing, travel bans, the cancellation of sporting and other mass participation events have dramatically affected daily life and physical activity. In particular, the COVID-19 pandemic may also lead to adverse changes in health behaviours in hypertensive patients [4,5].

In addition to changes in daily life due to social distancing and economic changes, other risk factors for increased blood pressure (BP) and hypertension not explicitly recommended as a target for intervention in the European guidelines [6] such as emotional/psychologic stress, changes in sleep patterns and diurnal rhythms may also exhibit significant changes during the COVID-19[7]. Finally, COVID-19 also changes novel nontraditional risk factors affecting both BP control and cardiovascular risk such as air pollution and environmental noise. We therefore set out to review the potential impact of the COVID-19 pandemic on lifestyle factors and behaviours as well as environmental changes likely to influence BP control and cardiovascular risk.

Social distancing and family problems

During the COVID-19 pandemic social distancing policies were instituted almost worldwide as a containment strategy for the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. Polices differ from lockdown (a strict national/local quarantine measure limiting movement by ordering to stay home except for essential tasks or to work in essential business), self-isolation (staying at home by people who have or might have SARS-CoV-2) for the purpose of the review we used following terms: quarantine – confinement for people who might have been exposed to COVID-19 or who’ve recently had close contact with someone with COVID-19; isolation – confinement for people who have SARS-CoV-2 or who have symptoms of COVID-19 and self-isolation which encompasses both situations (isolation and quarantine) to social distancing (keeping space from others outside home and avoiding large groups).

Varying with the strictness of these policies, people were required to stay home, limit their trips to primary needs (such as food shopping), and avoid contacts with friends and/or outside-living relatives. Schools, universities, offices, factories, as well as not-essential services have been closed for the short-term or long-term, forcing many students to study and many employees to work from home.

Some people started living alone, detached from their loved ones and deprived of personal freedom, developing boredom, frustration and potentially depression [8]. Others were forced to live with flatmates or other family members under one roof, increasing the risk for misunderstandings, irritability, quarrels and, in some cases, acts of psychological or physical violence against the most unprotected ones (women and children) [9]. People infected but asymptomatic were confined to isolation, living alone or with other family members in the same status, afraid of developing severe symptoms and often with the perception of being abandoned from the healthcare systems. Elderly people living in nursing homes have been denied contacts and visits even from the closest relatives for months, developing a sense of dismay and neglect leading to worsening of previous depression or dementia status. Furthermore, hospitalized patients were confined in isolated hospital rooms, having contacts only with healthcare workers, rendered anonymous by masks and other personal protective equipment. During the hospitalization period, no contacts with family members were allowed and there were few possibilities to obtain any news on the state of health of other family members. Lastly, self-isolation was limited not only to an individual level: cities, regions and countries were locked down, with no or few possibilities to move from a city to another or reconnect with family members living abroad.

People at home were at high risk of develop anxiety and depressive symptoms, as suggested by recent evidence [10]. The absence of interpersonal contacts and the detachment from reality may have induced many to fall into the anxiety spiral of mass media reporting continuously news, not always completely reliable, about contagions and pandemic-related victims, heightening anxiety and confusion. As demonstrated in previous studies [11,12], patients with hypertension are more likely to develop anxiety or psychological distress, showing an increased difficulty to describe feelings and adjust expression of emotion in stressful situations [13]. These negative feelings, enhanced by lockdown, self-isolation, family and personal problems, as well as by the psychological distress related to the own or relative’s health, may have contributed to worsen BP status. During lockdown, many hypertensive patients may have repeatedly detected uncontrolled BP values, while experiencing difficulties to get in touch with their physicians, renew their prescriptions and/or modify antihypertensive therapy as needed. Social isolation and family problems, such as the recent death of a relative or the onset of a COVID-19-related disability in a family member, may have affected adherence to antihypertensive therapy thereby impairing BP control. Finally, elderly and disabled people may have encountered difficulties in getting their antihypertensive medications or receiving help in case of discomfort, due to the lockdown or self-isolation.

Physical inactivity

One of the fundamental concerns induced by social distancing and the lockdown is a substantial reduction of physical activity and an increase of sitting time (Table 1). Scientific data on physical activity during lockdown are scarce, but data from 30 million users of Fitbit activity-trackers show a considerable reduction in daily step counts during March 2020 compared with the same period in 2019. The reduction in the countries initially most affected were −38% in Spain and −25% in Italy, whereas the reduction in
Sweden was only −9%\cite{14}. Tison et al. analysed worldwide changes in step count of the 455 404 users of the health and wellness smartphone app Argus (Azumio, Palo Alto, California, USA), Rapid decreases in step counts have been observed worldwide during the COVID-19 pandemic with a 27.3% reduction in mean steps within 30 days. The authors also noted a large variation between countries, for example a 48.7% reduction in Italy as compared with only 6.9% in Sweden\cite{15}. Although difficult to compare and certainly not representative, studies conducted prior to the current pandemic suggest that similar differences in step counts led to an increase in SBP of up to 7 mmHg in cross-sectional investigations\cite{16,17}. Another study showed a 4.5 mmHg increase in SBP for every additional hour of sitting per day\cite{18}.

