NEED TO KNOW

- Climate change, through its association with extreme weather events and air pollution, increases cardiovascular (CV) mortality and morbidity.
- Extreme heat and heatwaves increase cardiovascular disease (CVD), ischaemic heart disease (IHD) and congestive heart failure (CHF) mortality, morbidity and hospital admissions.
- Air pollution, particularly $PM_{2.5}$, increases CV mortality, IHD/MI, CV hospital admissions, CHF, stroke, hypertension, diabetes, arrhythmias and atherosclerosis.
- Extreme heat/heatwaves and air pollution act synergistically.
- Wildfire smoke contains many air pollutants and has been associated with increased all-cause and CV mortality.
- A sudden cardiac event is the leading cause of fire duty-related deaths.
- Reducing greenhouse gas (GHG) emissions by dietary changes (especially plant-based diets), increasing active transport, changing to renewable energy sources, increasing green spaces and stopping smoking also has cardiac benefits.
- There are many ways GPs and individuals can reduce their personal carbon footprint, however switching to renewable energy sources will have the greatest impact on Australia's emissions.

Environmental change and cardiovascular disease

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INTRODUCTION

CLIMATE change is adversely affecting human health and is expected to lead to further future increases in morbidity and mortality.[1,2] While COVID-19 dominated 2020, we cannot deny the overwhelming evidence that earth is facing a climate emergency.[3]

Since the 1970s, the world has observed a 1°C temperature rise above pre-industrial levels.[4] The global mean temperature is currently rising at a rate of 0.2 °C per decade because of previous and continued emissions; the past decade has seen eight out of 10 of the hottest years on record.[4,5] These changes are primarily being driven by fossil fuel combustion.[6] Global warming causing climatic variability is predicted to cause more frequent heatwaves, bushfires, droughts, severe storms/flooding, rising sea levels, water shortages and loss of biodiversity.[6]

Australia continues to break temperature records, the number of 'hot days' we experience (mean temperature more than 30 °C) is predicted to increase, as is the intensity and frequency of heatwaves.[7] The increase in heat is a leading source of climate-change-related health risk in Australia.[7] The 2019/2020 summer was devastating and unprecedented, with the hottest ever-recorded day nationwide, warmest December, second-warmest summer, numerous high temperature records, dangerous fire weather conditions and the highest December accumulated Forest Fire Danger Index on record.[8]

Climate change has several adverse health effects including (but not limited to): illness related to extreme weather events and air pollution; reduced food availability and quality; vector-borne diseases; mental illness; and occupational health impacts.[2] Vulnerable populations, such as those with pre-existing medical conditions like cardiovascular disease (CVD), the elderly, children, and the socioeconomically disadvantaged will suffer disproportionately.[9]

This How to Treat discusses how climate change, through its association with extreme weather events, and air pollution, increase cardiovascular (CV) mortality and morbidity. It also explores how GPs can manage patients acutely, the cardiac benefits of climate change mitigation and measures to reduce personal carbon footprints.

TEMPERATURE AND CVD

GLOBAL extreme temperature events, both high and low, are more frequent.

Temperature and all-cause and CV mortality have a V or U shaped relationship, with extremes of both high and low temperatures increasing CV mortality and morbidity worldwide.[10-15] A 2017 meta-analysis found CV mortality risk increased by 5% with extreme cold exposure and 1.3% with extreme heat.[16] Higher CVD mortality is more closely associated with adverse temperatures in winter compared with summer, and with increasing age.[17,18]

Extreme high temperatures cause acute or immediate increases in mortality (within a few days) while extremely low temperatures cause delayed effects.[19]

An Australian study found a V shaped relationship between mean temperature and CV deaths, with a 3.5% increase in CV mortality with heat exposure occurring within 0-1 day, and a 2.8% increase in CV mortality with cold exposure occurring at a lag of 10-15 days.[20]

Populations in warmer regions tend to be most vulnerable to cold and those in cold climates are most sensitive to heat. Heat effects (such as increased mortality) are greater for colder cities, while inhabitants of hotter cities are more affected by colder temperatures.[19,21-23]

Temperature variability (which can be intraday/diurnal or interday), has been associated with increased all-cause and CVD/coronary heart disease (CHD) mortality, hospital admissions for CVD, ischaemic heart disease (IHD), heart failure, arrhythmia and ischaemic stroke.[24-28]

Figure 1. Air pollution.

Extreme temperature and ischaemic heart disease

Temperature is an important environmental risk factor for IHD with both extremely cold and hot temperatures associated with increased mortality from IHD or CHD.[29-31] A similar U or V shaped relationship to CVD deaths is seen with IHD mortality, with more MI deaths caused by adverse temperatures in winter than in summer.[17]

Cold and heat exposure are associated with an increased MI risk, and CHD/MI hospitalisation.[33-38] That said, some studies have shown increased MI hospitalisations with cold but not high temperatures.[39,40]

The effect of heat exposure and heatwaves on MI are immediate, whereas the impacts of cold exposure are delayed.[32] The more immediate effects of heat exposure may explain the inconsistent findings in the relationship between heat exposure and MI hospitalisations, as heat exposure might result in an increase in out of hospital deaths with acute MI events.[41]

