METHODIST DEBAKEY CARDIOVASCULAR JOURNAL

Food for Thought: Nourishing Cardiovascular Health Amidst the Exposome

REVIEW

BASSEL DAHER, PHD, MSE

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

ABSTRACT

The cumulative exposures of an individual during their lifetime, known as the exposome, encompass environmental exposures and lifestyle factors that significantly impact cardiovascular health. The exposome concept aims to provide a comprehensive framework for understanding how various exposures combine to influence disease risk and health outcomes over a lifetime. Diet is a well-studied aspect of the exposome, recognized as a critical contributor to cardiovascular health and influencing various other health metrics and behaviors. Furthermore, understanding agricultural food systems and their interrelationships with dietary choice and impacts on environmental and human health requires a systems approach. Through a review of the literature, this publication will (1) elucidate the interconnections between the exposome and cardiovascular diseases through the lens of agricultural systems and environmental health; (2) examine the effect of diet on cardiovascular health; (3) examine the influence of socioeconomic and cultural factors on the agricultural food system and dietary choices; and (4) highlight the importance of adopting a systems approach that integrates dietary interventions with sustainable agricultural practices, emphasizing the need for holistic strategies to address the root causes of cardiovascular health issues through balanced human and environmental health interventions.

CORRESPONDING AUTHOR:
Bassel Daher, PhD, MSE

Texas A&M Energy Institute, Texas A&M University, College Station, Texas, US

bdaher@tamu.edu

KEYWORDS:
cardiovascular health; exposome; agriculture; food systems; diet; environment; climate change; systems approach

TO CITE THIS ARTICLE:
Daher B. Food for Thought: Nourishing Cardiovascular Health Amidst the Exposome. Methodist DeBakey Cardiovasc J. 2024;20(5):27-36. doi: 10.14797/mdcvj.1452

INTRODUCTION

Over the years, recommendations for cardiovascular health have evolved from focusing solely on reducing the death rate from cardiovascular disease and the prevalence of risk factors to a broader emphasis on improving overall cardiovascular system health and disease prevention.[1,2] Additionally, there has been growing emphasis on the importance of cardiovascular health from an early age and throughout all populations, even those not yet considered at risk for cardiovascular disease.[1] In 2010, the American Heart Association (AHA) presented a definition of cardiovascular health that included seven health behaviors and factors critical to ideal cardiovascular health, including frequency of cigarette smoking, body mass index, physical activity, diet, total cholesterol, blood pressure, and fasting plasma glucose.[2] In 2022, the definition was revised to include sleep quality as a new factor (and subsequently re-termed "Life's Essential 8") and to highlight the importance of psychological health and well-being.[1]

In the United States (US), the prevalence of ideal cardiovascular health is low, with less than 1% of all age groups studied meeting ideal levels for all metrics. Only 45% of adolescents, 32% of adults 20 to 39 years of age, and 11% of adults 40 to 59 years of age had five or more metrics at ideal levels.[3] A 2022 analysis found that the average cardiovascular health score among adults was 64.7 out of 100, with the lowest mean scores observed in diet, physical activity, and body mass index metrics.[4] The low level of cardiovascular health throughout the US, especially in metrics that are most affected by lifestyle and behavioral factors, has led to a new focus on environmental factors, promoting heart-healthy behaviors, and early prevention to support cardiovascular health in all populations throughout their lifespans.[5-7]

The "exposome concept" is highly relevant in the context of the new focus on environmental and behavioral components that affect cardiovascular health. The exposome was first introduced in 2005 to complement the genome; while the genome focuses on genetic factors, the exposome encompasses the environmental exposures and lifestyle factors that an individual experiences over the course of their life.[3] The exposome describes the changes in physiology and pathophysiology that occur as a result of environmental exposures and stressors, including chemical, physical, and socioeconomic factors such as air pollution, noise, ultraviolet radiation, mental health, and psychosocial stress.[4,8] In addition to exposures, the exposome also encompasses lifestyle and behavioral factors, including smoking and alcohol habits, diet, physical activity, and others.[4] Many of the factors considered within the exposome concept align with "Life's Essential 8" cardiovascular health factors, making it highly relevant to better understanding the integrated systems that affect cardiovascular health.[4,8] Diet is an especially important aspect of the exposome and its contributing role to cardiovascular health; food and dietary consumption habits can affect almost all of the behaviors set out by Life's Essential 8.[5-7]

The extreme events and impacts brought about by climate change encompass the variety of ways that environmental health can directly and indirectly affect the exposome and cardiovascular health. A review of 492 studies evaluating the association between events related to climate change and cardiovascular outcomes found that there is high-quality evidence indicating a connection between cardiovascular disease and extreme temperatures, hurricanes, and dust storms and moderate evidence for a connection between cardiovascular disease and ozone and wildfire smoke.[9] Other research highlights more indirect methods through which climate change could affect cardiovascular health, including mental health and ocean health.[10,11] These studies highlight that the environment has significant direct impacts on the exposome and on cardiovascular health. Environmental determinants also have considerable indirect impacts on the food and agricultural system that contributes to shaping our dietary choices. Additionally, the agricultural food system impacts the environment substantially. Understanding the relationship between environmental health, socioeconomic factors, and lifestyle and dietary choices can lead to more effective interventions to promote cardiovascular health.

Understanding the relationship between cardiovascular disease risk and the exposome, and specifically the roles that diet and agricultural systems play, requires a holistic system understanding. Through a review of the literature, this manuscript will (1) elucidate the interconnections between the exposome and cardiovascular diseases through the lens of agricultural systems and environmental health; (2) examine the effect of diet on cardiovascular health; (3) examine the influence of socioeconomic and cultural factors on the agricultural food system and dietary choices; and (4) highlight the importance of adopting a systems approach that integrates dietary interventions with sustainable agricultural practices, emphasizing the need for holistic strategies to address the root causes of cardiovascular health issues through balanced human and environmental health interventions.