On the other hand, the COVID-19 pandemic changed also transport habits, particularly in urban settings and fuelled the sales of bikes, as public transport usage declined, and people seek more socially distanced alternative travel methods. According to data from a consumer research group, online bike sales in France surged 350% in 3 months after declaration of COVID-19 as a pandemic\cite{19}. In addition to the current recommendation to participate in at least 30 min of moderate-intensity dynamic aerobic exercise on 5–7 days/week\cite{6}, tailored programmes for home-based exercise should be developed and accompanied by implementation programmes. Hypertensive patients should be advised to reduce sitting time and to implement short and intense ‘exercise snacks’ such as stair climbing or chair rising that can be done at home\cite{20} (Table 2).

### Increase in body weight

A high BMI might be an important risk factor for a severe course of COVID 19 disease\cite{21–27}. In fact, 85% of COVID-19 patients with obesity required mechanical ventilation and 62% of obese patients died in a report from Seattle\cite{21}. In New York City, a BMI more than 40 kg/m\textsuperscript{2} was the second strongest independent predictor of hospitalization following older age\cite{26}. The parameters that may explain the high mortality may include respiratory mechanics, reduced respiratory muscle strength and lung volumes in obese patients in addition to and the coexistence of type 2 diabetes and hypertension. Obesity in patients less than 60 years was identified as a risk factor for increased morbidity rates and these results differ from those obtained in other cases of pneumonia indicating an obesity-related survival benefit, that is a survival paradox\cite{22,28}.

A questionnaire-based study showed that 43 and 52% of patients reported eating and snacking more during the lockdown\cite{29}. Importantly, the affected individuals were more frequently overweight or obese, while almost 30% of patients experienced weight gain. The latter was more pronounced in overweight and obese patients\cite{29}. Of note, dietary recommendations during the COVID-19 pandemic have been published\cite{30}.

### TABLE 1. Positive and adverse effects of the lockdown and self-isolation during the coronavirus disease 2019 pandemic on blood pressure

<table>
<thead>
<tr>
<th>Potential effect on blood pressure increase</th>
<th>Level of influence</th>
<th>Patient</th>
<th>Physician, healthcare system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of food consumed ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processed ‘comfort foods’ rich in carbohydrates and salt ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium rich food ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snacking ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol consumption ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical activity ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting time ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological distress ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression ↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep quality ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adherence to therapy ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to diagnosis of hypertension ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therapeutic inertia ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to achieve blood pressure goals ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential effect on blood pressure decrease</th>
<th>Patient</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work-related stress ↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of sleep ↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO\textsubscript{2} emissions and air pollution ↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental noise ↓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 2. Selected measures to improve hypertension control and to reduce cardiovascular risk during the coronavirus disease 2019 pandemic

<table>
<thead>
<tr>
<th>General development and implementation of telemedicine and eHealth technology approaches for care</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support to increase physical activity</td>
<td>Patients</td>
</tr>
<tr>
<td>Reduce sitting time</td>
<td></td>
</tr>
<tr>
<td>Implement home-based exercise programs</td>
<td></td>
</tr>
<tr>
<td>Support healthy dietary patterns</td>
<td></td>
</tr>
<tr>
<td>Encourage patients to prepare food themselves with preference for fresh and unprocessed ingredients</td>
<td></td>
</tr>
<tr>
<td>Support to moderate alcohol intake</td>
<td></td>
</tr>
<tr>
<td>Encourage to drink nonalcoholic drinks (including alcohol free beer)</td>
<td></td>
</tr>
<tr>
<td>Implement regular alcohol free days per week</td>
<td></td>
</tr>
<tr>
<td>Support smoking cessation</td>
<td></td>
</tr>
<tr>
<td>Support implementation of lifestyle changes of patients as indicated above</td>
<td>Physicians</td>
</tr>
<tr>
<td>Develop and implement telemedical consulting</td>
<td></td>
</tr>
<tr>
<td>Follow-up not only on blood pressure and adherence but also on psychological/mental health depending on individual needs</td>
<td></td>
</tr>
<tr>
<td>Perform home blood pressure monitoring</td>
<td></td>
</tr>
<tr>
<td>Support individual resilience capacities against psychological/mental health challenges</td>
<td></td>
</tr>
</tbody>
</table>

### Environmental public health policies

- Support less road and air traffic
- Support less oil heating systems
- Support more bicycle traffic and pedestrian

---

Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.
Sodium and potassium intake

Experimental data, meta-analyses of clinical studies and some cohort studies have linked high Na+ intake with the rise of cardiovascular and BP and conversely K+ supplementation with favourable cardiovascular effects particularly in hypertension, thereby counteracting negative Na+ effects particularly when Na+ intake is high [31–34]. In western countries more than 70% of the Na+ people intake is hidden, since the main dietary sources of Na+ are processed and prepared prepackaged foods [35] whereas most of dietary K+ comes from fruits and vegetables. Although data on real food habits changes during the COVID-19 pandemic are limited, shopping and food habits may have changed dramatically as people reduced socialization while eating at home during lockdown or on self-isolation, as was observed during the last three economic recessions in 1990, 2001 and 2008. Stress related to confinement leads patients to overeat ‘comfort foods’ rich in sugar and salt, a behaviour defined as ‘food craving’ [36, 37]. Data from food sellers, documented a 15 to 30% estimated increase in selling packaged foods, shelf-stable staples, snacks, frozen and refrigerated foods and bread (https://foodindustryexecutive.com/2020/04/up-to-30-sales-increase-possible-for-packaged-foods-credit-suisse/). Many of these foods, especially takeout and processed foods, contain excessive salt and thus Na+. Examples of common processed foods include breakfast cereals, cheese, bread, savoury snacks, meat products, microwave meals or ready meals, cakes and biscuits and are mostly important sources of salt (https://www.nhs.uk/live-well/eat-well/what-are-processed-foods/). In addition, the limited access to daily grocery shopping may reduce the access to K+-rich foods such as vegetables (fresh or frozen), whole fruits and low-fat dairy products while increasing consumption of highly processed food products. During the lockdown, Italians [38] showed to have more desire to cook, and above all to knead. Accordingly, the consumption of homemade desserts, bread and pizza has increased but in most of the patients the observed changes of eating habit patterns in Italy appeared to adhere to the Mediterranean Diet [6]. However, in this study Na+ intake was not evaluated by means of 24-h urine collections. In hypertensive patients healthy dietary patterns should be supported. Patients should be encouraged to prepare food themselves, with preference for fresh and unprocessed ingredients (Table 2).