An increase in latitude is associated with a decreased risk of MI hospitalisation due to cold exposure.[32,33]

An Adelaide study found mortality, morbidity and hospital admissions related to congestive heart failure (CHF) were higher in winter relative to summer, with those older than 75 at risk of seasonal variations in morbidity and mortality.[42]

Extreme heat and CVD

Climate change negatively impacts CVD, by its association with extreme heat, which is particularly relevant in Australia as our maximum temperatures, heatwave exposure and vulnerability to these extremes is increasing.[7] The frequency, intensity and duration of heatwaves are expected to continue increasing with climate change.[43-45]

Heatwaves and high temperatures increase CV morbidity and CV mortality risk.[46-51] The larger the increase in temperature, the higher the risk of CVD death.[52] Heatwaves are associated with increased all-cause and CV mortality, especially among the elderly, and with an increased risk of IHD, stroke and CHF mortality.[49,53] Mortality risks are greater for more intense heatwaves.[49,53] With increasing temperatures and intense heatwaves of longer duration, mortality due to CVD, MI and CHF is expected to increase.[54,55] Particularly vulnerable are the elderly, those with pre-existing CVD (IHD, CHF and stroke) and those performing heavy physical labour.[56,57]

Heatwaves and extremely high temperatures increase hospitalisation for CVD, especially IHD and arrhythmias.[58-62] In the US, hospital admissions for CVD and MI have been shown to increase in synchrony with the average temperature on the same or preceding day.[63,64] Some studies have found no or negative associations between increased temperatures/extreme heat and CVD hospitalisations.[65-67] However, others have noted positive associations between high temperature and heatwaves and CV mortality, especially among the elderly.[68,69] This suggests individuals may die from CVD during high temperatures before seeking medical attention or being admitted to hospital.[70] An increased risk of out-of-hospital cardiac arrest (OHCA) has been reported with elevated temperatures and heatwaves.[71]

There is a short lag-effect of extreme heat on increased CVD hospitalisations and mortality of 0-4 days.[52]

The 'urban heat island' is a meteorological phenomenon whereby cities are warmer than surrounding, less-developed regional locations due to human activities, as urbanised areas absorb and re-emit the sun's heat more than 'green' areas.[72,73] Residents of urban regions are more vulnerable to the risk of heat-related mortality than those living rurally.[74,75] Almost 90% of Australians live in urban areas, and this is expected to increase.[76]

Pathophysiology

Mechanisms for the effects of temperature/season on CV death and MI have been postulated but are not definitive.

Cold may increase cardiac load through raised inflammatory markers and coagulation parameters.[77] Cooling of skin could increase systemic vascular resistance, heart rate and blood pressure (BP), decreasing myocardial oxygen supply.[78,79] These changes may lead to ischaemia.[80,81] In winter, a rapid decrease in temperatures could then trigger an acute MI/sudden cardiac death. Additionally, cold temperatures may trigger higher HbA1c levels in those with type 2 diabetes.[82]

Exposure to heat can increase heart rate, BP, blood viscosity and coagulability, arterial thrombosis and cholesterol levels; weaken core temperature regulation; reduce myocardial oxygen supply; and heighten MI and stroke risk.[83-85] Increased temperatures can cause dehydration, decrease sodium levels, increase circulation of the surface blood from vasodilation, and can lead to fluid and electrolyte disturbances, a frequent complication in patients with coronary dysfunction.[86,87] Under extreme heat stress, the body may lose its ability to thermoregulate, resulting in heat exhaustion, heat syncope and heat stroke.[88] These responses to extreme heat are more significant in the elderly, and in those with underlying CVD including IHD, heart failure and stroke.[89]

Table 1. Air pollution and CVD

Condition	Air pollution effect
CV mortality	Increased CV and all-cause mortality with short-term exposure to $PM_{2.5}$, PM_{10} and NO_2[132-136] Increased CV mortality with long-term $PM_{2.5}$ exposure[137-142]
Ischaemic heart disease	Short- and long-term exposure: Increased IHD death[138-146] Increased ACS/MI, particularly STEMI[147-153] Those with underlying CAD are at particular risk[154]
CVD hospital admissions	Increased admissions for CHF, AMI, cardiac dysrhythmias, and coronary atherosclerosis with short-term exposure, particularly $PM_{2.5}$[155-162] Elderly are particularly at risk[163-165]
Heart failure	Increased mortality[166] Increased hospital admissions[166,167] Increased incidence with long-term $PM_{2.5}$ exposure[153]
Stroke	Increased stroke mortality and hospitalisations with short-term $PM_{2.5}$ and PM_{10} exposure[168] Short-term $PM_{2.5}$ exposure: increased ischaemic (but not haemorrhagic) stroke hospital admissions[162] Increased stroke mortality with long-term $PM_{2.5}$ exposure[169,170] Increased stroke incidence with long-term $PM_{2.5}$ and PM_{10} exposure[170,171] Living close to a roadway is associated with increased stroke risk and severity[172]
Blood pressure	Increased BP (acute and chronic, increased prevalence)[173-179] Traffic-related air pollution poses a particularly high risk[180,181]
Diabetes	Increased insulin resistance[182,183] Increased diabetes[182,184-186]
Arrhythmias	Short-term exposure: Increased cardiac arrhythmia hospitalisation or mortality[187] Increased atrial fibrillation (AF)[188] Increased ventricular arrhythmias (VA), including in those with ICDs[189-191] Increased out-of-hospital cardiac arrest (OHCA), especially $PM_{2.5}$[192,193] Long-term exposure to PM may prolong QT[194]
Atherosclerosis	Increased atherosclerosis[195] Increased coronary artery calcium (CAC) score, odds of detectable CAC and CAC severity[196] Increased carotid intima media thickness (CIMT)[197,198] Increased arterial brachial index Traffic-related air pollution and proximity to traffic is significantly associated with increased coronary atherosclerosis and CAC score[198-200]
Other associations	Left and right ventricular hypertrophy after long-term exposure to NO_2[201,202] Increased CRP levels in those with metabolic syndrome[203] Obesity in children[182]

