iSTEAM Communications ISSN:2691-7300 https://realjournal.org/isteamc

Review Article, Review in Public Health

Evaluation on the high percentage rate of obesity and CVD in Guam regarding human consumption of microplastics

Juho Shin[1,*]

[1] Columbia University Mailman School of Public Health, New York, NY 10019, United States

[*] Correspondence: alex.shin061114@gmail.com

(Received: 11/04/2024; Accepted: 12/21/2024; Published: 12/26/2024)

DOI: https://doi.org/10.37906/isteamc.2024.8

Abstract: Cardiovascular disease (CVD) is the leading cause of mortality worldwide, with Guam exhibiting notably higher rates of CVD and obesity compared to the mainland United States. This review examines the potential link between microplastic (MP) consumption and the elevated prevalence of CVD and obesity in Guam, where the Pacific Islanders' diet involves high seafood intake, a major source of MPs. Research indicates that MPs can lead to oxidative stress and inflammation, which contribute to endothelial dysfunction, atherosclerosis, and other CVD-related conditions. Animal model studies demonstrate that exposure to MPs accelerates oxidative damage, resulting in myocardial fibrosis and apoptosis, thereby linking MPs to cardiovascular complications. Additionally, the association between MP ingestion and increased adiposity implies that MPs may exacerbate obesity, a significant CVD risk factor. This review underscores the importance of further investigation into the impact of MPs on human health, especially in populations with high seafood consumption, and their potential role in cardiovascular risk elevation in regions like Guam.

Keywords: Micro Plastics; Cardiovascular Disease; Oxidative Stress; Guam; Obesity

1. Introduction

Cardiovascular disease (CVD) accounts for the highest cause of death worldwide (Mathers et al., 2001). Cardiovascular Disease (CVD) includes a wide number of disorders, including diseases of the cardiac muscle and of the vascular system supplying the heart, brain, and other vital organs (Gaziano et al., 2006). This global trend is reflected in Guam, where compared with the United States overall, having higher mortality rates from cardiovascular disease and stroke (Murphy et al., 2015). While there are numerous causes for CVDs, Obesity is known to be one of the causes for CVD.

Microplastics (MP) are small fragments of plastics that are less than 5 millimeters in size (Gigault et al., 2018). Primary MPs are manufactured to be small and are released into the environment in their micro-sized form, while secondary MPs are formed from the breakdown of larger plastics (Jambeck et al., 2015). While air, bottled water, and seafood consumption accounts for the large majority of microplastic intake of humans, Pacific islanders, including Guam, have a higher intake of fish and seafood compared to other ethnic groups such as the Philippines or native americans (Cox et al., 2020) (Bennett et al., 2022). Since recent research claims that accumulation of MPs in tissues of animals leads to oxidative stress (Yu et al., 2018), which is one of the main causes of Cardiovascular disease (CVD) (Senoner & Dichtl, 2019), this paper aims to link the high CVD and Obesity rate in Guam with the high MP consumption.

2. Consumption of foods and rate of CVD in Guam

In Guam, rates of CVDs and stroke mortality are high compared to mainland U.S. (Jackson et al., 2015) In addition to CVD rate, In Guam, 49% of Chamorros and 20% of Filipinos are classified as obese. By contrast, in the United States, the overall obesity rate was 32.2%, which is lower than Guam's Chamorro population but comparable to the rates in Guam. In other regions, such as Japan and South Korea, the obesity rates are considerably lower, typically below 10% for adults. (Cox et al., 2020) (Leon Guerrero et al., 2009)

Obesity increases risk factors such as elevated blood pressure, dyslipidemia (high cholesterol and triglycerides), and insulin resistance, all of which significantly heighten the risk of heart attacks, strokes, and other CVDs. Additionally, excess fat, particularly around the abdomen, promotes chronic inflammation and oxidative stress, further damaging the cardiovascular system. (Van Gal et al., 2020) (Ortega et al., 2016)

3. Food Consumption in Guam

Pacific Islanders, including people in Guam, consume significantly more fish and seafood compared to other populations. The annual seafood consumption in Guam is higher compared to populations like Native Americans and the mainland U.S., contributing to higher exposure to microplastics through diet (Bennett et al., 2022) (Pinhey et al., 2022). Based on global studies, it is estimated that people who consume seafood regularly are exposed to between 74,000 and 113,000 microplastic particles annually, depending on age and gender (Cox et al., 2020).