Alcohol consumption

Alcohol consumption has been identified as one of the strongest modifiable risk factors for hypertension. At low intake (<10 g/day), alcohol may exhibit a transitory vaso-relaxant effect and above this dose a dose-dependent pressor effect is recognized [39].

The analysis of psychological reactions to COVID-19-related confinement measures suggests that the pandemic may also affect alcohol consumption patterns [40]. Indeed, many people reacted to the closure of pubs and restaurants by stocking up alcohol and drinking at home, what resulted in the disappearance of alcohol containing beverages from supermarket shelves in some countries [40].

Market research by Nielsen showed, that in March 2020 during the COVID-19 pandemic following a stay-at-home order, alcohol sales in the USA increased by 55% relative to the same time in 2019. The same trend was seen in Canada and the largest rise was observed in patients 35–54-year old, 44% of whom attributed this change to stress [41, 42]. In the United Kingdom, data from the Office for National Statistics show that sales in alcohol stores in March had already increased in month-to-month volume by 31.4% [40, 43]. In Australia, the Commonwealth Bank data showed an overall contraction in spending in March 2020, but nevertheless, a 34% increase in spending on alcohol products was reported. In addition, online alcohol sales increased from 50 to 500% compared with the same period in 2019 [44]. In contrast, in some countries, for example in South Africa and India, strict lockdown in late March 2020 included a ban on the sale of alcohol.

The impact of the COVID-19 pandemic on drinking patterns in patients struggling with alcohol dependence is unknown so far. In those individuals the lack of familial and social support may lead to an increase alcohol intake or cause relapse in previously abstinent patients [40]. Furthermore, in the group of persons who are on the brink of dependence during lockdown, the disruption of social networks, job insecurity and troubled relationships may trigger the manifestations of alcohol dependence. Some data indicate that the association between COVID-19-related stress and the quantity of consumed alcohol is more pronounced in women than men, consistent with previous reports [45]. Harmful alcohol use is also linked to a range of negative effects in families, from adults modelling poor drinking behaviours to children, to domestic violence and child neglect [46, 47].

In summary, there is a growing body of evidence, that COVID-19 pandemic is associated with increased alcohol consumption worldwide [40, 48, 49]. No data are available so far to what extent the COVID-19 pandemic-triggered increase in alcohol consumption may affect BP in patients with hypertension. However, it may be expected that the sudden rise in alcohol consumption may in the long-run affect BP both in the general population and in patients with hypertension. Therefore, hypertensive patients should be supported to moderate alcohol intake (Table 2).

Smoking

There is a substantial evidence for the effect of tobacco cigarette smoking on BP, cardiovascular functional responses, cardiovascular risk and mortality [50, 51]. Cigarette smoking indeed elicits an acute rise both in BP and heart rate (HR) and affects autonomic nervous function, as shown by increased catecholamine levels [50, 51].

Heavy smoking (>20 cigarettes/day) is associated with a persistent rise in BP, BP variability and increase in left ventricular mass [51]. The long-lasting effect of each cigarette makes it likely that a persistent increase in BP may occur also in lighter smokers. In addition, the relevance of tobacco cigarette smoking during the COVID-19 pandemic in relation to the risk for respiratory infections and their complications is again prioritized. It is possible, that the period of self-isolation and lockdown restrictions during the COVID-19 pandemic could be used by some smokers as an opportunity to quit smoking and social distancing can effectively take away the social aspect of smoking,
particularly if no one else smokes at home [2]. On the other hand, the increased stress of a potentially fatal disease, possibility of loss of employment, feelings of insecurity, confinement and boredom, could also increase the desire to smoke [2].

It should be noted however, that data regarding changes in tobacco smoking behaviour since the onset of COVID-19 are scant. Based on the survey of 1,491 adults in Australia, an overwhelming majority of respondents have not changed their smoking behaviour, with almost 93% of smokers and nonsmokers reporting no change (including starting/stopping or increasing) or positive change (reduction) in smoking status since the onset of COVID-19 pandemic [4]. Among smokers, 34.3% declared no change and 16.3% smoked less than usual as compared with the period prior to COVID-19 pandemic. In contrast 49.4% of smokers reported increase in smoking behaviour and this was associated with more pronounced depression, anxiety and stress symptoms during COVID-19 pandemic [4].

In contrast, a survey including 6,416 Chinese patients documented only a slight overall increase in smoking rate (from 12.8 to 13.6%), including a small percentage (1.6%) of nonsmokers who started smoking [52]. A recent study analysing smoking behaviour during the COVID-19 pandemic in Italy showed a slight decrease in consumption of cigarettes during the lockdown period. In the group of never smokers, only 2.3% considered starting smoking cigarettes [53]. Nevertheless, the study showed a trend for an increase in the purchase of tobacco cigarette products, possibly because during lockdown most consumers preferred having stocks of cigarette at home to avoid going out every day [53].