AIR POLLUTION AND CVD

AIR pollution is composed of particulate matter (PM) and gaseous components (see figure 1). Exposure to air pollutants is associated with adverse health outcomes, including CV (see table 1), respiratory and oncologic diseases.[90]

The PM fraction is categorised by aerodynamic diameter: less than 0.1µm ultrafine particles, less than 2.5µm fine particles ($PM_{2.5}$), less than 10µm coarse

Figure 2. Firefighting.

(PM_{10}).[91] PM is quantified in μg/m^3.

Predominant sources of fine PM are fossil fuel and biomass combustion, industry, agriculture, and windblown dust.[92] In Australian summers, bushfire smoke and dust storms are the main sources of PM_{10}, and in winter, wood heaters are an important source.[93]

PM_{10} can penetrate and lodge deep inside the lungs, while $PM_{2.5}$ penetrates the alveolar barrier and enters the blood stream. $PM_{2.5}$ is the principal air pollutant posing the greatest health threat.[94] The elderly, children, and those with pre-existing CV or respiratory disease are at increased risk.[95]

More than 90% of the global population is exposed to air pollution levels that exceed the WHO air quality guidelines (AQG) of $PM_{2.5}$ less than 10μg/m^3 annual mean, less than 25μg/m^3 24-hour mean, PM_{10} less than 20μg/m^3 annual mean and less than 50μg/m^3 24-hour mean. Ambient air pollution (particularly $PM_{2.5}$) is a global mortality risk factor, estimated to cause millions of premature deaths and disability adjusted life years, with CVD (IHD and stroke) accounting for 60-80% of these.[7,96-99]

Long-term low-level air pollution is associated with increased mortality worldwide, including in Australia, despite air pollution concentrations being below the WHO AQG.[96,100,101] It is estimated to shorten life expectancy by 8.6 months in Europe.[101]

$PM_{2.5}$ air pollution has been described as "the most important environmental risk factor contributing to global CV mortality and disability".[102] There is evidence of a causal relationship between short- and long-term exposure to air pollution (particularly $PM_{2.5}$) and CV mortality and morbidity, including MI, stroke and heart failure.[103-111]

Short-term exposure to $PM_{2.5}$ (few hours to days) increases the relative risk (RR) of acute CVEs, MI, hospitalisation or death from heart failure, stroke and arrhythmia.[112-115] Similar risks are reported for short-term exposures to gaseous pollutants such as NO_2, CO and CO_2.[112-115] Short-term air pollution exposure is an important trigger for MI globally, accounting for nearly 5% of MIs worldwide.[116]

Longer-term exposure (several years) amplifies these risks.[117] The risk is increased even when pollutant concentrations are below WHO standards.[118] Living in an area with chronically elevated $PM_{2.5}$ leads to an increase in CV mortality and all-cause mortality.[119]

Possible mechanisms include inflammation induced by $PM_{2.5}$, oxidative stress and vascular/endothelial dysfunction, which can facilitate the development of hypertension, diabetes and atherosclerosis.[120-126]

The toxicity of $PM_{2.5}$ can vary, depending on its composition and source. $PM_{2.5}$ from coal combustion is associated with higher IHD mortality risk than $PM_{2.5}$ from other common sources (soil and biomass combustion), as is $PM_{2.5}$ from diesel traffic.[127] Traffic exhaust increases MI, and is considered the single most preventable acute trigger for MI.[128,129] Combustion is also a leading source of NO_2 which is associated with increased CV mortality.[130] During extreme ambient air pollution episodes, $PM_{2.5}$ can exceed 500-1000μg/m^3, levels on par with active smoking.[131]

Pathophysiology

The mechanisms linking air pollution and cardiometabolic disease are complex.[204] Air pollution, particularly $PM_{2.5}$, induces oxidative stress and inflammation, resulting in acute, subacute and chronic responses promoting atherosclerosis and CV events.[205-6]

$PM_{2.5}$ inhalation causes vascular dysfunction, altered haemodynamics, augmented thrombosis, heightened arrhythmia potential and proatherosclerotic changes.

