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IMPACTUL TEMPERATURII RIDICATE A AERULUI ASUPRA PACIENȚILOR CU MALADII CARDIOVASCULARE

THE IMPACT OF HIGH THE AIR TEMPERATURES ON PATIENTS WITH CARDIOVASCULAR DISEASES

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Rezumat
Introducere. Schimbarea climei reprezintă una din cele mai mari amenințări globale pentru omenire în secolul XXI. Sănătatea este deja afectată de creșterea temperaturii globale și de distrugerea ecosistemelor naturale. Oamenii de știință afirmă unanim că o creștere a temperaturii globale cu 1,5°C și pierderea continuă a biodiversității riscă să afecteze semnificativ sănătatea populației globului cu consecințe ireversibile.
Material și metode. A fost realizat un studiu descriptiv, studiu de tip revizuire a literaturii. Studiul s-a bazat pe analiza literaturii de specialitate din biblioteca digitală *PubMed* și rețea socială *ResearchGATE* pentru selectarea articolelor științifice. Rezultatele căutării după cuvinte-cheie au identificat 87 de surse bibliografice în *PubMed* și au fost evaluate primele 10 pagină (câte 10 articole pe pagină) în *ResearcheGATE* (100 articole total). Eșantionul final a fost de 22 articole.
Rezultate. Analizele care încorporează o mare varietate de surse de date de mediu au identificat creșteri ale factorilor de risc cardiovascular, spitalizări și mortalitate din cauza poluării aerului intensificată, incendii, valuri de căldură, evenimente meteorologice extreme, creșterea nivelului mării și boli pandemice. Tendințele mondiale responsabile de încălzirea globală continuă să agraveze dezastrele naturale mediate de schimbările climatice.
Pacienții cu maladii cardiovasculare sunt în situații nedeterminate în ceea ce privește aplicarea tratamentului pe timp de canicula. Ei nu pot supraviețui fără tratament, dar în același timp, unele medicamente cu acțiune tropică pot influența nefavorabil starea acestor pacienți.
Concluzii. Tendințele actuale în ceea ce privește încălzirea globală și schimbările climatice pot avea un impact profund asupra epidemiologiei hipertensiunii arteriale și a bolilor cardiovasculare. Temperaturile extrem de calde și reci sunt legate de evenimente cardiovasculare acute. Variabilitatea temperaturilor poate crește riscul de evenimente cardiovasculare, în special la persoanele în vârstă, la care fiziologic adaptările la schimbările extreme de temperatură sunt mai lente.
Cuvinte-cheie: încălzire globală; temperaturi extreme; val de căldură; stres termic; sistem cardiovascular

Summary
Introduction. Climate change is one of the biggest global threats to humanity in the 21st century. Health is already affected by rising global temperatures and the destruction of natural ecosystems. Scientists unanimously state that an increase in global temperature of 1.5°C and the continued loss of biodiversity risks significantly affecting the health of the world's population with irreversible consequences.
Material and methods. A descriptive, literature review-type study was carried out. The study was based on the literature review of the *PubMed* digital library and *ResearchGATE* social network for the selection of scientific articles. The results of the keyword search identified 87 bibliographic sources in *PubMed* and the top 10 pages (10 articles per page) in *ResearcheGATE* (100 articles in total) were evaluated. The final sample was 22 articles.
Results. Analyses incorporating a wide variety of environmental data sources have identified increases in cardiovascular risk factors, hospitalizations and mortality from intensified air pollution, wildfires, heat waves, extreme weather events, sea level rise and pandemic diseases. Global warming trends continue to exacerbate natural disasters mediated by climate change.
Patients with cardiovascular diseases are in uncertain situations regarding the application of treatment during heatwave. They cannot survive without treatment, but at the same time, some drugs with tropical action can adversely affect the condition of these patients.
Conclusions. Current trends in global warming and climate change may have a profound impact on the epidemiology of hypertension and cardiovascular disease. Extreme hot and cold temperatures are linked to acute cardiovascular events. Variability in temperatures can increase the risk of cardiovascular events, especially in the elderly, in whom physiological adaptations to extreme temperature changes are slower.
Keywords: global warming; extreme temperatures; heat wave; heat stress; cardiovascular system

Introduction

Recent years have seen increases in average annual temperatures, with subsequent changes in weather systems and a shift from a stable and predictable climate to extreme temperatures and sudden weather events (e.g. droughts, hurricanes, fires, hot and cold spells) [1, 2].