Of interest, the world’s second largest tobacco company, British American Tobacco reported that the COVID-19 outbreak did not change patterns of consumption of cigarettes and has not affected their revenue, as even in the most affected countries consumers continued to purchase their products. Notably, in South Africa, the strict lockdown in late March 2020 included a ban on the sale of tobacco products in this country [54,55].

No data are available so far as to what extent a change in cigarette smoking patterns during the COVID-19 pandemic might affect BP in general and particularly in patients with hypertension. Nevertheless, hypertensive patients should be encouraged to stop smoking (Table 2).

Acute and chronic stress, depression, anxiety
Although no study has directly investigated the impact of COVID-19 on sympathetic cardiovascular function so far, a number of indirect and direct evidence suggest that during COVID-19 the sympathetic nervous system is activated with adverse consequences on BP and cardiovascular homeostasis. The collected evidence includes the finding that chronic stress which may accompany COVID-19, particularly in the phase of lockdown, is associated with sympathetic activation, as evaluated via measurement of plasma norepinephrine in venous blood, assessment of HR (taken as marker of adrenergic cardiac drive) and microneurographic recording of sympathetic nerve traffic [56–60].

Another argument in favour of an involvement of sympathetic cardiovascular function during COVID-19 is the fact that this latter pathological process is closely linked to an increase in body temperature and to an immune reaction. Both these responses are characterized by marked sympathetic activation [61,62]. This is particularly the case for the immunomodulatory responses of the sympathetic nervous system which may interact with the immune system via beta-2 adrenergic receptors and norepinephrine [62]. As mentioned above, the involvement of the sympathetic nervous system during COVID-19 may favour the development of a number of adverse cardiovascular and metabolic responses. First, the occurrence of resting tachycardia which implies an increase in cardiac work as well as myocardial oxygen consumption [63]. Second, the development of an endothelial dysfunction, which may trigger-specific circulatory districts, such as the coronary circulation, the occurrence of myocardial ischaemic episodes when combined to vasoconstriction [63]. Third, the progression of a prothrombotic process [63], which has been shown to be a very common clinical problem impacting on outcome in COVID-19 patients [64]. Finally, sympathetic overactivity promotes insulin resistance by decreasing tissue insulin sensitivity and favouring hyperglycaemia and thus causing a prodiabeticogenic response which could contribute to the unfavourable metabolic profile during the COVID-19 pandemic [65].

During the COVID-19 pandemic, patients with hypertension have to face psychological challenges similar to those of patients from the general population, as well as challenges common to other patients suffering from chronic diseases. Numerous studies report a high prevalence of psychological symptoms and disorders in various groups and populations exposed to COVID-19. In a recent meta-analysis [8], Salari et al. reported high overall prevalence of stress (29.6% – confidence interval (CI): 24.3–35.4), anxiety (31.9% – CI: 27.5–36.7) and depression (33.7% – CI: 27.5–40.6). In another meta-analysis, Pappa et al. [66] reported lower but still substantial prevalence of anxiety (23.2% – CI: 17.8–29.1) and depression (22.8% – CI: 15.1–31.5). A recent study from the USA evaluated the prevalence of anxiety or depression (based respectively on the Generalized Anxiety Disorder-2 and Patient Health Questionnaire-2) in representative samples from the US Census Bureau (>330,000 participants), one obtained in the first half of 2019 and four others during the pandemic, that is between April and May 2020. Compared with 2019, in April and May 2020, US adults were three to four times more likely to screen positive for anxiety (30.8 vs. 8.2%) and depression (23.5 vs. 6.6%) [67].

Although a pandemic is not included in the types of trauma at the origin of posttraumatic stress disorders (PTSD) as defined in the Diagnostic and Statistical Manual of Mental Disorders 5 [68], it appears obvious that patients most susceptible and/or exposed to direct and indirect consequences of the COVID-19 pandemic are at increased risk of developing PTSD. Notably, in previous infectious epidemics, the risk of PTSD was usually highest in survivors, followed by family victims and medical professionals [69]. Women, elderly, children, less
Kreutz et al.

educated and low-income groups are also more vulnerable. Other possible risk factors of PTSD include chronic illnesses and mental disorders, lack of social connection and support [8,69–71].

Besides concerns related to the risk of contamination by a virus for which no cure or vaccine exists, the population has also to face the psychological challenges of lock-down or self-isolation, implying social isolation and freedom deprivation. Social relationships constitute important emotional buffers that may brutally disappear in conditions of quarantine, with the emergence of symptoms such as irritability, insomnia, fear, confusion, anger, frustration, boredom that are related to the development of an acute stress disorder. Other adverse psychological effects may be related to physical inactivity and excessive screen time [72]. As mentioned before, confinement may also lead to increased substance use and domestic violence [68].

Finally, people from the general population may experience fear for their job, economic situation and more generally their future, and are facing a flurry of information, misinformation and alarming rumours, notably through the social media.

Several groups are thought to be particularly vulnerable to the psychological consequences of the pandemic. These include patients who contract the disease and their relatives [73]; patients at increased risk to contract the disease (elderly, immunocompromised); people with pre-existing medical conditions (including chronic diseases such as hypertension), psychiatric or substance use problems; healthcare providers, caregivers and other professionals in contact with the public [68]. These patients may be more prone to develop severe psychological disorders including PTSD.