Activation of the sympathetic nervous system, endothelial dysfunction, systemic and tissue inflammation, and oxidative stress, altered adipocyte expression, hypothalamic activation, impaired renal function, obesity and weight gain, and direct effects of inhaled nanoparticles are proposed mechanisms by which $PM_{2.5}$ increases BP and diabetes risk.[208-210]

Short-term inhalation of air particles has been shown to elevate BP and/or alter vascular indices, and personal strategies to lower pollution exposure demonstrate rapid effects in reducing BP.[211-214]

Temperature and air pollution: a two-way effect

High temperatures, particularly heatwaves, modify air pollution effects on mortality and CV outcomes, and high air pollution enhances temperature effects. The joint effect of temperature and air pollution is thought to be greater than the individual impacts.[215]

High temperatures enhance the total and CVD mortality risk associated with air pollution, and on days of high air pollution, both heat- and cold-related mortality risks increase.[216] Studies have generally found stronger associations with high temperatures and air pollution on all-cause/CVD mortality, compared with low temperatures.[217-224]

A US study found higher seasonal and annual temperatures increased CVD and IHD mortality risks associated with $PM_{2.5}$.[225] A greater increase in all-cause and CVD deaths, with increases in temperature in the warm season, was found for high-ozone days (these occur when air pollutants chemically react in the presence of sunlight, producing high levels of ozone close to the ground), but not during the cold period.[226] The heatwave effect on total and CV mortality is larger during high-ozone or high-PM_{10} days.[227] A recent Australian study found stronger heatwave effects on high-level (compared with low-level) PM_{10} days for emergency hospital admissions for cardiac arrest, conduction disorders and hypertensive disease.[228] The lag to the effects of high temperature and PM_{10} on CV morbidity and mortality is short.[164,229,230]

Heat stress activates the thermoregulatory system, which may increase systemic absorption of toxins and air pollutants.[231] The biological strength of a chemical or toxin can be exacerbated by increased body temperature.[232] The elderly are more susceptible to the interactive effects of high temperatures or heatwaves and PM_{10} on CV mortality, as well as to the adverse effects of PM.[225,233-235] This is because of a decreased capacity to effectively thermoregulate, with reduced sweat gland output, blood flow to the skin and cardiac output.[236]

Wildfire smoke exposure

Climate change contributes to increasing wildfire frequency, longer fire seasons and larger areas burned.[7,237-239] Wildfire smoke contains multiple air pollutants.[240] Bushfires and hazard reduction burns expose Australians to $PM_{2.5}$, which penetrates the respiratory and circulatory systems, causing oxidative stress and inflammation.[241,242]

More than 90% of the global population is exposed to air pollution levels that exceed the WHO air quality guidelines.

The 2019/20 summer bushfires were unprecedented, with smoke affecting approximately 11 million people in NSW, Queensland, ACT and Victoria.[243] The bushfire smoke caused air quality to be many times the hazardous levels set by the WHO, and the 24-hour mean $PM_{2.5}$ concentration exceeded the 95th percentile of historical values on most days.[244,245] The bushfire pollution is estimated to have caused 417 excess CVD-related deaths,1124 CVD and 2027 respiratory hospitalisations, and 1305 ED presentations for asthma.[245]

Wildfire smoke exposure is associated with increased all-cause and CV mortality.[246-251] PM_{10} and $PM_{2.5}$ are hazardous components of wildfire smoke, short-term exposure to which increases all-cause and CVD mortality.[134] The increase in daily $PM_{2.5}$ concentration during December 2019 in Australia was estimated to induce an increase of greater than 5.6% in daily all-cause mortality and 4.5% in CV mortality.[252] The risks of air pollution and wildfires are amplified when combined with high temperatures during heatwaves, with an increased effect on mortality.[253]

The studies assessing CV morbidity and wildfire smoke are inconsistent, finding some or no association. Rates of OHCA and MI hospitalisations were associated with wildfire-related $PM_{2.5}$ in Australia.[254,255] ED visits and hospitalisations for CHF were associated with wildfire smoke exposure in some studies, but not in others.[256-258] ED visits for IHD were higher on smoke-affected days in one Sydney study, but no associations for IHD hospital admissions were reported in other studies.[257-260] While there is insufficient evidence to determine whether wildfire smoke exposure is associated with specific CV outcomes, there is evidence that ambient $PM_{2.5}$ exposure (the predominant air pollutant in wildfire smoke) is associated with increased CV morbidity.[261]

Firefighting and CVD

Hotter temperatures and increased extreme weather events place outdoor and manual labourers at increased risk of heat-related illnesses, occupational risks and death. This is particularly true for emergency service workers (see figure 2).[262]

The leading cause of fire duty-related deaths is a sudden cardiovascular event (CVE), including sudden cardiac arrest (SCA) and MI.[263] Sudden cardiac death (SCD) causes 45-50% of firefighter duty-related fatalities; 90% of these are caused by CHD.[263] More than 30% of SCDs occur during or shortly after firefighting activity; more than 60% of firefighter SCDs occur during other duties including the alarm response, training drills and simulated fires.[263-265] There are 17-25 duty-related nonfatal CVE (MI and strokes) for every fatal event.[266,267]