Heat waves are becoming more intense and extreme as a consequence of global warming. Epidemiological evidence reveals the impact of heat waves on mortality and morbidity, with few studies being conducted in regions characterized by high population density, low income and limited health resources and susceptible to the impact [3, 4, 5].

The weather plays an important role in triggering some conditions. High temperature and humidity are the two factors that can have serious consequences both for healthy people, but especially among people with cardiovascular,

neuropsychic, endocrine, and metabolic conditions and, in general, chronically ill people and children. Hot weather, including high humidity, increases blood flow to the skin. Thus, the heart is forced to beat faster to pump the required amount of blood. Exposure to high temperatures leads to the alteration of the mechanisms that regulate the internal temperature, associated with a series of individual factors that determine the reduction of heat tolerance, thus it can cause various manifestations [6–8].

Blood pressure is influenced by the degrees on the thermometer because the human body strives to regulate its body temperature [8].

Hot asphalt, and concrete blocks that radiate heat are among the factors that amplify the heat wave and that can affect the proper functioning of the body, including in the case of clinically healthy people, in the absence of proper hydration and maintaining a body temperature around 37oC [8].

Temperature variability and extreme heat events have become more common in many parts of the world.

Globally, atmospheric air temperature is increasing, the global average temperature is 0.99oC warmer in the first 2 decades of the 21st century compared to 1850-1900. In Canada, the rate of temperature increase is about twice the global rate – from 1948 to 2020 average annual temperatures in Canada increased by 1.8°C [4]. Unusually warm weather was observed during the 2003 heat wave in Central Europe. Overall, more than 70,000 deaths were estimated to be attributed to these extreme conditions, with more than a third of the deaths occurring in France, Italy and Spain. Since then, population exposure to extreme heat has increased globally, resulting in 220 million more heatwave exposure events in 2018 compared to the 1986–2005 average [2]. The hottest summer ever recorded in Europe was in 2022, and an estimated 61.672 people died from heat-related causes [8].

In Ukraine, between 1990 and 2013, there was an increase in the incidence of cardiovascular disease against the background of an increase in average annual air temperature with a direct correlation between average annual temperatures and the number of newly registered cases of cardiovascular disease (correlation coefficient +0.5). In the regions of Ukraine with strong direct and medium correlations between the number of newly registered cases of diseases of the circulatory system and the average annual air temperature, the urban population predominates, and vice versa, in regions with weak both direct and inverse correlations - rural. The atmospheric air in cities with strong and average direct correlations between the number of newly diagnosed cases of cardiovascular diseases and the average annual ambient temperatures, with a predominance of the urban population, is characterized by significant pollution compared to the predominance areas [9].

The purpose of this paper is to highlight the effects of heat waves on the health of the population and patients with cardiovascular diseases.

Material and methods

A descriptive, literature review-type study was carried out. The study was based on the literature review of the *PubMed* digital library and *ResearchGATE* social network for the selection of scientific articles.

The following keywords were searched: "global warming"; "extreme temperatures"; "heat wave"; "heat stress"; "human health"; "cardiovascular morbidity"; "cardiovascular hospitalization"; "cardiovascular death". Keywords were searched in both the title and abstract of the articles. Searched keywords corresponded to the lexicon of medical terms and descriptors – MeSH, of the US National Library of Medicine.

The Boolean operators AND and OR were used to specify the search field and the metacharacter $ – for inclusive and plural search of some terms.

The inclusion criteria were the following:

- include general information about the heat wave and its impact on the population and the particular impact on cardiac patients,
- publication language – English,
- period of publication of the article 01.01.2018-31.03.2024,
- articles – in full text.

The exclusion criteria were:

- analysis of diseases other than those of the circulatory system;
- assessment of the impact of heat other than that induced by global warming;
- the presence of only the summary;
- comments, case reports, news and letters are not accepted.

The extracted bibliographic sources were included in the revision database in Excel format. Statistical processing was carried out in the Excel application for spreadsheets and IBM SPSS Statistics (both programs are licensed). The list of references used was developed using the specialized application – *Mendeley*.

The results of the keyword search identified 87 bibliographic sources in *PubMed* and the top 10 pages (10 articles per page) in *ResearcheGATE* (100 articles in total) were evaluated. To highlight some local aspects, some sources written by local authors and web pages were additionally analyzed. The final sample was 22 articles (fig. 1).