Patients with hypertension may be more prone to psychological distress and therefore deserve a specific attention during the COVID pandemic. Indeed, PTSD due to individual or mass traumas has been related to the development of hypertension [12], and particularly severe and refractory forms of [11] hypertension seems to be often associated with altered psychological patterns mostly related to expression of emotions [11].

Furthermore, although there is no current reason to believe that hypertension per se (i.e. irrespective of advanced age and comorbidities) is a risk factor for more severe COVID-19 infection [1], it has been widely described as such, which may lead to further distress. Additional sources of anxiety include the unfortunate public debate on possible harmful effects of angiotensin-converting enzyme inhibitors and AT1 blockers in patients infected by SARS-CoV-2 [2]. As other patients with chronic diseases, hypertensive patients may have also experienced difficulties to get in touch with their physician or renew their drug supplies during the lockdown, which is an additional source of stress. Finally, distress may result in decreased treatment adherence or even lead to the development of an addiction, in particular to alcohol, known to have a negative impact on BP control.

In summary, when consulting hypertensive patients, including also telemedical care, doctors should not only monitor BP levels and adherence, but follow-up on psychological/mental health depending on individual needs (Table 2).

Sleep behaviours, circadian rhythm and 24-h blood pressure profiles

Unhealthy sleep behaviours – short or long sleep duration, late chronotype, daytime napping, insomnia, snoring excessive daytime sleepiness – are associated with increased cardiovascular risk [74]. Uninterrupted sleep of 6–8 h a day is an important component of a healthy lifestyle [75]. Sleep disorders are also related with the nondipping BP profile and high nocturnal BP, two phenotypes closely related to high cardiovascular risk. There is also a relationship between sleep disorders and uncontrolled hypertension [76]. Home confinement, increased stress level and social isolation may influence sleep behaviour and if those alterations are prolonged, they may have long-standing effects on BP levels and cardiovascular risk.

The lockdown, forcing people into home confinement, affected sleep patterns. This was shown in a study conducted by analysing the anonymous aggregated data from over 2 million users of fitness trackers worldwide during the lockdown [77]. In general, average sleep time increased worldwide with results varying across different countries. Moreover, in most countries people went to bed later and got up later than usual. A survey from Italy reported that during home confinement, sleep time markedly changed, with people going to bed and waking up later, and spending more time in bed [78].

Depression, anxiety and social isolation related to the lockdown and COVID-19 pandemic also affected sleep quality. A survey from Italy reported that despite an increase in time spent in bed, people were reporting lower sleep quality [78]. A survey from China reported a 37% increase in the rate of insomnia from before to peak of the COVID-19 pandemic [79]. Another survey showed that 13.6% of participants developed new-onset insomnia and additional 12.6% reported worsening of previously present insomnia during the COVID-19 pandemic [80]. The development of insomnia or worsening of insomnia was among other factors related to prolonged time spent in bed.

Sleep quantity and quality in frontline healthcare workers is also an important issue that evolved during the COVID-19 pandemic. Shift-work, in particular short shift intervals and consecutive night shifts, are related with increased hypertension risk [81]. High stress level, higher work demands and shift-work might therefore influence sleep behaviour in frontline healthcare workers. A study from China has shown a higher prevalence of sleep disturbances and worse sleep quality in frontline healthcare workers as compared with nonfrontline healthcare workers [82]. Those findings were confirmed in a systematic review which included 13 studies [66].

In summary, despite an overall potential longer time spent in bed, an increase in poor sleep quality and insomnia may have occurred during the COVID-19 pandemic. Those findings might be of clinical importance. First of all sleep disturbances may persist well after the pandemic, and such problems are often precursors of psychiatric disorders and might associate with higher cardiovascular risk [83]. Second, going to bed and waking up later may have an effect on
circadian rhythm and result in delayed sleep–wake phase syndrome when patients are returning to extrinsically imposed schedules [84]. Third, frontline healthcare workers, who are exposed to work-related stress and shift-work, report sleep disturbances. Overall, sleep disorders related to the COVID-19 pandemic in short-term and when persistent in long-term may potentially predispose to cardiovascular disease including the onset of hypertension and poorer BP control in patients with already established hypertension.

**Environmental changes**
COVID-19 changed economic patterns due to social and physical distancing and confinement measures, which in turn reduced environmental burden, notable CO2 emissions and air pollution [85,86]. Under lockdown, economic activity mostly ceased, while even a lack of official restrictions but awareness of COVID-19 is sufficient to induce a change in behaviour and resulting CO2 emissions and air pollution.

Emission trajectories were heavily influenced by lockdown, which was most consequential in the first half of April 2020, when global emissions were 17% lower than an equivalent day in 2019 [85]. A 17% reduction of emissions corresponds to levels last seen in 2006 underscoring the rapid emission growth in the recent decade.

With 43%, road traffic contributed the most to the emissions decline (43%), followed by the power sector (electricity and heat) and industry (manufacturing and material production such as cement and steel). The peak daily fall in global aviation activity (60%) was the largest of any sector observed, contributing 10% of CO2 emissions (not considering other non-CO2 emissions greenhouse gas emissions from aviation). As people stayed at home, emissions from the residential sector increased slightly.