Since fish and other seafood, which form a major part of the diet in Guam, have been found to contain up to 11,000 microplastic particles per year for heavy seafood consumers, (Cox et al., 2020) these statistics support the notion that Guam's population, due to their diet and environmental factors, may have a higher exposure to microplastics, which could correlate with the island's elevated rates of CVD and Obesity.

4. MP & Oxidative Stress

The term oxidative stress was devised by Sies (Sies, 2015) to broadly describe a disturbance in the balance of reactive oxygen species (ROS) and antioxidants.

Study that was conducted in 2018 on E. sinensis reported that the accumulation of Microplastics (MP) in tissues of E. sinensis can negatively affect growth as well as cause damage and induce oxidative stress (Yu et al., 2018). In this study, Eriocheir sinensis were exposed to polystyrene microplastics to investigate their uptake, accumulation, and effects on growth and oxidative stress. 500 juvenile female crabs were kept under controlled laboratory conditions. After acclimatization, the crabs were exposed to varying concentrations of microplastics (40, 400, 4000, and 40000 μg/L) for 7 days, and their growth, survival rate, and hepatosomatic index (HSI) were measured.

The results showed that the crabs exposed to the highest concentration of microplastics (40000 μg/L) exhibited significantly lower weight gain (WG) compared to the control group. Microplastic accumulation was found in various tissues, and oxidative stress and liver inflammation were observed in crabs exposed for 21 days.

In addition to this research, a study that was held in July 2021 explored how microplastic (MP) exposure induces oxidative stress in fish, a critical factor in understanding MP toxicity. MP ingestion leads to the generation of reactive oxygen species (ROS), causing an imbalance in the body's natural antioxidant defenses, which resulted in oxidative damage at the cellular level. MPs were accumulated primarily in the gills and intestines of fish, then entered the circulatory system, spreading to other tissues. As MPs interacted with cells, they triggered the formation of free radicals, further exacerbating oxidative

stress.(Kim et al., 2021) These findings in animals could potentially be applied to humans in a similar manner, since studies indicate that MPs or NPs can also accumulate in mitochondria and further disrupt the mitochondrial electron transport chain, where these events eventually lead to the generation of different types of reactive free radicals, which can induce DNA damage and protein oxidation in the cardiovascular system (Das, 2023).

5. Oxidative Stress & CVD

Reactive Oxygen Species (ROS) are chemically reactive molecules that play a dual role in cells. At low, basal levels, ROS are essential for normal cellular functions, such as signaling and maintaining balance within the cell. However, when ROS levels become too high, they become harmful. Excessive ROS can damage key cellular components, including DNA, lipids, and proteins, leading to cellular dysfunction. This damage can trigger processes like necrosis or apoptosis (Senoner & Dichtl, 2019). A study by Gracia et al. (2017) also explored the relationship between cardiovascular disease (CVD) and oxidative stress, emphasizing that excessive reactive oxygen species (ROS) play a pivotal role in endothelial dysfunction, a key factor in the development of atherosclerosis. This research highlighted how ROS leads to lipid peroxidation, inflammation, and apoptosis, all of which contribute to plaque formation in arteries and the progression of CVD. The findings underscored the critical involvement of oxidative stress in the pathophysiology of CVD, establishing it as a primary factor in vascular damage and disease progression. (Cervantes Gracia et al., 2017)

5.1 Apoptosis

The term apoptosis is proposed for a mechanism of controlled cell deletion (Kerr et al., 1972). Apoptosis is crucial for eliminating redundant, autoreactive, or neoplastic cells. Recent studies suggest a significant role of apoptosis in various cardiovascular diseases. Apoptosis plays a crucial role in cardiac development, as programmed cell death is essential for the formation of septal, valvular, and vascular structures (Pexieder, 1975).