Results and discussions

What is a heat wave and its impact on health

Heatwave is a meteorological phenomenon characterized by abnormally high temperatures, which can have negative effects on health, especially in regions with high humidity. The heat wave is defined as an increase in the daily temperature by more than 10oC compared to the average temperature of the analysed area [7]. Exposure to high temperatures can cause an alteration of the mechanisms that regulate internal temperature and a reduction in heat tolerance [8].

Heat is more than just discomfort: it can lead to illness and death. Most deaths occur on the first and second day of a heat wave when the body is not used to high temperatures, the elderly being most frequently affected [7].

Diseases caused by exposure to heat

- **Sunstroke** - occurs when the body can no longer maintain a constant body temperature, as the adaptation

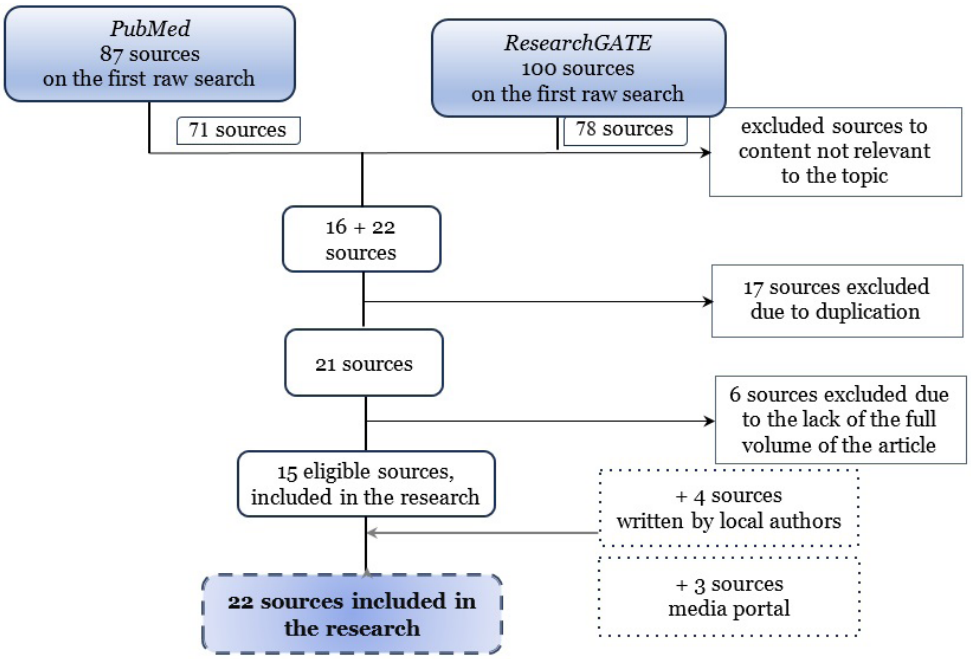

Figure 1. *The algorithm for selecting bibliographic sources.*

mechanisms have been overcome. It occurs following direct exposure to sunlight or high temperatures indoors and is manifested by: fever, headache, dizziness, nausea, confusion, irrational behaviour, convulsions and hot and dry skin, and loss of consciousness. Heat stroke is the most serious type of heat illness. It's a medical emergency. Heatstroke requires immediate first aid and medical attention. Delayed treatment can lead to death.

- **Thermal exhaustion** – occurs as a result of water and mineral losses, through sweating during outdoor or indoor activities. Heat exhaustion is manifested by: dizziness, weakness, pallor, hypotension, rapid pulse, headache, nausea, abdominal cramps, muscle spasms, cold and profuse sweating, irritability, vertigo, disorientation, intense thirst, and visual disturbances.
- **Heat syncope (heat collapse)** – circulatory collapse occurs due to the inability of the circulatory system to compensate for peripheral vasodilatation and dehydration. Syncope is induced by temporary insufficient blood flow to the brain while a person is standing. Symptoms include fatigue, weakness, dizziness, nausea, anxiety, cold sweats, and epigastric pain, soon followed by loss of consciousness. Recovery is quick after resting in a cool area.
- **Heat cramps** – are sharp muscle pains that can occur alone or in combination with one of the other heat stress disorders. They appear as a result of mineral losses, in people who make intense physical effort, in conditions of high temperatures, without properly hydrating themselves. Caloric cramps are manifested by contractions in the abdominal muscles, and in the upper and lower limbs, and can be associated with the feeling of thirst, headache, and fatigue. In the case of cramps caused by heat, it is recommended to stop physical activity and rest in a cool place. The consumption of liquids such as water, natural fruit juices, and drinks based on minerals and vitamins (calcium, magnesium, zinc, vitamin C) is indicated. If these cramps last more than an hour, a medical consultation is required.
- **Caloric (hyperthermic) shock** – can occur under conditions of strong thermal aggression, associated with a particular physical effort. Hyperthermia occurs against the background of the body's inability to maintain its normal temperature. The temperature rises quickly, reaching or even exceeding 40°C. It affects people who present one or more risk factors (elderly, obese, alcoholics, non-acclimatized/dehydrated people), but also young people who either make an intense physical effort in a moderately warm environment or perform an effort of moderate intensity, in a warm and humid environment. The integuments are dry, and warm (sweating is missing), the internal temperature rises to 40-41oC, the language becomes incoherent, delirium, convulsions, agitation, and even coma occur. Heat shock is a medical emergency.
- **Rashes** – are small red spots on the skin with severe itching when in a warm and humid environment that appear as a result of excessive sweating for a long time. The spots are the result of inflammation caused when the ducts of the sweat glands are blocked. In most cases, the heat rash will disappear when the individual returns to a cooler environment.
- **Thermal oedema** – is intumescence (swelling) that generally occurs among people who are not acclimatized to working in hot conditions. Swelling is often most noticeable in the ankles [8,10,11].