With lockdown, air quality improved considerably, first in China and then in many cities worldwide. The US observed a 25% reduction in NO2 levels during strict COVID-19 response [87]. In Milan in Northern Italy’s pollution-prone flatlands, lockdown resulted in a significant reduction of pollutants concentration mainly due to avoided vehicular traffic (PM10, PM2.5, BC, benzene, CO, and NOx) [88]. In Europe, lockdown and curtailed coal and oil consumption reduced air pollution what may translate into 11 000 saved lives (7000–21 000) (27% reduction in air pollution-related mortality) and into about 6000 fewer cases of asthma in children [89]. In China, air pollution reduction may save about 12 000 lives, number substantially higher than deaths from COVID-19 [90].

Long-run and indirect effects are likely to dominate overall effects of COVID-19. First, a COVID-19 triggered recession will also reduce greenhouse gas emissions in 2020. Notably, emissions in the power sector are falling more than proportionally with demand reduction. The specific effect here is that coal power plants exit the market first, as all power plants, including renewables, nuclear, and more recently also gas, are cheaper than coal (merit order effect) [91]. However, lack of liquidity will also mean bankruptcy for small enterprises and thus delay innovation, which is crucial to accelerate the transition to clean energy; an effect that may outweigh all others in the long run [92].

**Environmental noise**
The effects of exposure to high levels of environmental noise are wide-ranging and include various adverse health effects, due to annoyance, sleep disturbance, and metabolic effects.

The current WHO Environmental Noise Guidelines for the European Region established this threshold, because exposure to an Lden more than 55 dB has a significant negative impact on health [93]. Of interest, hypertension is one of the most frequently identified health consequences of environmental noise [94].

Acute exposure to higher noise levels increases BP as evidenced by 24-h ambulatory BP monitoring [94]. Impact of noise on BP rise as well as hypertension development includes complex mechanisms, involving functional and structural vascular changes [95–98]. It was shown that normotensive patients with long-term (years) exposure to aircraft noise are characterized by increased arterial stiffness [99].

However, a meta-analysis of 40 studies spanning the years 2000–2015 did not allow drawing definite conclusions about any threshold value for the relationship between environmental noise and the prevalence of hypertension [100].

Two meta-analyses found that the prevalence of hypertension is proportional to the noise sub-type and source of exposure [101,102]. First, a meta-analysis of 27 cross-sectional studies (26 from Europe and one from Japan) evaluating road traffic exposure in more than 116 500 adult individuals between 1970 and 2010 showed a dose-dependent increase in the risk of hypertension [101]. A second meta-analysis assessing the effect of aircraft noise on the incidence of hypertension showed even stronger relationship between noise and hypertension [102]. These observations are consistent with the reports indicating that air traffic noise is more annoying than road traffic noise [103]. For rail traffic noise, two recently published studies did not confirm the association between exposure to this type of noise and the incidence of hypertension [104,105].

Until recently, no studies evaluating the impact of reduction in environmental noise on BP in the general population or on the incidence of hypertension and BP control in hypertensive patients were available. During COVID-19 pandemic, data from continuous minute-by-minute noise monitoring around the Frankfurt airport in Germany documented substantial decrease in aircraft noise during the lockdown. In March of 2020, an average reduction of 7.6 dB for road noise level Lden was observed in Paris, and aircraft noise emission in the Charles de Gaulle Airport dropped to the level of 21.5 dB Lden [105]. Barcelona showed an average decrease of 10dB Lden in traffic noise during the first weeks of lockdown. A clear drop in both daytime and night-time environmental noise levels at the Chopin Airport in Warsaw was observed when comparing the noise assessment from March 2019 with that of March 2020 [106]. Thus, a reduction in environmental noise levels during the COVID-19 pandemic and particularly the lockdown has been well documented.
Kreutz et al.

However, to the best of our knowledge, no studies evaluating the impact of COVID-19 on the association between the profound reduction in environmental noise and BP level are available, either with regard to the general population or hypertensive patients.

Previous studies indicated an increase in hypertension risk with the increase in environmental noise. When we reverse this relationship, we may expect a reduction in hypertension prevalence with the drop in environmental noise. The experimentally proven BP rises under the influence of short-term noise episodes are more than expected to disappear with noise cessation. Indeed, the beneficial effect of lockdown-induced reduction in environmental noise may be short-lived, as road and rail traffic and aircraft, noise levels are rising in a number of leading European cities since coronavirus restrictions eased.

Delayed diagnosis and care

During the lockdown for COVID-19, regular patient care for chronic diseases like hypertension was compromised in many regions of the world [107]. Recommendations from Choosing Wisely Canada, adopted by many countries, included ‘Don’t go in person to a hospital, clinic, or healthcare provider for routine care (preventive visits, routine blood work) …’ and ‘Don’t offer nonessential services to patients in person, if virtual tools such as telephone or online visits are available. Delay nonessential care and laboratory testing when possible.’ (https://choosingwiselycanada.org/covid-19/). While these recommendations are very useful for the control of the pandemic, they induce consequences for noncommunicable diseases (NCDs). This was first recognized for acute care of cardiovascular diseases, since there was a decreased number of patients attending emergency departments due to acute myocardial infarction (MI) [108] and acute stroke [109], and presentation of acute MI was delayed [106]. In the USA, a sharp increase in death rates due to cardiac and cardiovascular disease, not attributed to COVID-19, was observed during the ongoing pandemic [110]. Moreover, recent data showed an increase in the frequency of out-of-hospital cardiac arrests in France, Italy, and the USA, with higher odds of out-of-hospital arrest [odds ratio (OR) 1.92] and mortality (OR 1.89) during the pandemic period compared with prepandemic period [111].