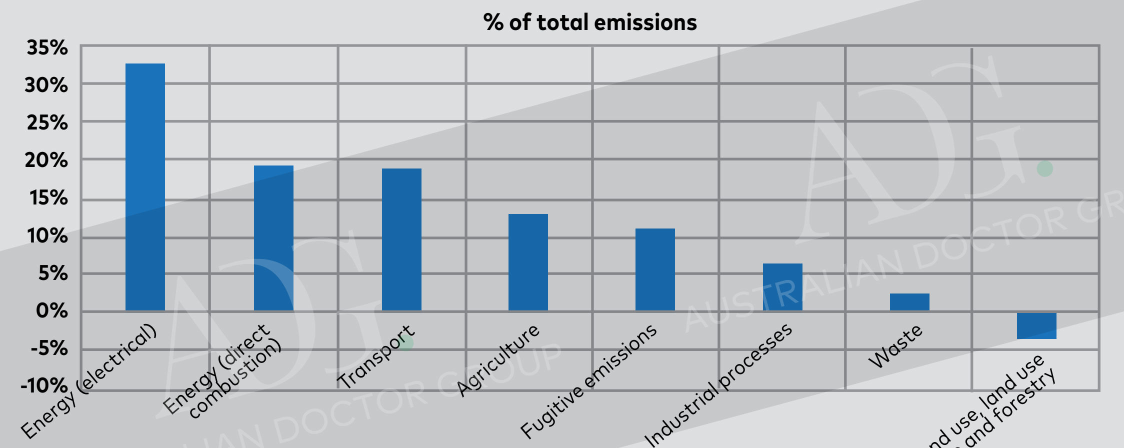
The strenuous physical activity (often with PPE), emotional stress, sympathetic nervous system activation and environmental conditions (heat and pollutants in fire smoke) encountered while firefighting place strain on the CV system. These exposures alone or in concert increase the risk of CVE among susceptible individuals, such as those with CHD or underlying structural CVD.[268,269] The vascular, cardiac ▸

Table 2. Individual interventions to reduce risk of air pollution

Activity	Considerations
Wearing face masks	High-efficiency face masks reduce acute CV effects of air pollution in patients with CAD living in areas of high pollution[285] N95 masks are protective, and reduce BP and HR variability[286] Mask effectiveness depends on filtration capacity Masks may be uncomfortable in hot weather and are not well tolerated by children and older individuals
Installing air purifiers	Air purifiers with HEPA filters reduce indoor $PM_{2.5}$ by more than 50% and lead to improvements in BP, insulin sensitivity, inflammatory markers, stress hormones and metabolic profiles[287,288]
Lifestyle and preventive measures	Statins and a healthy diet may help mitigate the cardiopulmonary effects of air pollution[289] Exercise may attenuate the adverse effects of air pollution, but excessive inhalation of pollutants during exercise may negate any protective effect[290,291] Avoid exercise outdoors when air quality is poor/during peak exposure times, avoid roadways/traffic Be aware of health risks of travel to heavily polluted regions
Reducing in-traffic exposures	Avoid commutes during rush hour, install in-cabin HEPA filters, close car windows, recirculate in-cabin air
Staying indoors	Provides some protection, dependant on ventilation and building quality Outdoor pollutants may penetrate houses in very bad conditions, if air-conditioning systems lack high-efficiency air filters or houses lack air purifiers
Reducing the amount of outdoor air pollution that penetrates the home	Close windows, use door and window seals, indoor air purifiers and air-conditioning filters
Following air quality information	Local air quality can vary rapidly; real-time hourly $PM_{2.5}$ data and smoke forecasts can help plan daily activities and reduce exposure to air pollution. Use smartphone apps, eg, AirRater[292]

Source: Brook RD et al[207]

Figure 3. Australia's carbon emissions.



Source: Australian Government[293]

Box 1. Cardiac benefits from GHG reductions

- Dietary changes:
  - Choosing a plant-based diet, reducing consumption of ruminant meat, and dairy (particularly cheese) contributes to the mitigation of climate change and has cardiac health benefits.[294-296] Farming is a significant source of GHG emissions, and contributes to water pollution as well as deforestation.[297-299]
  - Reduce processed/extensively packaged foods. These are often high in fat and sugar, require large amounts of petroleum-based fuels in their production and generate large amounts of plastic waste (see figures 4 and 5). Consume locally produced, seasonal fresh fruits and vegetables to reduce carbon emissions from transport and packaging.[300]
  - Buy organic foods if possible. These have lower pesticide residues, providing greater levels of certain nutrients.[301,302]
- Increase active transport:
  - Incorporate physical activity into the daily commute. Increasing active transport reduces obesity, CAD, diabetes and cancer, and also reduces air pollution, traffic and GHG emissions.[303,304] Walking reduces obesity compared with time spent in a car, which increases obesity risk.[304] Those walking or cycling to work have reduced CVD and all-cause mortality.[305,306]
  - Postmenopausal women who walk have reduced CVE and women who cycle have reduced all-cause mortality.[307,308]
  - Commuting by car is associated with an increased risk of MI compared with commuting by bus, cycling or walking.[309]
- Change to renewable energy source:
  - Renewable energy sources (solar/wind) instead of fossil fuel combustion (especially coal) for heat and electricity improves air quality and lowers CVD risk.[310] Reductions in air pollution reduce CVE and improve life expectancy.[303,310,311]
- Increase green spaces:
  - These may be public or private and include green infrastructure, natural open spaces, community gardens, school grounds, shorelines or similar.
  - Health benefits including lower rates of mortality, obesity, CVD, mental illness and stress.[312-314]
  - Green spaces mitigate climate change and improve resilience and recovery from the impacts of climate change. Providing shade and reducing the urban heat island effect reduces heat illness and premature death from extreme heat; improved air quality lowers rates of CVD from air pollution.[315,316]
- Stop smoking:
  - Smoking is a known risk factor for CVD. Fine PM from active cigarette smoking and second-hand smoke increases CVD mortality.[317] The significant environmental impact of smoking includes tobacco growing, manufacturing and distribution, consumption, and post-consumption waste.[318]
- Architectural solutions:
  - Improved housing insulation, which reduces excessive heating of indoor spaces, can provide cardiac health benefits while reducing energy use.[55,319,320]