AGRICULTURAL PRACTICES AND ENVIRONMENTAL DETERMINANTS

Agricultural practices and environmental health are deeply interdependent. Environmental factors such as soil quality,

water availability, and climate conditions significantly influence the productivity and sustainability of agricultural systems.[12-15] Conversely, agricultural practices impact various aspects of the environment, including soil erosion, water usage, pesticide and fertilizer runoff, and greenhouse gas emissions.

The effects of agricultural food systems and the environment on cardiovascular health are extensive. Improving cardiovascular health requires a comprehensive understanding of our food system and its numerous impacts. The food and agriculture system influences individual health directly through diet and dietary choices and indirectly through its effects on the environment.

Current agricultural practices in the US primarily prioritize large-scale monocropping with intensive tillage, fertilizer, and pesticides to ensure high productivity.[12] These methods have major impacts on the environment. Monocropping degrades soil by repeatedly depleting the same nutrients.[13] This eventually leads to decreases in yields unless fertilizers are consistently applied to provide the necessary nutrients.[13] Similarly, pesticides are necessary to combat pests that target monocultures; without crop diversity, whole harvests can be overcome by fungi, diseases, and pests that spread quickly. Fertilizers and pesticides create environmental issues when agricultural water runoff leads to water pollution. Overuse of pesticides and fertilizers and poor irrigation practices increase water contamination.[14] Furthermore, over-tillage releases greenhouse gasses trapped in the soil, increasing emissions and contributing to climate change.[15]

Land degradation and soil erosion are environmental impacts caused by intensive tillage, water runoff, and over-extraction of groundwater for irrigation as well as weather events such as high winds and desertification.[15] Land and soil degradation occur when topsoil is eroded and the quality of agricultural soil is decreased. Soil salinity, acidity, and heavy metal contamination are also side effects of poor agricultural practices. Land degradation eventually leads to lowered yields and decreased biodiversity.[15]

The current agricultural system in the US prioritizes large-scale versatile crops; for example, over half of the US's crop cash receipts in 2022 came from corn and soybeans, with both crops accounting for twice as much as the next-largest categories.[16] Both corn and soy are primarily made into livestock and poultry feed; more corn is used to make ethanol, high-fructose corn syrup, glucose, dextrose, and starch that is used for cereals and food.[17,18] These trends reflect the Western diet's high consumption of animal proteins.[19] When comparing the US food supply to the Healthy Eating Index, the only category where supply was consistently sufficient was Total Protein Foods (which includes meat, poultry, and eggs). The same study found that US supply consistently did not meet recommended proportions for fruit, vegetables, and whole grains, among others.[20]

The current food system, designed to maximize yield and profits with limited consideration of nutritional outcomes and environmental impacts, results in the overuse of pesticides and fertilizers as well as preservatives and additives to increase longevity, flavor, and affordability in processed foods.[21] It is challenging to study the effects of additives and chemicals, especially in cases where such exposure only occurs in low levels; however, there is evidence that neo-formed substances in processed foods and trace quantities of pesticides have negative effects on cardiovascular health.[21] Soil and water pollution are also effects of agriculture and industry that have been shown to negatively impact cardiovascular health.[22] Some pollutants, such as fertilizers, can be directly tied back to agriculture, while others, such as heavy metals, micro- and nano-plastics, and chemical pollutants can come from other origins.[22]

DIET AND CARDIOVASCULAR HEALTH

Maintaining a healthy diet is one of the most impactful strategies for supporting cardiovascular health and has consistently been shown to lower the risk of cardiovascular disease.[6,7,23] Furthermore, diet has effects on various other aspects of the exposome, including chemical exposures, mental health, and physical activity.[24-26]

Diet affects cardiovascular disease through different mechanisms. Increased low-density lipoprotein (LDL), commonly known as "bad" cholesterol, is a strong risk factor for cardiovascular disease. LDL increases triglycerides in the bloodstream and promotes systemic inflammation, which ultimately contributes to atheromatous plaque in the arteries bringing oxygen to the heart.[27,28] Other factors also increase plaque, such as diabetes and increased BMI.[28] These factors are strongly influenced by diet.

The AHA's dietary recommendations specifically encourage the consumption of minimally processed or whole foods, fruits, vegetables, and whole grains, which have been proven to support cardiovascular health.[29] Other recommendations also support the consumption of whole foods, including recommendations to consume healthy sources of protein (plant proteins, fish and seafood, low-fat dairy, or lean unprocessed meats).[5] The evidence supporting the benefits of whole foods is strong: Whole foods often contain more fiber and nutrients and less fat than processed alternatives. There is substantial research

connecting the consumption of ultra-processed food and cardiovascular disease as well as other related conditions such as obesity, hypertension, and dyslipidaemia.[30] A 10% increase in ultra-processed food consumption is associated with a ≥ 10% increase in the rates of overall cardiovascular, coronary heart, and cerebrovascular diseases.[31] The possible mechanisms through which processed food affects the body are many; some research suggests that the degraded physical structure, food additives, and neo-formed contaminants in ultra-processed foods may have a variety of effects on absorption kinetics, glycemic response, and gut microbiota.[32]

The research on dietary components that negatively affect cardiovascular health is thorough. Saturated fats and trans fats are well known to have negative effects on cardiovascular health, and trans fats in particular are well known to have highly negative effects on cardiovascular health. The World Health Organization recommends that trans fats make up less than 1% of total energy intake.[6] Saturated fats are primarily found in palm kernel oil, coconut oil, butter, peanut oil, animal fats and other sources, while trans fats are found in low levels in milk and meat products.[27,33] More frequently, trans fats are created in industrial processes and are commonly used to increase the shelf life of processed foods.[28]