Diseases caused by long-term exposure to heat

Chronic heat exhaustion, sleep disturbances, and susceptibility to minor injuries and illnesses have all been attributed to the possible effects of prolonged heat exposure. Heat exposure has been associated with temporary infertility in both women and men, with the effects being more pronounced in men. Sperm density, motility, and the percentage of sperm in normal shape can decrease

significantly when the groin temperature rises above a normal temperature. Workers exposed to high thermal loads should inform their family doctors about their exposure.

The risk of heat illness varies from person to person. A person's overall health influences their ability to adapt to heat (and cold). Overweight people have difficulty maintaining caloric balance. Age (especially for people around 45 and over), poor general health and a low level of exercise will make people more susceptible to extreme heat. Medical conditions can determine how susceptible their body is to heat. People with heart disease, high blood pressure, respiratory disease and uncontrolled diabetes may require special precautions. People with skin diseases and rashes may be more susceptible to heat. Other factors include the capacity of the circulatory system, sweat production, and the ability to regulate electrolyte balance. Medications, too, can impact how people react to heat [10, 12].

The National Institute for Occupational Safety and Health (NIOSH) reports that several studies comparing the heat tolerance of men and women have concluded that women are less heat tolerant than men. While this difference appears to diminish when such comparisons take cardiovascular training status, body size, and acclimation into account, women tend to have a lower sweat rate than men across fitness, size, and acclimation equals. If the sweat rate is lower it means that there may be an increase in body temperature [10].

Signs and symptoms that can warn of the inability of the human body to adapt to the heat:

- confusion,
- disorientation,
- dizziness,
- nausea,
- physical and mental fatigue,
- headaches,
- insomnia,
- increased frequency of heart contractions or heart rhythm disturbances,
- shallow, rapid breathing,
- increased thirst,
- excessive sweating or, on the contrary, the appearance of anhidrosis (lack of sweating),
- sweating in the extremities,
- cold and soft skin,
- cramps/spasms, fainting,
- convulsions,
- muscle coma [7, 8, 13].

The impact of heatwaves on patients with cardiovascular disease

Heat waves affect human health and will become more frequent due to global warming, leading to increased mortality in the general population, especially cardiovascular mortality [14].

High temperatures may be associated with increased hospital admissions related to general cardiovascular disease, in particular hypertension/hypotension, acute myocardial infarction and ischemic stroke. Age, sex, and intensity/duration of exposure to high temperatures (eg, heat wave exposure versus hot day or exposure to high ambient temperature) may modify the relationship between high temperatures and various hospital encounters related to cardiovascular disease; however, preexisting CVD subtypes either showed no effect or had inconsistent effects on the association between high temperatures and CVD visits or hospitalisations [15].

Analyses incorporating a wide variety of environmental data sources have identified increases in cardiovascular risk factors, hospitalizations and mortality from intensified air pollution, wildfires, heat waves, extreme weather events, sea level rise and pandemic diseases. Global warming trends continue to exacerbate natural disasters mediated by climate change [16].

Sunstroke dramatically increases the stress on the heart. In patients with underlying cardiovascular disease, the heart's ability to meet the body's heat dissipation needs may be exceeded, leading to several cardiac complications.