◂ and haemostatic/prothrombotic responses to this strain lead to ischaemia and arrhythmias, or plaque rupture and thrombus formation causing a CVE.[268,270] The ultimate cause of death is a terminal arrhythmia; this may result from an MI in those with CHD, or may be associated with cardiomegaly or left ventricular hypertrophy.[271,272]

Firefighters have higher burdens of classic CVD risk factors (smoking, hypertension, obesity).[273] On-duty CVEs occur almost exclusively in firefighters with previously diagnosed CVD, underlying structural heart disease, CVD factors and subclinical CHD, or a combination of these.[271,273,274] Age over 60 increases risk of SCD.[263]

Strategies to reduce CVE in this group includes annual medical evaluations for all firefighters; banning smoking/tobacco use in fire services; wellness programs promoting exercise and healthy diets; aggressive treatment of CVD risk factors; education; screening; and investigations to detect subclinical disease.[275]

Increased thrombogenicity and impaired vascular function have been observed secondary to an increase in core body temperature and dehydration.[276] Thus, limiting the duration of extreme exposures, active cooling, and rehydration following heat exposure and physical exertion may help mitigate the CVD risk. Aspirin may have a role after a bout of firefighting.[277]

Figure 4. Plastic waste.

MANAGEMENT

Acute management

TO help patients cope with intense heat exposure, encourage them to increase (non-alcoholic) fluid intake, avoid the hottest environments, wear loose-fitting clothes, take frequent cool showers or baths, and reduce physical activity.[278] Reduce working hours if working in hot environments and where possible use air conditioning or seek a public space with air conditioning. This reduces heat-related health risk and risk of death during heatwaves.[279] However, extensive use of air conditioning may increase energy demands and contribute to the urban heat island effect; power outages also limit the protective effect of air-conditioning.[280,281]

Patients on CV drugs (particularly diuretics, beta blockers, renin-angiotensin system inhibitors and anticholinergic drugs) require increased monitoring/dose adjustment and may need temporary suspension.

Increase patient awareness regarding symptoms of heat exhaustion and heat stroke.[282] Inpatient education regarding preventive behavioural change could help reduce temperature-related readmission of CHD/stroke.[283] Individual interventions to reduce risk of air pollution are in table 2.

The greatest mortality effect of

Figure 5. Plastic waste.

high temperatures occurs on the first and up to three days after exposure. If a heatwave is predicted, increasing patient awareness, social networking, access to air-conditioned environments, physician and hospital preparedness, and heatwave alert response systems help prevent heat-related deaths.[284]

Australia's carbon emissions

In the year to March 2020 Australia produced 528.7 million tonnes of carbon dioxide equivalent.[293] The percentage of emissions by sector is shown figure 3.

Greenhouse gas reduction and cardiac co-benefits

Measures to reduce greenhouse gas (GHG) emissions can have cardiac health benefits (see box 1).

Plant-based diet

Agriculture was responsible for 12.9% of Australia's GHG emissions, the third-largest source after energy and transport.[293] Direct livestock emissions account for nearly 70% of these GHG emissions, and ruminant livestock accounts for 52% of Australia's methane emissions.[321]

Diets rich in plant-based food and lower in animal products are healthier and associated with less environmental impact.[322-324] Compared with a Western diet, the Mediterranean diet is estimated to decrease GHG emissions by 72%, land use by 58% and energy consumption by 52%. The Western diet increased the previous descriptors by 12-72%.[325]

Reducing red and processed meat, or consuming only foods whose production involves low GHG emissions, leads to significantly lower GHG emissions and has health benefits.[326,327] Plant-based diets could reduce mortality from stroke, type 2 diabetes, CHD and cancer by 6-10%, and reduce diet-related GHG by 29-70% by 2050 compared with a standard diet.[328]

The Mediterranean, Dietary Approaches to Stop Hypertension (DASH) and Nordic diets are associated with lower mortality and reduced non-communicable diseases.[329,330] The Mediterranean diet decreased severe CVE among individuals with significant risk factors for CVD.[331] Similarly, the DASH diet (mainly plant-based foods, some animal products, low and non-fat dairy products), decreased all-cause mortality in adults with hypertension.[332] The Nordic diet (high in plant-based foods, whole grains, nuts, dairy, fish, shellfish and free-range livestock) has beneficial effects on cardiometabolic function.[333]