However, excessive or inappropriate apoptosis can lead to congenital heart disease (Pexieder, 1975). Direct evidence of apoptosis has been observed in mesenchymal cells during the development of the rat heart, highlighting its significance (Gigault et al., 2018). Furthermore, excessive apoptosis in the cardiac conduction system may contribute to heart block (James, 1994) (James et al., 1996).

5.2 Endothelial Dysfunction

In the context of cardiovascular disease (CVD), endothelial dysfunction is a significant contributor to the pathogenesis of atherosclerosis and other cardiovascular conditions. The endothelium, the inner lining of blood vessels, plays a critical role in vascular homeostasis by regulating blood flow, inflammation, and coagulation. Elevated ROS levels can compromise the endothelial barrier, promoting cellular injury, apoptosis of endothelial cells, and Atherosclerosis (Senoner & Dichtl, 2019).

This apoptosis not only disrupts the structural integrity of blood vessels but also activates inflammatory pathways, further exacerbating endothelial dysfunction. Additionally, the loss of viable endothelial cells diminishes the production of protective molecules such as Nitrogen oxide(NO), which is vital for vasodilation and maintaining healthy blood pressure. Consequently, the interplay between ROS, endothelial dysfunction, apoptosis, and Atherosclerosis creates a vicious cycle that accelerates the progression of CVD (Senoner & Dichtl, 2019).

5.3 Atherosclerosis

Atherosclerosis is a progressive condition characterized by the accumulation of plaques in the arterial walls, which can obstruct blood flow and lead to cardiovascular diseases (Cervantes Gracia et al., 2017). In

the early stages of atherosclerosis, ROS can impair the endothelium, weakening its ability to regulate blood flow and maintain vascular homeostasis. This endothelial dysfunction is a critical factor in the formation of atherosclerotic plaques (Dhalla et al., 2000). The oxidative stress induced by excessive ROS not only damages the endothelial cells but also promotes the oxidation of low-density lipoproteins (LDL) in the bloodstream. These oxidized LDL molecules are then taken up by immune cells, forming foam cells, which accumulate within the arterial walls to form fatty streaks—an early sign of atherosclerosis (Peluso et al., 2012).

As the plaque develops, further oxidative damage leads to inflammation and the recruitment of additional immune cells. Over time, this inflammation and oxidative stress result in plaque instability, increasing the risk of thrombosis, where the plaque ruptures and forms a blood clot. This process can lead to serious cardiovascular events such as heart attacks or strokes (Madamanchi et al., 2022).

6. Obesity from MPs leading to CVD

As stated previously, studies suggest that the accumulation of MPs in human tissues may contribute to oxidative stress, causing CVDs. MPs can increase ROS production, potentially accelerating the damage to the vascular system, further linking environmental factors to the development of cardiovascular diseases.

By focusing on oxidative stress and its role in promoting atherosclerosis, we can better understand how both endogenous and external factors, such as MPs, might contribute to the growing prevalence of cardiovascular disease.

In June 2024, researchers investigated the cardiotoxic effects of polystyrene micro- and nanoplastics (MNP) by exposing cardiac tissues to 0.5 μm polystyrene particles. The experiment focused on how these particles induced cardiac fibrosis through the Wnt/β-catenin signaling pathway and influenced oxidative stress, leading to myocardial apoptosis. Using diagnostic tools such as left ventricular ejection fraction (LVEF), cardiac magnetic resonance (CMR), and echocardiography, researchers assessed the extent of cardiac dysfunctions, including impaired heart function, abnormal heart rate, and vascular damage. This research highlights the detrimental effects of MNP exposure on the cardiovascular system, suggesting that prolonged exposure may lead to multiple CVDs (Chowdhury et al., 2023).

In a recent study, microplastics and nanoplastics (MNPs) were detected in the carotid artery plaques of 58.4% of patients undergoing carotid endarterectomy, with polyethylene being the most common, found at an average concentration of 21.7±24.5 μg per milligram of plaque. Additionally, 12.1% of patients had measurable amounts of polyvinyl chloride in their plaques. Patients with MNPs in their plaques had a significantly higher risk of myocardial infarction, stroke, or death (hazard ratio: 4.53, 95% CI: 2.00 to 10.27, $P<0.001$) compared to those without MNPs. This statistical association suggests a potential link between MNP exposure and an elevated risk of cardiovascular disease (CVD) (Marfella et al., 2023).