Studies from Germany, China and other sources indicate that ambient temperature is associated with blood pressure (BP). In general, high ambient temperatures decrease BP in young and middle-aged adults, lower temperatures appear to increase BP in adults, and heat stress increases human morbidity and mortality compared with normothermic conditions. Thus, in the *China Hypertension Survey* conducted from October 2012 to December 2015, which included 451,770 people, a 10oC decrease in ambient temperature was statistically associated with a 0.74 mmHg and 0.60 mmHg increase in BP systolic and diastolic respectively. Increased BP could be a mechanism behind cardiovascular mortality caused by cold but not heat. During cold weather periods, an increase in BP variability may complicate the diagnosis and management of hypertension, thus contributing to the high cardiovascular mortality observed in winter [12].

Studies show data that cardiovascular mortality, commonly associated with high BP, was linked to changes in outdoor temperature. At the same time, indoor temperature appears to have a stronger effect on BP than outdoor temperature. The causes of hypertension are incompletely understood, and therefore the mechanism(s) by which heat exposure affects BP is an open question [17].

Acute exposure to gaseous pollutants (CO, NO2, O3, and sulphates) leads to endothelial dysfunction as a result of unavailability of nitric oxide. Chronic exposures to gaseous pollutants cause atherogenesis, insulin resistance, and thrombosis due to increased secretion into the systemic circulation of proinflammatory and oxidative mediators with activation of the hypothalamic-pituitary-adrenal axis. The molecular mechanisms of cellular adaptation to heat stress are ensured by the increased synthesis and accumulation of heat shock proteins – chaperones [18].

In the summer of 2019, Europe experienced a strong heatwave episode. Telemonitoring of patients with heart failure provides an elegant tool for close monitoring of disease burden. Research suggests a direct impact of global warming on human health, with acute episodes expected

to occur more frequently, threatening patients with chronic diseases, especially patients with heart failure. In clinical practice, this prompts consideration of extreme heatwave episodes and suggests that we already have useful tools, including telemonitoring available in frail patients [14].

The results of scientific research by calculating odds ratios (OR) indicate that elderly women are the most vulnerable to cardiovascular mortality related to heat waves [3].

By calculating the OR in the studies on the risk of cardiovascular mortality, an increase in the number of deaths was recorded on days with heat waves compared to those without heat waves. These effects increase with the intensity of the heat wave [3].

Few studies have examined the acute effect of a single heat exposure on indices of vascular structure and function. Microvascular function was found to be improved in the lower limb after 45 minutes of lower leg immersion in water at 42°C and unchanged in the upper limb after 60 minutes of combined whole-body and waist-down water immersion at 40.5°C. Microvascular function was assessed indirectly using peak reactive hyperemia and/or area under the response curve to a period of brief ischemia. More robust methods of assessing microvascular function, such as laser Doppler perfusion, microdialysis or contrast-enhanced ultrasound, should be used in this context for a more comprehensive assessment [19].

Heatwaves can affect heart patients by:

✓ *Angina pectoris* – due to the increase in oxygen consumption in the heart muscle, angina attacks can occur at high temperatures.

✓ *Heart failure* – the heart cannot pump enough blood to keep body temperature low and blood pressure high enough. As a result, the body can overheat, and the result can be fatal.

✓ *Stroke* – loss of too much fluid from the body leads to dehydration. As a result, the blood becomes more viscous and increases the risk of thrombus formation, which causes ischemia [13].

Air pollution under the influence of climate change constitutes a serious combination for human health and for the life support systems on which people depend (primarily – the medical service) [1, 2].

Research in the field supports the link between pollution and endothelial dysfunction (a marker of early cardiovascular disease). Subjects exposed to high short-term PM2.5 concentrations had reduced flow-mediated dilation, which is the endothelium-mediated ability to dilate systemic arteries in response to an increase in blood flow, and had increased systemic arterial stiffness (as measured by growth index or pulse wave velocity). The reduction in flow-mediated dilation was also present with long-term exposure to PM2.5; these effects were all proportional to the pollutant dose [1].

Morbidity (all-cause and cause-specific) is much less commonly used as a study outcome than mortality in examining the health impacts of climate change in the studies reviewed. Several studies have examined the association between temperature variability (including maximum daily temperature, temperature change between adjacent days, heat waves and cold spells) and overall health impact through indirect outcomes such as all-cause hospital admissions, visits to the emergency room and ambulance referrals. Among those measuring cause-specific morbidities, cardiovascular disease has been the main focus, with the increased focus on heat-related illnesses [20].