Vegetarians have a lower risk of IHD and diabetes compared with non-vegetarians.[334] A meta-analysis of vegetarians and vegans vs omnivores noted vegetarian diets were associated with a lower incidence of cancer and mortality from IHD; vegan diets were associated with a lower risk of cancer.[335] Mediterranean-like, pescetarian and vegetarian diets reduced the RR of type 2 diabetes, cancer and CAD mortality by 10-40%; however, all-cause mortality was reduced only by the Mediterranean and pescetarian diets.[336]

Not all plant-based diets are beneficial in terms of chronic disease risk. Plant-based diets containing higher amounts of healthy foods such as whole grains, fruits, vegetables, nuts, legumes, oils, tea and coffee were associated with a lower risk of ▸

Box 2. How to mitigate climate change

- **Reduce your personal carbon footprint:**
  - Transport changes:
    - — Reduce motor vehicle use — walk, cycle, carpool, use public transport.
    - — If driving, plan your route to avoid heavy-traffic areas and additional pollution from idling vehicles, avoid rush hour, use alternate routes.[341]
    - — Use a low- or zero-emission vehicle (hybrid or electric).
  - Dietary changes:
    - — Reduce ruminant meat, dairy.
    - — Reduce packaged/takeaway foods.
    - — Buy local, seasonal, organic, and sustainably produced foods, cook more at home.
    - — Grow an edible garden.
  - Conserve energy:
    - — Turn off lights and devices when not in use and switch off at the power point: standby mode uses up to 90% of energy compared to fully on.[342]
    - — Avoid leaving devices charging overnight.
    - — Change to LED light bulbs.
    - — Insulate your home.
    - — Set thermostat at 18-20°C during winter and 25-27°C in summer to cut bills.[343]
    - — Install a smart meter.
  - Reduce food waste:
    - — Australians throw away 3.1 million tonnes of food per year.[344] Food waste generates 8% of global GHG emissions.[345]
    - — Start composting.
    - — Get FOGO (Food Organics, Garden Organics) in your local council.
  - Conserve water:
    - — Use a low-flow showerhead, four-minute showers, use half flush, wash with full loads, fix leaks, use cold instead of hot water.
  - Reduce personal/home/work waste: first reduce, then re-use, then recycle:
    - — Think about the life cycle of products.
    - — Reduce single-use products/plastics.
    - — Buy in bulk.
    - — Re-use: divert waste from landfills, give away or sell unwanted products.
    - — Repair, repurpose, 'upcycle'.
    - — Buy second-hand.
    - — Buy recycled and/or environmentally responsible products.
    - — Recycle appropriately: hard/soft plastics, paper, e-waste, batteries (see figures 6, 7 and 8).
    - — In the workplace: reduce, re-use, recycle, rethink, research.[346]
    - — Reduce paper use and printing.
  - Reduce (personal) fashion footprint:
    - — The fashion industry contributes to 8-10% of global CO_2 emissions, 20% of industrial water pollution and 35% of oceanic microplastic pollution, as well as consuming 79 trillion litres of water per year.[347-350]
    - — A large amount of textile waste (more than 92 million tonnes per year) also ends up in landfill.[351,352]
    - — In Australia, every 10 minutes, six tonnes of clothing and textiles go into landfill.[353] Most is comprised of artificial fibres which take 200 years to break down.
    - — Avoid 'fast fashion': buy less, choose quality clothing and make it last. Extending the life of garments by nine months reduces the water footprint by 5-10%.[354]
    - — Buy natural and sustainable fibres.
    - — Support ethical, fair-trade and responsible brands.
    - — Shop locally made, second-hand/vintage/op shops.
    - — Recycle, repair, 'upcycle' your old clothes: donate to charity, give away, swap and sell unwanted clothes.
  - Reduce air travel, thus reducing CO_2:
    - — Rethink attending conferences requiring air travel, use video.[355]
    - — Holiday locally.
    - — Carbon offset flights.
- **Financial divestment:**
  - — Change investments to those not investing in fossil fuel and related companies, and those that do invest in renewable energy.
  - — Support local, sustainable and ethical brands/companies.
- **Switch to renewable energy sources:**
  - — Switch work and home to renewable sources or to an electrical provider using energy from renewable sources.
- **Consider environmental sustainability in clinical decisions:**
  - — Avoid unnecessary pathology testing, limiting CO_2 emissions from pathology collection consumables.[356]
- **Keep patients out of hospital:**
  - — The carbon footprint attributable to healthcare was 7% of Australia's total.[357]
  - — Hospitals account for nearly half and GP clinics 4% of total healthcare CO_2 emissions.
- **Join and support advocacy/environmental organisations:**
  - — Join advocacy groups.
  - — Influence government policy: contact politicians regarding the health implications of climate and energy policy.[358]
  - — Increase public awareness to protect human health.[359]

Figure 6. Recycle responsibly.

Figure 7. Recycle responsibly.

Figure 8. Recycle responsibly.

CAD and diabetes. Those including higher amounts of less healthy plant foods such as refined grains, potatoes/fries, processed foods, and foods high in added sugar are linked to increased cardiometabolic risk.[337,338]

How GPs can help mitigate climate change

Suggestions appear in box 2. Also see Sainsbury et al 2019.[339]

Take the '1 tonne challenge'.[340] If just half of Australian households reduced their annual emissions by 1 tonne, this would be equivalent to 50 million tonnes.