A study in March 2022 aimed to determine whether ingestion of MPs, specifically polystyrene beads, could contribute to the development of pre-clinical signs of cardiovascular disease. Researchers conducted their experiments on Male C57BL/6 mice, which were exposed to normal drinking water or water supplemented with polystyrene beads of two sizes (0.5 μm and 5 μm) and two concentrations (0.1 μg/ml and 1 μg/ml) over 12 weeks. The study monitored various health metrics including body weight, glucose and insulin levels, changes in gut microbiome, and gene expression in adipose tissue. Mice exposed to MPs showed accelerated weight gain and increased body fat compared to controls, followed by elevated fasting plasma glucose and insulin levels, particularly in mice exposed to the smaller beads at the higher concentration (Zhao et al., 2022). This research states that the consumption of MPs was suggested to increase the adiposity and risk of obesity, highlighting the interplay between obesity and microplastic exposure in the development of cardiovascular diseases. (Van Gal et al., 2020) (Ortega et al., 2016)

7. Conclusion

This review establishes potential links between microplastic (MP) consumption, oxidative stress, and cardiovascular disease (CVD), particularly in regions such as Guam with high seafood consumption. By examining oxidative stress and its established role in promoting atherosclerosis, endothelial dysfunction, and apoptosis, we see how MPs can exacerbate these processes, potentially contributing to the higher rates of CVD observed in Guam. Additionally, the association between MPs, obesity, and increased oxidative stress further suggests that MP ingestion may be a contributing factor to the rising prevalence of CVD. While evidence from preclinical studies points to the harmful effects of MPs on the cardiovascular system, more research is needed to confirm these effects in humans and to better understand the long-term health implications of MP exposure. Also, the CVD rate and food consumption of Guam requires further update in their values and data. The potential relationship between MPs and CVD underscores the importance of environmental health in addressing cardiovascular risks.

Acknowledgments: I would like to express my sincere gratitude to Dr. Norman Kleiman from Columbia University for his invaluable guidance and expertise throughout the research process. His insights into public health and environmental science greatly enriched this study. I would also like to thank Imke Folkerts, Dr. Kleiman's teaching assistant, for her support and assistance, which was essential in refining the methodology and analysis. Their contributions have been instrumental in the completion of this work.

References:

Cervantes Gracia, K., Llanas-Cornejo, D., & Husi, H. CVD and Oxidative Stress. Journal of Clinical Medicine, 6(2), 22. MDPI, from: https://www.mdpi.com/2077-0383/6/2/22

Yu, P., Liu, Z., Wu, D., Chen, M., Lv, W., & Zhao, Y. Accumulation of polystyrene microplastics in juvenile Eriocheir sinensis and oxidative stress effects in the liver. Aquatic Toxicology. Elsevier, from: https://www.sciencedirect.com/science/article/abs/pii/S0166445X18300420

Kim, J.-H., Yu, Y.-B., & Choi, J.-H. Toxic effects on bioaccumulation, hematological parameters, oxidative stress, immune responses and neurotoxicity in fish exposed to microplastics: A review. Environmental Pollution. Elsevier, from: https://www.sciencedirect.com/science/article/pii/S0304389421003861

Dhalla, N. S., Temsah, R. M., & Netticadan, T. Role of oxidative stress in cardiovascular diseases. Journal of Hypertension. Lippincott Williams & Wilkins, from: https://journals.lww.com/jhypertension/abstract/2000/18060/role_of_oxidative_stress_in_cardiovascular.2.aspx

Sies, H. Oxidative stress: a concept in redox biology and medicine. Redox Biology. Elsevier, from: https://www.sciencedirect.com/science/article/pii/S2213231715000038

Mathers, C. D., Lopez, A., Stein, C., Ma Fat, D., Rao, C., Inoue, M., et al. (2001). Deaths and Disease Burden by Cause: Global Burden of Disease Estimates for 2001 by World Bank Country Groups. Disease Control Priorities Project Working Paper 18. Bethesda, MD: World Bank, from: https://www.ncbi.nlm.nih.gov/books/NBK11808/