In the long-term, delayed diagnosis and limited access to medical consultations and pharmacies may have unfavourable consequences in hypertensive patients. In an attempt to counterbalance the limited access to general practitioners, and outpatient clinics and also in view of the reluctance of patients to visit their family doctor and hospitals for chronic conditions such as hypertension due to fear of contagion [107], home BP measurements and telemedical consulting if needed were proposed [112]. The literature dealing with remote healthcare for cardiovascular diseases during COVID-19-related lockdown or self-isolation has been recently reviewed [107]. Though often useful, recommendations included in these articles mostly represented expert opinion. While obviously no data on the long-term consequences of COVID-19 with respect to hypertension control are available yet, it has been emphasized in the last version of the ESC/ESH Practice Guidelines for the Management of Hypertension [6], that physicians should aim for BP control within 3 months, once high BP has been diagnosed – a goal hard to reach during the pandemic [113].

Another factor critically related to BP control is adherence. Currently, there are no data available as to how the COVID-19 pandemic might have influenced adherence to BP-lowering medications. Given that the pandemic likely will be followed by an economic crisis, the cost of antihypertensive drugs may become more and more important, particularly in healthcare systems requiring substantial co-payments to medication. In this context, a recent study from the USA clearly proved the relationship between cost-related medication nonadherence (affecting roughly 10% of the population studied) and hypertension control [114].

In summary, in hypertensive patients BP control should be evaluated strictly also during the pandemic. Patients should be encouraged to implement home BP monitoring. Adherence to antihypertensive treatment should be also assessed (Table 2).

Economic damage, unemployment and migration

The World Trade Organization has indicated the COVID-19 pandemic as the biggest threat to the global economy since the financial emergency of 2008–2009. At the country level, the economic consequences of the pandemic have been linked to the differences in the extent of pandemic and in implementation of infection prevention and control strategies. Infection prevention and control strategies are mainly based on two main paradigms, containment and mitigation [115]. Containment, designed to prevent community transmission at the beginning of an outbreak, is accomplished by monitoring the spread of the disease to allow for targeted self-isolation. Mitigation includes travel restrictions, the closure of schools, the cancellation of events until the blocking of production and commercial activities at regional or national level with enormous economic costs. Some countries, such as Germany, were mainly based on containment strategies that only switched to mitigation in certain regional areas. Others, such as France, Italy, Spain and the United Kingdom, have had the worst outbreaks in Europe and have extended mitigation measures at national level, leading to the creation of the largest lockdown ever seen in Europe [116]. The lockdown also lasted longer in countries with larger outbreaks [117]. Manufacturing and tourism sectors are hardest hit by lockdown measures. Each month in lockdown was estimated to cause an approximate loss of 2% points in annual Gross Domestic Product growth [118]. The tourism sector alone faces an output decrease as high as 50–70%, an aspect which mainly affects Southern Europe [119]. In addition, tourism will remain limited even when lockdowns are lifted. Economy of many EU countries are now facing the threat of high inflation and increasing unemployment as a result of lack of productivity.

The economic impact of COVID-19 pandemic will have significant bearing on vulnerable groups including refugees, migrants, internally displaced people and host communities. All over the world, lockdowns and border closure have sparked the return of migrants who have lost support and networks, or employment options. Ethnic minorities
are overrepresented in low-income and discriminated social groups. These groups face unique sets of challenges related to their lack of right to healthcare and exclusion from welfare programs. Furthermore, national and local authorities often do not have a precise picture of the number and distribution of migrants in their jurisdiction. The lack of properly disaggregated data makes it difficult to quantify the specific impacts they suffer. This hinders their inclusion in public health efforts and makes it challenging to gather precise information on affected individuals, as well as monitor and trace the course of the outbreak [119]. Ensuring that all groups of migrants, regardless of their status, have access to healthcare is a necessary condition for effective responses to the COVID-19 pandemic outbreak. Since its early stages, the outbreak has triggered countless episodes of xenophobia, directed towards internal migrants in China, Asian migrants in countries all over the world, and progressively towards European migrants and foreigners in general, including in China itself and in areas only marginally affected by COVID-19.

In the emergency phase, resources were mainly allocated to ICUs distracting them from facilities for NCDs [120]. On the other side, patients with NCDs are reluctant to visit health facilities for fear of becoming infected [121] and new care models, including telemedicine, may not yet be fully implemented [120]. The inertia of NCDs patients to seek assistance and the inability of caring physicians to assist them can become major challenges [110,122]. If we consider the hundreds of millions of patients with NCDs, in the coming months, the indirect impact of the COVID-19 pandemic on NCDs-related deaths may well become more significant than that of the epidemic itself on patients directly affected by the infection.

The case of children and adolescents

COVID-19 is either rare in children or it has not been diagnosed that often because this age group remains asymptomatic [123]. Initial data from China reflect that children had significantly lower rates and severity of COVID-19 than adults; 2% of cases were aged 0–19 years, 0.9% less than 10 years, with no child deaths [124]. Children continue to constitute a low proportion of those diagnosed with COVID-19 in reports for Europe and the USA representing 1.2% of cases in Italy and 5% of COVID-19-positive cases in the United States [125]. However, the exact prevalence of COVID-19 in children is difficult to ascertain, as there is no single place to obtain country comparable age-related data.

The COVID-19 seems to have a milder course and most of COVID-19 cases in children were less severe than adult cases, the obvious question is why? This may be related to both exposure and host factors and accordingly several suggestions have been put forward including fewer comorbidities, strong innate immunity and weaker adaptive immune responses, immune priming to coronavirus infections and variable angiotensin converting enzyme 2 expression [123].