Unsaturated fats are considered better for cardiovascular health; studies where saturated fat was replaced with unsaturated fats consistently show a lowered risk of cardiovascular disease.[33] Polyunsaturated fats usually come in the form of liquid plant oils, such as soybean, corn, safflower, sunflower oils, walnuts, or flax seeds. Monounsaturated fats are found in canola and olive oils and nuts. The AHA's recommendation simplifies this list by suggesting that consumers replace saturated and trans fats with nontropical liquid plant oils.[33]

Another component of cardiovascular disease risk is oxidative stress, which refers to the overproduction of reactive oxygen species (ROS). ROS, more commonly known as free radicals, have harmful effects on lipids, proteins, and DNA. ROS can also result in cell inflammatory signal activation and programmed cell death.[34,35] Myocardial ischemia-reperfusion injury, heart failure, atherosclerosis, hypertension, and atrial fibrillation are all either caused by, worsened by, or the cause of ROS overproduction.[34,35]

ROS can be neutralized by antioxidants; consequently, an antioxidant-rich diet has been shown to have an impact on both cardiovascular health and existing cardiovascular disease.[33,36] Additionally, antioxidant intake can reduce blood pressure, improve lipid profiles, lower inflammation, and support gut microbiota. Antioxidants include vitamin C, vitamin E, polyphenols, and terpenoid groups, which are found most often in fruits, vegetables, teas, cereals, and nuts.[37,38]

Other food components also have strong associations with dietary health. Dietary fiber has positive effects on blood pressure, gut microbiota, and cholesterol and has been shown to lower the risk of cardiovascular disease.[39,40] Fruits and vegetables, especially in their whole, unprocessed form, whole grains, and nuts are all rich sources of dietary fiber.

Omega-3 fatty acids have anti-inflammatory properties and have been shown to reduce cardiovascular disease risk through a variety of mechanisms.[36,41] Although omega-3 fatty acids have much potential, the practical food sources are complex to recommend. Omega-3 fatty acids are found in fatty fish (depending largely on diet and capture or farming location of the fish), krill, walnuts, flax and chia seeds, and some algaes.[42-44] However, omega-3 fatty acid supplements are not a consistent source; many nonprescription supplements have only a small percentage of omega-3 fatty acids or are oxidized by the time they can be purchased.[42] These concerns make whole food sources of omega-3 preferable.

Sodium is known to cause high blood pressure, which is a known factor of cardiovascular disease risk, and a low-sodium diet is consistently recommended for cardiovascular health.[37,45] Sugar consumption has also been linked to increased cardiovascular disease, although the mechanisms are indirect. Sugars affect cardiovascular disease risk by increasing the risk for other precursors such as obesity and type two diabetes.[38] As a high-calorie component of the diet, consumption of sugar can easily lead to overconsumption of calories compared to energy expenditure. Research on artificial sugars also indicates that high consumption of artificial sugars may also increase cardiovascular disease risk.[38,39]

The dietary guidelines set out for cardiovascular health are intended not to be food-specific, but nonetheless specific diets have been popularized that follow heart-healthy eating patterns and make cardiovascular health accessible. The most prime example is the Mediterranean diet, modeled after the diet of populations in the Mediterranean basin during the 1950s and 60s. This diet generally includes a variety of fruits and vegetables, nuts, whole grains, fish, and extra virgin olive oil. The Mediterranean diet has been studied extensively and is recognized as having positive effects on cardiovascular health.[40,46-48] Although other heart-healthy diets have also been popularized, the Mediterranean diet is one of the most well-studied and adaptable to different individual preferences and settings.[47] The Mediterranean diet's popularity is a strong argument that heart-healthy diets

can be consistently implemented. Similar diets are found in "blue zones," areas with high average life expectancies. These areas typically practice heart-healthy diets and are considered an example population of healthy aging. One study of blue zones found that CAC (coronary artery calcium) was significantly better in California's beach city blue zones, and the prevalence of a number of cardiovascular risk factors had actually decreased in the past few years in the blue zone cities.[49]

The direct influences of diet on cardiovascular health are clear, and there are many guidelines, examples, and popular diets that highlight the applicability of heart-healthy lifestyles. Given this context, it is imperative to understand the additional factors influencing dietary choices, such as socioeconomic status, cultural preferences, food availability, and marketing practices, to effectively promote and sustain heart-healthy eating patterns across diverse populations.

SOCIOECONOMIC AND CULTURAL INFLUENCES ON DIETARY CHOICES

In parallel to environmental factors, socioeconomic determinants also directly and indirectly affect diets and cardiovascular health. One of the major factors directly affecting dietary patterns is the simple price of food. The cost of groceries has risen by 19% in the last 3 years, driven in large part by the pandemic.[50] Notably, however, grocery prices have risen faster than the rate of inflation so that families are now paying 25% more than they were before the pandemic. Twenty percent of grocery inflation has been driven by three categories: beef/veal, poultry, and fresh fruits and vegetables, with fresh produce accounting for the most inflation of any category at 7.8%.[50]

Much of grocery inflation can be attributed to supply shocks, such as diseases affecting poultry and fruit, lowered production due to natural disasters and extreme weather, and international supply chain disruptions. An additional factor is corporate profiteering and monopolistic ownership: between 55% and 85% of the US meat market is controlled by only four companies, and a proposed merger between Kroger and Albertsons grocery stores could lead to their ownership of nearly 17%.[50,51] If combined with Walmart's 21% share, those two entities would account for almost 40% of the total grocery market.[52]