Murphy, S. L., Kochanek, K. D., Xu, J., & Heron, M. Deaths: final data for 2012. National Vital Statistics Reports, 63, 1–117. Hyattsville, MD: National Center for Health Statistics, from: https://pubmed.ncbi.nlm.nih.gov/26759855/

Gaziano, T., Reddy, K. S., Paccaud, F., et al. Cardiovascular Disease. In: Jamison, D. T., Breman, J. G., Measham, A. R., et al., editors. Disease Control Priorities in Developing Countries (2nd ed.). Washington, DC: World Bank, from: https://www.ncbi.nlm.nih.gov/books/NBK11767/?report=reader#_NBK11767_pubdet_

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human Consumption of Microplastics. Environmental Science & Technology. Washington, DC: American Chemical Society, from: https://pubs.acs.org/doi/abs/10.1021/acs.est.9b01517

Bennett, G., Bardon, L. A., & Gibney, E. R. A Comparison of Dietary Patterns and Factors Influencing Food Choice among Ethnic Groups Living in One Locality: A Systematic Review. Nutrients, 14(5), 941. Basel, Switzerland: MDPI, from: https://www.mdpi.com/2072-6643/14/5/941

Alberghini, L., Truant, A., Santonicola, S., Colavita, G., & Giaccone, V. Microplastics in Fish and Fishery Products and Risks for Human Health: A Review. International Journal of Environmental Research and Public Health. Basel, Switzerland: MDPI, from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9819327/

Senoner, T., & Dichtl, W. Oxidative Stress in Cardiovascular Diseases: Still a Therapeutic Target? International Journal of Molecular Sciences, 20(19), 4745. Basel, Switzerland: MDPI, from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6769522/

Kerr, J. F. R., Wyllie, A. H., & Currie, A. R. Apoptosis: A Basic Biological Phenomenon with Wide-Ranging Implications in Tissue Kinetics. British Journal of Cancer, 26(4), 239–257. London, UK: Nature Publishing Group, from: https://www.nature.com/articles/bjc197233

Haunstetter, A., & Izumo, S. Apoptosis: Basic Mechanisms and Implications for Cardiovascular Disease. Circulation Research, 82(11), 1111–1119. Dallas, TX: American Heart Association, from: https://www.ahajournals.org/doi/full/10.1161/01.RES.82.11.1111#sec-1

Pexieder, T. Cell Death in the Morphogenesis and Teratogenesis of the Heart. Advances in Anatomy, Embryology and Cell Biology, 51, 3–99. New York, NY: Springer, from: https://scholar.google.com/scholar_lookup?title=Adv+Anat+Embryol+Cell+Biol&publication_year=1975&pages=3&pmid=1136873

James, T. N. Normal and abnormal consequences of apoptosis in the human heart: from postnatal morphogenesis to paroxysmal arrhythmias. Circulation, 90, 556–573. Dallas, TX: American Heart Association, from: https://pubmed.ncbi.nlm.nih.gov/8026044/

James, T. N., St. Martin, E., Willis, P. W., & Lohr, T. O. Apoptosis as a possible cause of gradual development of complete heart block and fatal arrhythmias associated with absence of the AV node, sinus node, and internodal pathways. Circulation, 93, 1424–1438. Dallas, TX: American Heart Association, from: https://pubmed.ncbi.nlm.nih.gov/8641033/

Takeda, K., Yu, Z. X., Nishikawa, T., Tanaka, M., Hosoda, S., Ferrans, V. J., & Kasajima, T. Apoptosis and DNA fragmentation in the bulbus cordis of the developing rat heart. Journal of Molecular and Cellular Cardiology, 28, 209–215. London, UK: Elsevier, from: https://pubmed.ncbi.nlm.nih.gov/8745228/

Gigault, J., ter Halle, A., Baudrimont, M., Pascal, P.-Y., Gauffre, F., Phi, T.-L., El Hadri, H., Grassl, B., & Reynaud, S. Current opinion: What is a nanoplastic? Environmental Pollution. Elsevier, from: https://www.sciencedirect.com/science/article/abs/pii/S0269749117337247?via%3Dihub