Medication of cardiac patients during heatwave

Patients with cardiovascular diseases are in uncertain situations regarding the application of treatment during heatwave. They cannot survive without treatment, but at the same time, some drugs with topical action can adversely affect the condition of these patients.

Some drugs commonly prescribed for heart disease increase the risk of heat stroke. Beta-blockers and non-dihydropyridine calcium channel blockers impair the ability to increase cardiac output in response to heat stress. Diuretics exacerbate the hypovolemic state of heatstroke and increase the risk of electrolyte disturbances. Inhibitors of the renin-angiotensin system (angiotensin-converting enzyme inhibitors and angiotensin receptor blockers) increase the risk of acute kidney injury associated with heat stroke. Oral hypoglycemic agents (metformin, sulfonylureas, sodium-glucose co-transporter 2 [SGLT2] inhibitors) also may have deleterious effects in dehydration situations. Although salicylates are recognized as antipyretic drugs in the management of fever, this is achieved by modulating the hypothalamic temperature set point. Unlike fever, heatstroke hyperthermia is not caused by hypothalamic dysfunction, and thus antipyretics, such as aspirin, are of no benefit and may even worsen the associated coagulopathy and liver dysfunction [4].

People prescribed drugs to treat heart failure and high blood pressure were more likely to die during heat episodes (22°C+) compared to days with adequate temperatures (<17°C). The point estimate for patients prescribed vasodilators is relatively high at 1.83 (1.19 to 2.80), with 95% CI due to the small number of individuals in this subgroup. There was also strong evidence that non-steroidal anti-inflammatory drugs increase the chance of death during heat waves. Evidence for an association with anticholinergic drugs was weak, although the point estimate is comparable to other similar drug classes investigated [21].

Prevention and adaptation

During heat waves, at-risk patients should be informed about strategies to mitigate the risk of heat stroke. When the ambient temperature exceeds the core body temperature, the use of fans is ineffective because they simply recirculate warm air. However, when combined with a cold shower or bath, ventilation is more effective. If air conditioning is not available in residences, malls, grocery stores and hotels, alternative locations must be set up where people can take refuge from heat waves [4].

Medications that may exacerbate heatstroke may be proactively withheld during severe heat waves, particularly in vulnerable patients who may not be able to adhere to other preventive measures. Family members, neighbours and community members should be encouraged to frequently

check on people at risk, single people [4].

Recommendations for cardiac patients during the heat wave:

✓ to avoid leaving the house between 11.00-17.00 on days when the air temperature exceeds 30°C, the middle of the day is the most dangerous period, as the sun is very strong;

✓ to wear loose clothes, in light colours, loose, made of natural, cool materials such as linen, cotton, silk, etc.;

✓ to cover the head with a hat, hat or to use a parasol;

✓ drink a lot of fluids, more than usual, even if you are not thirsty. A quantity of 25-30 ml per 1 kg of body weight is recommended. Avoid very sweet or alcoholic drinks, because they dehydrate the body;

✓ to eat seasonal fruits and vegetables - helps the body to cope with the stress caused by the heat wave;

✓ to check the blood pressure level frequently;

✓ to avoid copious meals, which contribute to an increase in body weight and complicate the fight against heat;

✓ to limit the level of physical effort to the maximum, to take regular breaks during work;

✓ to check weather warnings and updates, to find out if alerts have been issued for extreme temperatures and what are the recommendations of specialists to protect yourself from the negative effects of the heat wave;

✓ to maintain the air temperature, in the home, between 22-24°C or with a difference of 5-7°C compared to the atmospheric air temperature. During the day, the windows must be closed, and the most suitable period for airing the rooms is during the night, also allowed in the evening and the morning, if there are no tropical nights;

✓ during tropical nights, it is preferable to find alternative methods of ventilation, and cooling the home;

✓ fans are effective in situations when the air temperature is 27-32°C [13].

There is an urgent need to focus on the implementation of existing cost-effective health interventions and policies if the world is to meet the targets for Sustainable Development Goal 3 and achieve at least a 30% reduction in premature mortality from non-communicable diseases by 2030 [6, 21, 22].

Conclusions

Cardiovascular diseases are one of the biggest problems of modern medicine. Current trends in global warming and climate change may have a profound impact on the epidemiology of hypertension and cardiovascular disease. Extreme hot and cold temperatures are linked to acute cardiovascular events. In addition, temperature variability may increase the risk of cardiovascular events, especially in the elderly, in whom physiological adaptations to extreme temperature changes are slower.

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