Outside of food prices, access to food presents additional challenges. It is estimated that 17.4% of Americans live in a place that has low access to supermarkets or grocery stores (more than 1 mile in urban areas or 10 miles in rural areas) and have low income. This percentage has grown slightly since 2015.[53] These numbers highlight a reality of the food options available to many: fresh produce and whole foods are not equitably accessible to nearly one-fifth of the population. Additionally, time poverty and available preparation is another challenge. Many who cannot afford healthy pre-made foods also do not have the time, knowledge, and resources required to be able to purchase, prepare, and store fresh and whole food ingredients.[54,55]

Proper communication and education about food and diet can help consumers make healthy decisions. Research suggests that clear and visible nutrition information can educate consumers on nutritional quality and encourage healthy choices.[56] In particular, front-of-package nutrition labeling has been promoted by the World Heart Federation.[57]

The indirect effects of cultural values affect the US agricultural system on a much larger scale. The US Farm Bill heavily subsidizes corn, soybeans, wheat, rice, sorghum, dairy, and livestock feed. Higher consumption of these subsidized commodities has been associated with high cholesterol, obesity, and dysglycemia.[58] Furthermore, the longstanding subsidies for major food categories, combined with lobbying and publicity campaigns, have made foods such as dairy and meat cultural staples in the American diet.[59]

Given the clear and ample understanding of the impact of diet on cardiovascular health factors, the real costs of our current food system to human health, and to society, are stark. The most affordable and most easily produced foods are often ultra-processed and nutritionally poor; as a result, the most affordable diets are also the diets most lacking in the key components supporting cardiovascular health.[48] These diets lack whole foods, antioxidants, healthy proteins, and fiber while being high in salt, unhealthy fat, and calories.[48] The result is an epidemic of obesity, high blood pressure, and cardiovascular disease.[1]

In addition to the actual cost of health care to treat cardiovascular disease, there are costs through society from lost productivity during recovery, premature deaths, and overall quality of life decreases. One analysis estimated that the costs related to human health due to diet-related illness and health issues in the US were equal to the cost of the food system itself.[47] The US food system in 2021 cost $1.1 trillion annually, while annual healthcare costs related to obesity cost $359 billion, costs related to other noncommunicable diseases (such as cardiovascular disease, hypertension, cancer, and diabetes) were $604 billion, and food insecurity and the impact of pollution cost another $182 billion.[47] In a literal sense, a food system that does not support health is a costly system, both medically and economically.

RECOGNIZING THE INTERCONNECTEDNESS OF DIET, AGRICULTURE, AND CARDIOVASCULAR HEALTH: SYSTEMS APPROACH TO ADDRESSING CARDIOVASCULAR HEALTH

There is strong evidence supporting the need to broaden the perspective of public health interventions aimed at addressing cardiovascular diseases. By understanding the many interconnections between the environment, agricultural systems, and dietary choices, we can better identify critical root causes of cardiovascular disease and take advantage of new opportunities to improve cardiovascular health.

There are many benefits to integrating support for food consumption behaviors and sustainable agricultural practices. Many healthy dietary patterns, such as eating whole unprocessed foods, eating primarily plant-based or healthy proteins, and eating a variety of foods align with sustainable agriculture practices. Transitioning to an agriculture system that prioritizes diverse, quality, and affordable food can have synchronous returns on supporting healthy food consumption behaviors.

Policy interventions and public health initiatives can promote dietary and food system changes. Policy interventions could range from food labeling and transparency regulations to taxes or subsidies to encourage the consumption of healthy foods and discourage the consumption of unhealthy foods.[60] More broadly, education and food-assistance programs can support communities to have more freedom and agency as they make their dietary choices.[61] More large-scale policy interventions could work with food industry entities to collaborate toward other types of agricultural and food production.

Research and collaboration across the agricultural and health sectors are necessary to better understand and take advantage of the many interconnections. Although it is clear that many of the goals of cardiovascular health and sustainable agriculture overlap, as depicted in Figure 1, additional research could elucidate the most efficient and effective ways to promote change and facilitate healthier agricultural and food systems.