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. Marine pollution: Plastic waste inputs from land into the ocean. Science, from: https://pubmed.ncbi.nlm.nih.gov/25678662/

Chowdhury, S. R., Dey, A., Mondal, S., & Gautam, M. K. Environmental microplastics and nanoplastics: Effects on cardiovascular system. Journal of Hazardous Materials. Elsevier, from: https://www.sciencedirect.com/science/article/abs/pii/S2352007823003530?via%3Dihub

Das, A. The emerging role of microplastics in systemic toxicity: Involvement of reactive oxygen species (ROS). Science of the Total Environment. Elsevier, from: https://www.sciencedirect.com/science/article/abs/pii/S0048969723036999

Peluso, I., Morabito, G., Urban, L., Ioannone, F., & Serafi, M. Oxidative Stress in Atherosclerosis Development: The Central Role of LDL and Oxidative Burst. Endocrine, Metabolic & Immune Disorders Drug Targets, 12(4), 250–256. Bentham Science Publishers, from: https://www.ingentaconnect.com/content/ben/emiddt/2012/00000012/00000004/art00007#

Madamanchi, N. R., Hakim, Z. S., & Runge, M. S. Oxidative stress in atherogenesis and arterial thrombosis: the disconnect between cellular studies and clinical outcomes. Journal of Thrombosis and Haemostasis. Wiley, from: https://www.jthjournal.org/article/S1538-7836(22)13033-3/fulltext

Cervantes Gracia, K., Llanas-Cornejo, D., & Husi, H. CVD and Oxidative Stress. Journal of Clinical Medicine, 6(2), 22. MDPI, from: https://www.mdpi.com/2077-0383/6/2/22

Zhao, J., Gomes, D., Jin, L., Mathis, S. P., Li, X., Rouchka, E. C., Bodduluri, H., Conklin, D. J., & O'Toole, T. E. Polystyrene bead ingestion promotes adiposity and cardiometabolic disease in mice. Chemosphere. Elsevier, from: https://www.sciencedirect.com/science/article/pii/S0147651322000793?via%3Dihub

Van Gal, L. F., Mertens, I. L., & De Block, C. R. Mechanisms Linking Obesity With Cardiovascular Disease. Obesity Research & Clinical Practice. Elsevier, from: https://www.elsevier.com/obesity_research_clinical_practice

Marfella, R., Prattichizzo, F., Sardu, C., Fulgenzi, G., Graciotti, L., Spadoni, T., D'Onofrio, N., et al. Microplastics and Nanoplastics in Atheromas and Cardiovascular Events. New England Journal of Medicine. from: https://www.nejm.org/doi/full/10.1056/nejmoa2309822

Pinhey, T. K., Heathcote, G. M., & Craig, U.-K. Health Status of Diabetic Persons in an Asian-Pacific Population: Evidence from Guam. Asian American Journal of Health. from: https://guam.edu/research_asian_american_health

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2020). Correction to Human Consumption of Microplastics. Environmental Science & Technology. Washington, DC: American Chemical Society, from: https://pubs.acs.org/doi/abs/10.1021/acs.est.9b01517

Jackson, S. L., VanFrank, B. K., Lundeen, E., Uncangco, A., Alam, L., Coleman King, S. M., & Cogswell, M. E. Sodium in Store and Restaurant Food Environments — Guam, 2015. Morbidity and Mortality Weekly Report (MMWR). CDC, from: https://cdc.gov/mmwr/volumes/65/wr/mm6520a2.htm

Ortega, F. B., Lavie, C. J., & Blair, S. N. Obesity and Cardiovascular Disease. Circulation Research, 115, 306–883. Dallas, TX: American Heart Association, from: https://www.ahajournals.org/doi/full/10.1161/CIRCRESAHA.115.306883

Leon Guerrero, R. T., Paulino, Y. C., Novotny, R., & Murphy, S. P. Diet and obesity among Chamorro and Filipino adults on Guam. Public Health Nutrition. Cambridge University Press, from: https://pmc.ncbi.nlm.nih.gov/articles/PMC2762033/