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Unclean cooking fuel use and health outcomes in older adults: potential mechanisms, public health implications and future directions

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Abstract

Unclean cooking fuels (i.e., polluting fuels including kerosene/paraffin, and solid fuels) are a major contributor to diseases and mortality, specifically in low- and middle-income countries. This review aimed to identify potential mechanisms, public health implications and future directions of unclean cooking fuel use and health outcomes in older adults. There is an expanding body of literature to demonstrate associations between unclean cooking fuel use and multiple mental and physical health outcomes in older adults. Two key mechanisms likely driving such associations include inflammation and oxidative stress. Considering that inflammation and oxidative stress have been implicated in multiple other health conditions (e.g., arthritis and osteoporosis) in addition to those investigated to date on this topic it would be prudent to continue investigation of unclean cooking fuel use and with yet to be studied health outcomes. Moreover, future research is indeed now required to identify pathways to eliminating unclean cooking fuel globally to better the health of an aging global population and to support the implementation of Sustainable Development Goal 7.

Keywords

Unclean cooking fuel; older adults; public health; review

Background

Unclean cooking fuels (i.e., polluting fuels), including kerosene/paraffin, and solid fuels (coal/charcoal, wood, agriculture/crop, animal dung, shrubs/grass) are a major contributor to diseases and deaths, specifically in low- and middle-income countries.

Globally, approximately 3 billion people use traditional biomass such as fuelwood, which has detrimental health and environmental effects on households and the world at large, as their main source of cooking fuels (1). Importantly, access to clean cooking fuel is distributed disproportionately globally. Between 2010 to 2019, the rate of access to clean cooking fuels increased approximately 1% each year. This increase was mainly due to improvements in clean cooking access in five low- and middle-income countries, including: Brazil, China, India, Indonesia and Pakistan with relatively stable rates in other low- and middle-income countries (2). Current estimates project that one third of the global population will continue to use polluting fuels in 2030, with the majority residing in Sub-Saharan Africa (2). Finally, the use of unclean cooking fuels may disproportionally impact females since females are more likely to cook, owing to traditional roles, and thus have a higher exposure to such pollutants (3).

Unclean cooking fuel use and health outcomes

Population aging is occurring rapidly globally and the speed of aging in low- and middle-income countries is outpacing that of high-income- countries. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health An aging population coupled with a high prevalence of unclean cooking fuel use, particularly in low- and middle-income countries, is of public health concern as unclean cooking fuel use in the home has been found to be associated with a plethora of detrimental mental and physical health outcomes in middle-age and older adults, including: depression and anxiety (4–14), mild cognitive impairment and cognitive decline (15), slow gait speed (16), low hand grip strength (17), sleep problems (18–20), vision impairment and eye disease (21–26), cancer (27–29), respiratory disease (30–32), cardiovascular disease (33–35), and mortality (36–38), for example. Studies investigating the association between unclean cooking fuel use and health outcomes have controlled for a plethora of covariates with differences across studies. Common covariates included in statistical models across studies include age, sex, setting (e.g., rural or urban), education, wealth, marital status, employment status, smoking status, alcohol consumption, body mass index, number of chronic conditions, and disability. It should also be noted that exposure to unclean cooking fuel use is detrimental to all age groups, however, it is likely that older adults are at the greatest risk of adverse health outcomes owing to prolonged exposure to associated pollutants. For example, autopsy studies from children and young adults living in Mexico City have found associations between exposure to urban air pollution and particulate deposition or inflammation within the brain (39,40). Moreover, there may be potential interactions between exposure to unclean cooking fuels and ageing physiology. However, to the best of the authors' knowledge there is a scarcity of research looking at interactions between exposure to unclean cooking fuels and age particularly between middle age and older adults. Future research should aim to address this gap in the literature.

Potential mechanistic pathways between unclean cooking fuel use and health outcomes

In regard to unclean cooking fuel use there are likely common mechanistic pathways that explain its association with multiple adverse health outcomes. First, a large amount of pollution (e.g., PM2.5, PM10) is released and inhaled when cooking with biomass fuels in the home, and exposure to particulate matter (PM) may be detrimental to both physical and mental health by elevated oxidative stress and inflammatory reactions (9). Indeed, oxidative stress and inflammation have been implicated in multiple health outcomes that have been found to be associated with unclean cooking fuel use. For example, inflammation and reactive oxygen species (ROS) play important roles in neural and cardiovascular function, however, their accumulation in either brain or cardiac tissue results in disease. For example, both inflammatory dysfunction and ROS accumulation is evident in major depression, cardiovascular disease and respiratory disorders (41), whereas inflammation predisposes the development of cancer and promotes all stages of tumorigenesis (42). Inflammation and oxidative stress have also been implicated in eye disease, for example, oxidative stress plays a pivotal role in developing and accelerating retinal diseases including age-related macular degeneration, glaucoma, diabetic retinopathy, and retinal vein occlusion. Indeed, an excess amount of ROS can lead to functional and morphological impairments in retinal pigment epithelium, endothelial cells, and retinal ganglion cells (43). This is indeed particularly problematic for older adults as they are already at heightened risk of various eyes diseases and vision impairment, including, for example, cataracts and age-related macular degeneration (44,45).