Even when only a small number of children and adolescents are directly affected directly by COVID-19, the pandemic has collateral effects extending throughout the whole paediatric age group. While it is a priority to mitigate the immediate impact of COVID-19, it is important to call for attention to the pandemic’s longer effect on children’s health caused by the implemented lockdown. Negative effects on health are likely to be much worse when children are confined to their homes without outdoor activities and interactions with same age friends. Impact on obesity and related comorbidities, mainly high BP, as well as psychological effects are among the main consequences of the lockdown and socio-economic disruptions.

The lockdown is negatively targeting obesogenic behaviours as discussed above particularly in children decreasing physical activity, increasing sedentary screen time, less favourable diets and irregular sleep length and patterns. These behaviours, alone or in combination are associated with un-wanted weight gain. Consequently, the lockdown exacerbates the epidemic of childhood obesity and increased disparities in obesity risk, an important cause of BP elevation in paediatric age [126].

A relevant issue in childhood is the school closures, a challenge with unpredictable side effects considering the critical role of schools providing a structured education and promoting a child’s mental and psychological growth. Since the structured day’s hypothesis founded on the premise that organized day represented herein by a school day, defined as preplanned, segmented, and adult supervised compulsory environment, schools play an overall protective role for children against obesogenic behaviours. During lockdown there is a less structured routine, regulation and more autonomy for children in the home environment in which unfavourable activities displace favourable ones. The importance of the school has been demonstrated using summer as a time period where children are at risk of accelerated weight gain and loss in cardiorespiratory fitness [127]. Moreover, weight gained during the summer months is maintained during the school year and accrues summer to summer [128]. Negative effects on health are likely to be much worse when children are confined to their homes without any outdoor activities and interaction with same aged friends. The expected quick loss of physical condition is especially relevant and worse in overweight and obese children that will take longer to regain it than normal weight children.

An important but easily neglected consequence of the lockdown is the psychological impact on youth. Stressors such as prolonged duration, fears of infection, frustration leading to boredom, information coming from the wrong sources, lack of personal space, and family financial loss can have negative long-term effects on children and adolescents [10]. It has previously been shown that the mean posttraumatic stress scores were four times higher in children who had been self-isolated than in those who were not [10].

Overall children and adolescents have lower rates of actual COVID-19 viral infection than adults, but nevertheless they might constitute the group mostly affected by the lockdown placing them in an unfortunate position of isolation that create unfavourable environment for maintaining healthy lifestyle behaviours. The accelerated weight gain, loss of cardiorespiratory fitness combined with higher stress levels, are risk factors for developing high BP. Recognizing the adverse collateral effects of the COVID-19
pandemic lockdown is critical and needs to be the first step for taking preventive measures. Resilience should be nurtured and implemented by public health programs to support the child to get through this difficult time of COVID-19 pandemic. Childhood is a special time of vulnerability having little voices to advocate for their needs.

**SUMMARY AND CONCLUSION**

Alterations of life-style, daily routine, family and personal problems as well as problems deriving from superimposed lockdown and/or self-isolation during the COVID-19 pandemic may be long-lasting. While some effects including reduced work-related stress, increased sleep duration and decrease in environmental noise and pollution may in fact decrease BP and cardiovascular risk, other patient-related factors may in the long-run counterbalanced these beneficial effects with their – possibly persisting – negative impact by increasing BP and cardiovascular risk (Fig. 1, Table 1). In addition, physician and healthcare-related factors associated with delayed diagnosis and increased therapeutic inertia will contribute to poorer control of BP and cardiovascular risk (Table 1). Therefore, hypertension-related problems may continue even beyond the COVID-19 pandemic. Consequently, it is important to develop and implement in the future potential measures to meet the challenges that arise from the COVID-19 pandemic by increasing BP and cardiovascular risk (Table 2). At the beginning of the pandemic, there was also a concern about potential adverse effects of drugs inhibiting the renin–angiotensin system on the risk for COVID-19 (reviewed in [1]). Despite early attempts to contradict this concern by expert reviews and statements of scientific organizations, including the European Society of Hypertension COVID-19 task force on 14 March 2020. The information that appeared in the media may have contributed to the withdrawal of this group of drugs in some of the patients according to a recent survey (Weber T et al. J Hypertens 2020, in press). Taking together, all factors discussed herein with their potential impact on BP in the COVID-19 pandemic, it becomes clearly evident, that there is an unmet need to conduct appropriate observational studies on BP control patterns during the pandemic, for example in ongoing registries or cohort studies. The latter is unfortunately lacking so far.

Although minimizing social contacts is necessary and effective in preventing COVID-19 transmission and protecting, it should be not dismissed that living in community with relatives and friends is crucial and the possibility of reaching and helping patients with chronic diseases, such as hypertension, should be always ensured, even during catastrophic events or pandemics.

**ACKNOWLEDGEMENTS**

Conflicts of interest

There are no conflicts of interest.

**REFERENCES**


Risk factors, hypertension and coronavirus disease 2019


Kreutz et al.

54. BAT court bid to overturn South Africa tobacco ban hit by delay. https://www.ft.com/content/5a5d5511-e5fa-4b04-b02e-800213e6c1e6 [Accessed 5 August 2020]
78. Molyvirla L, Thieriot H. 111,000 air pollution-related deaths avoided in Europe as coal, oil consumption plummet. Centre for Research on Energy and Clean Air. 2020; Available at energynodecleanair.org [Accessed November 2020]
Risk factors, hypertension and coronavirus disease 2019