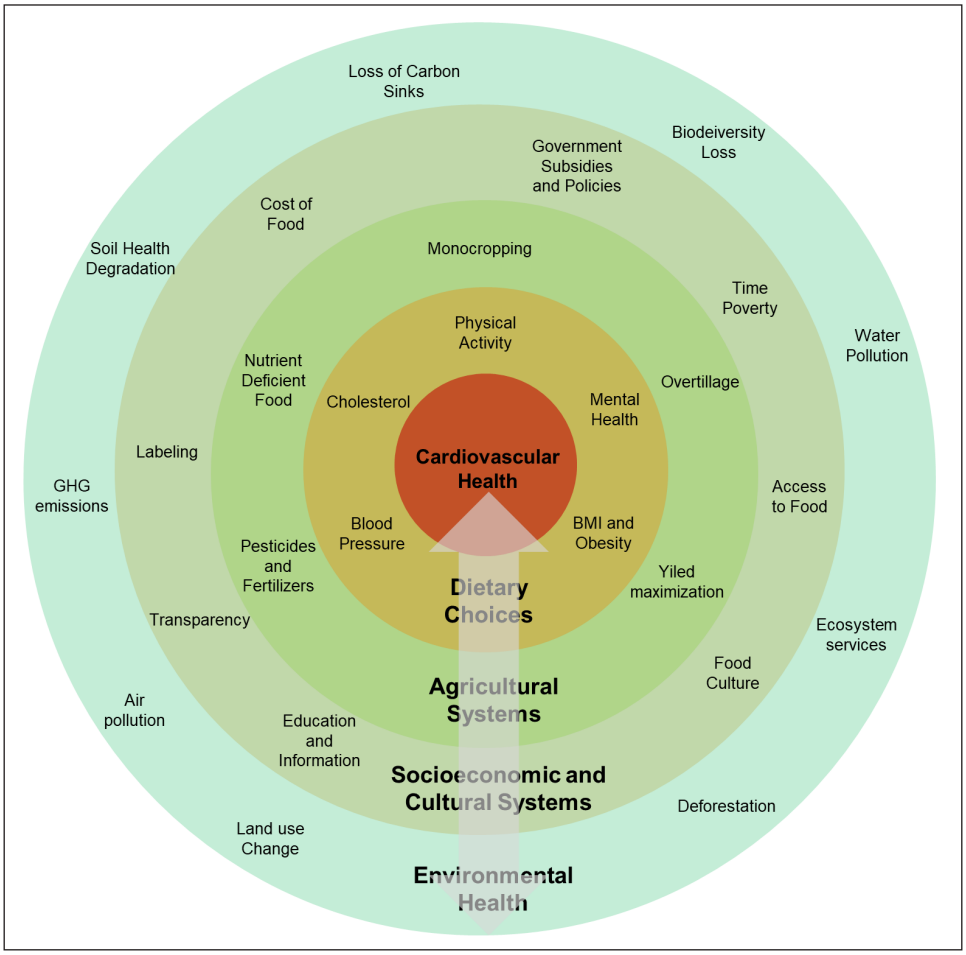

Figure 1 Interconnections between the exposome and cardiovascular disease.

CONCLUSIONS

The exposome concept, with its emphasis on the totality of environmental exposures and lifestyle factors, provides a valuable framework for understanding how these diverse elements interact to influence health over a lifetime. The intricate relationships between diet, agricultural practices, environmental health, and cardiovascular health underscore the need for a comprehensive and systemic approach to improving cardiovascular outcomes. Current agricultural practices in the US, dominated by monocropping and heavy use of fertilizers and pesticides, have significant environmental repercussions that indirectly affect cardiovascular health. Transitioning to more sustainable agricultural practices that prioritize soil health, biodiversity, and reduced chemical inputs is critical for both environmental sustainability and public health. Moreover, dietary choices, deeply influenced by socioeconomic and cultural factors, play a direct role in cardiovascular health. There is evidence that diets rich in whole unprocessed foods, fruits, vegetables, whole grains, and healthy fats are beneficial for cardiovascular health, while diets high in ultra-processed foods, unhealthy fats, and sugars increase the risk of cardiovascular diseases.

Addressing these dietary challenges requires policy interventions that make healthy foods more accessible and affordable, educational programs that inform the public about healthy eating, and systemic changes in food production and distribution. Cross-sectoral collaboration is critical for the development of interventions that are consistent with the complexity and level of interdependency of interconnected systems. Research that integrates the goals of cardiovascular health and sustainable agriculture can help identify effective strategies and interventions. By adopting a systems approach that considers the interdependencies between environmental health, agricultural practices, and dietary choices, we can develop holistic solutions that promote both human health and environmental sustainability. Such integrative strategies and policies can pave the way for improved cardiovascular health outcomes and a healthier, more sustainable food system for future generations.

KEY POINTS

- Maintaining a healthy diet is considered one of the most impactful strategies for supporting cardiovascular health and has consistently shown to lower the risk of cardiovascular disease. Furthermore, popular diets such as the Mediterranean diet highlight that heart-healthy eating has the potential to be popular and widely adopted. Nonetheless there are low mean scores of cardiovascular health diets throughout the US.
- Agricultural practices of monocropping, intensive tillage, fertilizer, and pesticides ensure high productivity and profitable crops but also lead to soil depletion, water pollution, and increased greenhouse gas emissions. Furthermore, the US agricultural subsidies are not necessarily aligned with health outcomes.
- Environmental determinants affect cardiovascular health; air pollution, chemical and pesticide exposure, and climate change events can all have negative effects on cardiovascular health.
- Socioeconomic and cultural influences affect dietary choices. The cost, availability, and convenience of food influences what people eat, and the education and transparency around food and nutrition information affects their decision making.
- It is imperative to adopt a systems approach to cardiovascular health by holistically understanding the influences and determinants of the exposome. Stakeholders from the medical, policy, and agricultural spheres must collaborate to effectively leverage shared priorities.

FUNDING INFORMATION

Bassel Daher was partially supported by grant #P20TW01 2709 from the National Institute of Health Fogarty International Center (NIH/FIC) to complete the work in this manuscript.

COMPETING INTERESTS

The author has no competing interests to declare.

AUTHOR AFFILIATIONS

Bassel Daher, PhD, MSE orcid.org/0000-0002-0096-6783
Texas A&M Energy Institute, Texas A&M University, College Station, Texas, US; Department of Biological and Agricultural Engineering, Texas A&M University, College Station, Texas, US; Bush School of Government and Public Service, College Station, Texas, US

REFERENCES

1. **Lloyd-Jones DM, Allen NB, Anderson CAM,** et al. Life's Essential 8: Updating and Enhancing the American Heart Association's Construct of Cardiovascular Health: A Presidential Advisory From the American Heart Association.