CASE STUDY

BOB, 61, retired and with a previous CABG in 2016 lives in rural NSW. During December 2019-January 2020, his property was surrounded by bushfires and he was helping fight fires. He wore an N95 mask when the air pollution was bad. He felt short of breath during those months, which he felt was due to the significant air pollution and bushfire smoke. He had no chest pain.

He presents for routine cardiology review (later than normal because of COVID-19), and mentions shortness of breath on exertion, though not as bad as during the fires. All his risk factors are controlled: he has never smoked, his LDL is 1.7mmol/L (2.0-3.4 mmol/L), his BP is low (110/70) and his random glucose is 4.5mmol/L (3.0-7.7 mmol/L).

His stress echo is abnormal on ECG criteria, which is a new development compared with previous tests. Coronary angiogram shows 50% distal left main stenosis, an occluded left anterior descending (LAD) artery, severe disease in the circumflex and obtuse marginal (OM), and a new 70% stenosis in the proximal right coronary artery (RCA).

The left internal mammary artery graft to his LAD and the right internal mammary artery to his OM are patent with good anastomosis. The radial artery graft to his posterior descending artery is occluded. Bob undergoes stenting to his proximal RCA with a good result.

Bob was three years post CABG, had arterial grafts (which last longer than vein grafts), had good control of all his risk factors and attended regular follow-up post-CABG. The heat and air pollution during the bushfires are likely contributors to the progression of his CAD.

CONCLUSION

THE evidence for climate change and increasing cardiac morbidity and mortality is compelling. CVD is only one of many health impacts of climate change. CVD is a leading cause of mortality in Australia.

While the increased CVD risks associated with climate change may seem small (although significant) compared with traditional risk factors, they are indiscriminate and have a large public health impact. This environmental risk factor is one medical professionals can and need to change, for the health of our patients and for a sustainable future.

RESOURCES

- **Doctors for the Environment Australia** dea.org.au
- **Climate and Health Alliance** caha.org.au
- **Greenpeace** greenpeace.org.au
- **Getup** getup.org.au
- **Marketforces** marketforces.org.au
- **War on waste** ab.co/3rWzKc3
- **IVIEW Fight For Planet A: Our Climate Challenge** ab.co/38jT5fD

References on request from howtotreat@adg.com.au

How to Treat Quiz.

ENVIRONMENTAL CHANGE AND CARDIOVASCULAR DISEASE

GO ONLINE TO COMPLETE THE QUIZ **ausdoc.com.au/howtotreat**

1. Which THREE features are predicted because of climatic variability?
- a More frequent heatwaves.
- b Increased biodiversity.
- c Water shortages.
- d More bushfires.

2. Which THREE populations are at greater risk of illness related to climate change?
- a The elderly.
- b The socioeconomically disadvantaged.
- c Those with pre-existing medical conditions.
- d Adolescents.

3. Which TWO statements regarding temperature and CVD are correct?
- a Extremely low temperatures cause more acute effects while extremely high ones cause delayed/lag effects.
- b CV mortality risk is increased more by exposure to cold than by heat exposure.
- c The relationship between temperature and all-cause/CV mortality is exponential.
- d Populations in warmer regions tend to be most vulnerable to cold and those in cold climates are most sensitive to heat.

4. Which THREE conditions have increased hospital admissions because of temperature variability?
- a Heart failure.
- b IHD.
- c Arrhythmia.
- d Haemorrhagic stroke.

5. Which TWO pathophysiological mechanisms have been postulated as effects of heat exposure?
- a Reduced myocardial oxygen supply.
- b Elevated heart rate and blood pressure.
- c Increased systemic vascular resistance.
- d Raised inflammatory markers and coagulation parameters.

6. Which ONE air pollutant is the single most preventable cause of acute triggers for AMI?
- a Bushfire smoke.
- b Traffic exhaust.
- c Coal combustion.
- d Biomass combustion.

7. Which THREE statements regarding temperature and air pollution are correct?
- a Heat stress activates the body's thermoregulatory system which may decrease the absorption of toxins and air pollutants into the body.
- b High temperatures modify air pollution effects on mortality and CV outcomes.
- c High air pollution may enhance temperature effects.
- d The joint effect of temperature and air pollution is thought to be greater than their individual impacts.

8. Which TWO statements regarding bushfires are correct?
- a Bushfires and hazard reduction smoke contains $PM_{2.5}$, which penetrates the respiratory and circulatory system.
- b There is no current evidence to link wildfire smoke and premature mortality.
- c The leading cause of fire duty-related deaths is a sudden CVE.
- d More than 70% of cardiac fatalities occur during or shortly after firefighting activity.

9. Which THREE may assist with the acute management of intense heat exposure?
- a Increased caffeinated beverage intake.
- b Increased monitoring/dose adjustment/temporary suspension of patients on CV drugs.
- c Frequent cool showers/baths.
- d Reduced working hours if working in hot environments.

10. Which TWO statements regarding a plant-based diet are correct?
- a They are healthier and associated with less environmental impact.
- b They could reduce mortality from stroke, type 2 diabetes, CHD and cancer.
- c A vegan diet is associated with a lower incidence of cancer and mortality from IHD.
- d All plant-based diets are beneficial in terms of chronic disease risk.

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