Circulation. 2022 Aug 2;146(5):e18-e43. doi: 10.1161/CIR.0000000000001078

2. **Lloyd-Jones DM, Hong Y, Labarthe D,** et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. Circulation. 2010 Feb 2;121(4):586-613. doi: 10.1161/CIRCULATIONAHA.109.192703
3. **Wild CP.** Complementing the genome with an "exposome": the outstanding challenge of environmental exposure measurement in molecular epidemiology. Cancer Epidemiol Biomarkers Prev. 2005 Aug;14(8):1847-50. doi: 10.1158/1055-9965.EPI-05-0456
4. **Münzel T, Sørensen M, Hahad O, Nieuwenhuijsen M, Daiber A.** The contribution of the exposome to the burden of cardiovascular disease. Nat Rev Cardiol. 2023 Oct;20(10):651-669. doi: 10.1038/s41569-023-00873-3
5. **Lichtenstein AH, Appel LJ, Vadiveloo M,** et al. 2021 Dietary Guidance to Improve Cardiovascular Health: A Scientific Statement From the American Heart Association. Circulation. 2021 Dec 7;144(23):e472-e487. doi: 10.1161/CIR.0000000000001031
6. **Shan Z, Li Y, Baden MY,** et al. Association Between Healthy Eating Patterns and Risk of Cardiovascular Disease. JAMA Intern Med. 2020 Aug 1;180(8):1090-1100. doi: 10.1001/jamainternmed.2020.2176
7. **Chiuve SE, Fung TT, Rimm EB,** et al. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr. 2012 Jun;142(6):1009-18. doi: 10.3945/jn.111.157222
8. **Motairek I, Makhlouf MHE, Rajagopalan S, Al-Kindi S.** The Exposome and Cardiovascular Health. Can J Cardiol. 2023 Sep;39(9):1191-1203. doi: 10.1016/j.cjca.2023.05.020
9. **Kazi DS, Katznelson E, Liu CL,** et al. Climate Change and Cardiovascular Health: A Systematic Review. JAMA Cardiol. 2024 Aug 1;9(8):748-757. doi: 10.1001/jamacardio.2024.1321
10. **Khraishah H, Alahmad B, Ostergard RL Jr,** et al. Climate change and cardiovascular disease: implications for global health. Nat Rev Cardiol. 2022 Dec;19(12):798-812. doi: 10.1038/s41569-022-00720-x
11. **Jacobsen AP, Khiew YC, Duffy E,** et al. Climate change and the prevention of cardiovascular disease. Am J Prev Cardiol. 2022 Sep 11:12:100391. doi: 10.1016/j.ajpc.2022.100391
12. **Sanaullah M, Usman M, Wakeel A, Cheema SA, Ashraf I, Farooq M.** Terrestrial ecosystem functioning affected by agricultural management systems: A review. Soil and Tillage Res. Feb 2020;196:104464. doi: 10.1016/j.still.2019.104464
13. **Belete T, Yadete E.** Effect of Mono Cropping on Soil Health and Fertility Management for Sustainable Agriculture Practices: A Review. J Plant Sci. 2023 Nov 20;12(5). doi:10.11648/j.jps.20231106.13
14. **Tudi M, Daniel Ruan H, Wang L,** et al. Agriculture Development, Pesticide Application and Its Impact on the Environment. Int J Environ Res Public Health. 2021 Jan 27;18(3):1112. doi: 10.3390/ijerph18031112
15. **Springer [Internet].** Berlin, Germany: Springer Nature; c2024. Hossain A, Krupnik TJ, Timsina J, et al. Agricultural Land Degradation: Processes and Problems Undermining Future Food Security; 2020 Oct [cited 2024 Sep 4]. Available from: https://link.springer.com/chapter/10.1007/978-3-030-49732-3_2
16. **USDA [Internet].** Washington, DC: US Department of Agriculture; c2024. Corn, soybeans account for more than half of the 2022 U.S. crop cash receipts; updated 2024 Sep 5 [cited 2024 Sep 7]. Available from: http://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=76946
17. **USDA [Internet].** Washington, DC: US Department of Agriculture; c2024. Capeheart T, Proper S. Corn is America's Largest Crop in 2019; 2019 Jul 29 [cited 2024 Sep 7]. Available from: https://www.usda.gov/media/blog/2019/07/29/corn-americas-largest-crop-2019
18. **USDE [Internet].** Washington, DC: US Department of Energy; c2024. Alternative Fuels Data Center: Maps and Data - U.S. Corn Use by Market Year; 2024 Jan [cited 2024 Sep 7]. Available from: https://afdc.energy.gov/data/search?q=corn
19. **Reinhardt SL, Boehm R, Blackstone NT,** et al. Systematic Review of Dietary Patterns and Sustainability in the United States. Adv Nutr. 2020 Jul l;11(4):1016-1031. doi: 10.1093/advances/nmaa026
20. **Miller PE, Reedy J, Kirkpatrick SI, Krebs-Smith SM.** The United States food supply is not consistent with dietary guidance: evidence from an evaluation using the Healthy Eating Index-2010. J Acad Nutr Diet. 2015 Jan;115(1):95-100. doi: 10.1016/j.jand.2014.08.030
21. **Carolan M.** The Real Cost of Cheap Food. Second edition. Oxfordshire, UK: Routledge, Taylor & Francis Group; 2018 Feb. 234 p. doi: 10.4324/9781315113234
22. **Shrivastav A, Swetanshu, Singh P.** The Impact of Environmental Toxins on Cardiovascular Diseases. Curr Probl Cardiol. 2024 Jan;49(1 Pt C):102120. doi: 10.1016/j.cpcardiol.2023.102120
23. **Münzel T, Hahad O, Daiber A, Landrigan PJ.** Soil and water pollution and human health: what should cardiologists worry about? Cardiovasc Res. 2023 Mar 31;119(2):440-449. doi: 10.1093/cvr/cvac082
24. **Diab A, Dastmalchi LN, Gulati M, Michos ED.** A Heart-Healthy Diet for Cardiovascular Disease Prevention: Where Are We Now? Vasc Health Risk Manag. 2023 Apr 21:19:237-253. doi: 10.2147/VHRM.S379874
25. **Montero-Salazar H, Donat-Vargas C, Moreno-Franco B,** et al. High consumption of ultra-processed food may double the risk of subclinical coronary atherosclerosis: the Aragon

Workers' Health Study (AWHS). 2020 Aug 13;18(1):235. doi: 10.1186/s12916-020-01678-8

26. **Bremner J, Moazzami K, Wittbrodt M,** et al. Diet, Stress and Mental Health. Nutrients. 2020 Aug 13;12(8):2428. doi: 10.3390/nu12082428
27. **Lakka TA, Bouchard C.** Physical activity, obesity and cardiovascular diseases. Handb Exp Pharmacol. 2005:(170):137-63. doi: 10.1007/3-540-27661-0_4
28. **Briggs MA, Petersen KS, Kris-Etherton PM.** Saturated Fatty Acids and Cardiovascular Disease: Replacements for Saturated Fat to Reduce Cardiovascular Risk. Healthcare (Basel). 2017 Jun 21;5(2):29. doi: 10.3390/healthcare5020029
29. **Islam MdA, Amin MN, Siddiqui SA, Hossain MdP, Sultana F, Kabir MdR.** Trans fatty acids and lipid profile: A serious risk factor to cardiovascular disease, cancer and diabetes. Diabetes Metab Syndr. 2019 Mar-Apr;13(2):1643-1647. doi: 10.1016/j.dsx.2019.03.033
30. **Wang DD, Li Y, Bhupathiraju SN,** et al. Fruit and Vegetable Intake and Mortality: Results From 2 Prospective Cohort Studies of US Men and Women and a Meta-Analysis of 26 Cohort Studies. Circulation. 2021 Apr 27;143(17):1642-1654. doi: 10.1161/CIRCULATIONAHA.120.048996
31. **Chen X, Zhang Z, Yang H,** et al. Consumption of ultra-processed foods and health outcomes: a systematic review of epidemiological studies. Nutr J. 2020 Aug 20;19(1):86. doi: 10.1186/s12937-020-00604-1
32. **Srour B, Fezeu LK, Kesse-Guyot E,** et al. Ultra-processed food intake and risk of cardiovascular disease: prospective cohort study (NutriNet-Santé). BMJ. 2019 May 29:365:l1451. doi: 10.1136/bmj.l1451
33. **Juul F, Vaidean G, Parekh N.** Ultra-processed Foods and Cardiovascular Diseases: Potential Mechanisms of Action. Adv Nutr. 2021 Oct 1;12(5):1673-1680. doi: 10.1093/advances/nmab049
34. **Sacks FM, Lichtenstein AH, Wu JHY,** et al. Dietary Fats and Cardiovascular Disease: A Presidential Advisory From the American Heart Association. Circulation. 2017 Jul 18;136(3):e1-e23. doi: 10.1161/CIR.0000000000000510
35. **Wang W, Kang PM.** Oxidative Stress and Antioxidant Treatments in Cardiovascular Diseases. Antioxidants (Basel). 2020 Dec 17;9(12):1292. doi: 10.3390/antiox9121292
36. **Dubois-Deruy E, Peugnet V, Turkieh A, Pinet F.** Oxidative Stress in Cardiovascular Diseases. Antioxidants (Basel). 2020 Sep 14;9(9):864. doi: 10.3390/antiox9090864
37. **Tortosa-Caparrós E, Navas-Carrillo D, Marín F, Orenes-Piñero E.** Anti-inflammatory effects of omega 3 and omega 6 polyunsaturated fatty acids in cardiovascular disease and metabolic syndrome. Crit Rev Food Sci Nutr. 2017 Nov 2;57(16):3421-3429. doi: 10.1080/10408398.2015.1126549
38. **Wu Q, Burley G, Li L, Lin S, Shi Y.** The role of dietary salt in metabolism and energy balance: Insights beyond cardiovascular disease. Diabetes Obes Metab. 2023 May;25(5):1147-1161. doi: 10.1111/dom.14980
39. **Yin J, Zhu Y, Malik V,** et al. Intake of Sugar-Sweetened and Low-Calorie Sweetened Beverages and Risk of Cardiovascular Disease: A Meta-Analysis and Systematic Review. Adv Nutr. 2021 Feb 1;12(1):89-101. doi: 10.1093/advances/nmaa084
40. **Meng Y, Li S, Khan J,** et al. Sugar- and Artificially Sweetened Beverages Consumption Linked to Type 2 Diabetes, Cardiovascular Diseases, and All-Cause Mortality: A Systematic Review and Dose-Response Meta-Analysis of Prospective Cohort Studies. Nutrients. 2021 Jul 30;13(8):2636. doi: 10.3390/nu13082636
41. **Jimenez-Torres J, Alcalá-Diaz JF, Torres-Peña JD,** et al. Mediterranean Diet Reduces Atherosclerosis Progression in Coronary Heart Disease: An Analysis of the CORDIOPREV Randomized Controlled Trial. Stroke. 2021 Nov;52(11):3440-3449. doi: 10.1161/STROKEAHA.120.033214
42. **Preston Mason R.** New Insights into Mechanisms of Action for Omega-3 Fatty Acids in Atherothrombotic Cardiovascular Disease. Curr Atheroscler Rep. 2019 Jan 12;21(1):2. doi: 10.1007/s11883-019-0762-1
43. **Sherratt SCR, Libby P, Budoff MJ, Bhatt DL, Mason RP.** Role of Omega-3 Fatty Acids in Cardiovascular Disease: the Debate Continues. Curr Atheroscler Rep. 2023 Jan;25(1):1-17. doi: 10.1007/s11883-022-01075-x
44. **Santos HO, Price JC, Bueno AA.** Beyond Fish Oil Supplementation: The Effects of Alternative Plant Sources of Omega-3 Polyunsaturated Fatty Acids upon Lipid Indexes and Cardiometabolic Biomarkers-An Overview. Nutrients. 2020 Oct 16;12(10):3159. doi: 10.3390/nu12103159
45. **Oliver L, Dietrich T, Marañón I, Villarán MC, Barrio RJ.** Producing Omega-3 Polyunsaturated Fatty Acids: A Review of Sustainable Sources and Future Trends for the EPA and DHA Market. Resources. 2020 Dec 16;9(12):148. doi: 10.3390/resources9120148
46. **Wang YJ, Yeh TL, Shih MC, Tu YK, Chien KL.** Dietary Sodium Intake and Risk of Cardiovascular Disease: A Systematic Review and Dose-Response Meta-Analysis. Nutrients. 2020 Sep 25;12(10):2934. doi: 10.3390/nu12102934
47. **Delgado-Lista J, Alcala-Diaz JF, Torres-Peña JD,** et al. Long-term secondary prevention of cardiovascular disease with a Mediterranean diet and a low-fat diet (CORDIOPREV): a randomised controlled trial. Lancet. 2022 May 14;399(10338):1876-1885. doi: 10.1016/S0140-6736(22)00122-2
48. **Martínez-González MA, Gea A, Ruiz-Canela M.** The Mediterranean Diet and Cardiovascular Health. Circ Res. 2019 Mar;124(5):779-798. doi: 10.1161/CIRCRESAHA.118.313348
49. **Lakshmanan S, Kinninger A, Golub I,** et al. 20-Year trend of high prevalence of zero coronary artery calcium in beach cities of Southern California: A blue zone? Am J Prev Cardiol. 2020 Oct 21:4:100098. doi: 10.1016/j.ajpc.2020.100098

50. **Groundwork Collaborative [Internet].** Washington, DC: Groundwork Collaborative; c2024. Pancotti E, Ramamurti B, Wilson C. What's Driving the Rise in Grocery Prices - and What the Government Can Do About It; 2024 Feb [cited 2024 Sep 4]. Available from: https://groundworkcollaborative.org/wp-content/uploads/2024/02/24.02.01-Whats-Driving-the-Rise-in-Grocery-Prices-and-What-the-Government-Can-Do-About-It.pdf
51. **USC Gould Business Law Digest [Internet].** Los Angeles, CA: USC Gould School of Law at University of Southern California; c2024. Lockard S. An Examination of The Proposed Kroger and Albertsons Merger, Its Potential Effects on the Economy, and Its Regulatory Battle With the FTC; 2023 Dec 15 [cited 2024 Sep 4]. Available from: https://lawforbusiness.usc.edu/an-examination-of-the-proposed-kroger-and-albertsons-merger-its-potential-effects-on-the-economy-and-its-regulatory-battle-with-the-ftc/
52. **Financial Times [Internet].** London, UK: The Financial Times Ltd; c2024. Armstrong R, Reiter A. The Kroger-Albertsons deal has a chance; 2024 Sep 5 [cited 2024 Sep 8]. Available from: https://www.ft.com/content/e6f907cc-89dd-42d5-b89f-bf4e01e08109
53. **Houghtaling B, Greene M, Parab KV, Singleton CR.** Improving Fruit and Vegetable Accessibility, Purchasing, and Consumption to Advance Nutrition Security and Health Equity in the United States. Int J Environ Res Public Health. 2022 Sep 7;19(18):11220. doi: 10.3390/ijerph191811220
54. **Giurge LM, Whillans AV, West C.** Why time poverty matters for individuals, organisations and nations. Nat Hum Behav. 2020 Oct;4(10):993-1003. doi: 10.1038/s41562-020-0920-z
55. **Kris-Etherton PM, Petersen KS, Velarde G,** et al. Barriers, Opportunities, and Challenges in Addressing Disparities in Diet-Related Cardiovascular Disease in the United States. J Am Heart Assoc. 2020 Apr 7;9(7):e014433. doi: 10.1161/JAHA.119.014433
56. **Jones A, Neal B, Reeve B, Ni Mhurchu C, Thow AM.** Front-of-pack nutrition labelling to promote healthier diets: current practice and opportunities to strengthen regulation worldwide. BMJ Glob Health. 2019 Dec 14;4(6):e001882. doi: 10.1136/bmjgh-2019-001882
57. **Champagne B, Arora M, ElSayed A,** et al. World Heart Federation Policy Brief: Front-Of-Pack Labelling: Unhealthy Changes in the Global Food System. Glob Heart. 2020 Oct 16;15(1):70. doi: 10.5334/gh.935
58. **Do WL, Bullard KM, Stein AD, Ali MK, Narayan KMV, Siegel KR.** Consumption of Foods Derived from Subsidized Crops Remains Associated with Cardiometabolic Risk: An Update on the Evidence Using the National Health and Nutrition Examination Survey 2009-2014. Nutrients. 2020 Oct 23;12(11):3244. doi: 10.3390/nu12113244
59. **McCarthy J.** Influence of the Food Industry: The Food Environment and Nutrition Policy. In: Temple NJ, Wilson T, Jacobs, DR, Bray GA, editors. Nutritional Health: Strategies for Disease Prevention. Totowa, NJ: Humana Press; 2023. p. 375-388. doi: 10.1007/978-3-031-24663-0_30
60. **Andreyeva T, Marple K, Moore TE, Powell LM.** Evaluation of Economic and Health Outcomes Associated With Food Taxes and Subsidies: A Systematic Review and Meta-analysis. JAMA Netw Open. 2022 Jun 1;5(6):e2214371. doi: 10.1001/jamanetworkopen.2022.14371
61. **Mozaffarian D, Angell SY, Lang T, Rivera JA.** Role of government policy in nutrition-barriers to and opportunities for healthier eating. BMJ. 2018 Jun 13:361:k2426. doi: 10.1136/bmj.k2426

TO CITE THIS ARTICLE:
Daher B. Food for Thought: Nourishing Cardiovascular Health Amidst the Exposome. Methodist DeBakey Cardiovasc J. 2024;20(5):27-36. doi: 10.14797/mdcvj.1452

Submitted: 20 July 2024 **Accepted:** 08 August 2024 **Published:** 05 November 2024