Inflammation and ROS have been implicated in geriatric syndromes, in particular frailty, in older adults (46,47). Oxidative stress might lead to an activation of apoptotic pathways leading to cellular damage, aberrations in the expression of many transcription factors responsible for shifting protein synthesis to protein degradation, a decline in mitochondrial function, and an impairment of repair mechanisms (48). These interacting pathways may contribute to the detrimental effects of oxidative stress on muscles, bones, and the immune system (49). Loss of muscle mass and strength may reduce physical activity and thereby contribute to frailty (50). Frailty can also be considered as the opposite to successful aging, and is a relevant issue in geriatric medicine, since frailty is associated with a higher risk of poor outcomes such as falls, depression, disability, and mortality. Therefore, unclean cooking fuel use in middle aged and older adults can indirectly be associated with the development of frailty and unsuccessful aging. However, future longitudinal studies are needed to show this potential causal relationship. Moreover, it is possible that unclean cooking fuel use accelerates inflammaging, a condition characterized by elevated levels of blood inflammatory markers that carries high susceptibility to chronic morbidity, disability, frailty, and premature death. Potential mechanisms of inflammageing include genetic susceptibility, central obesity, increased gut permeability, changes to microbiota composition, cellular senescence, the NOD-, LRR- and pyrin domain-containing protein 3 (NLRP3) inflammasome activation, oxidative stress caused by dysfunctional mitochondria, immune cell dysregulation, and chronic infections (51). Frailty and inflammaging are thus potentially two conditions that heighten health risks of unclean cooking fuel use within older adult populations. Moreover, it should be noted that since frailty is a disorder that is further along in pathogenesis when compared to other health outcomes, then it is also possible that frailty may be the result of the health risks due to unclean cooking fuel use.

Next, PM exposure appears to alter both neurotransmitters within dopamine and glutamate systems (52). Whereas the level of dopamine has been shown to influence gait speed (53), anxiety modulation (54), depression (55), and cognitive impairment (55). PM, produced through unclean cooking fuel, may induce metabolic alterations that are consistent with the activation of the hypothalamus-pituitary-adrenal axis (56). Activation of the hypothalamus-pituitary-adrenal axis can lead to many unwanted issues such as depression, cognitive disorders, and frailty in older adults (57,58). Moreover, PM exposure has been found to be associated with a significant increase in serum levels of stress hormones and prolonged secretion of the stress hormone cortisol which has been implicated in the pathogeneses of unhealthy aging and related issues, such as depression and sleep disorders (59,60). When specifically considering cancer carcinogenic polycyclic aromatic hydrocarbons (PAH) are released during the use of unclean cooking fuels. PAH have been widely investigated and classified as carcinogenic to humans (IARC Group1) (61). Indeed, approximately 60.5% of the global total PAH emissions were from combustion of biomass fuels including wood and crop residues (62). Finally, when external human structure such as the eyes are exposed to high levels of PM and carbon monoxide via unclean cooking fuel, irritant effects may transpire, for example, eye complications (e.g., pain, redness, tearing) may materialize. Prolonged exposure may subsequently lead to eye disease and vision impairment (63).

Interestingly, unclean cooking fuel has been found to be associated with undernutrition in adults (64). Mechanisms by which polluting fuel exposure causes undernutrition in adults are still not well understood. However, it is believed to be involved in inefficient burning and combustion generated gases, toxic pollutants, and PM pathogenic processes. For example, carbon monoxide (CO) is one of the common gases emitted from inefficient burning of fuel and it has been found to be a trigger of weight reduction in obese mice (65). This is likely to be a consequence of elevated metabolism from upregulation of mitochondrial biogenesis and mitochondrial uncoupling causing alterations in morphology of the epidermal fat depot and adipocyte number (65). Another possible mechanism maybe owing to DNA damage by toxic pollutants such as PAH. Indeed, PAH has been found to be associated with a higher risk of chronic obstructive pulmonary disease, which could subsequently lead to elevated metabolic requirements, anorexia, less food intake, and accelerated catabolism (66). Nutritional problems are common in older adults, even in older obese adults, and undernutrition is associated with decreased functional capacity, impairment in balance and gait functions, falls, and depressed mood (67). Although previous studies on unclean cooking fuel and undernutrition have been conducted in young to middle age adults, it is known that undernutrition even in younger age groups is linked with severe short-term (e.g. delayed motor and cognitive development), medium-term (e.g. poorer school performances), and long-term consequences (e.g. abnormal metabolic status and increased risk of noncommunicable chronic diseases in adulthood) (64). Therefore, unclean cooking fuel use related problems, even at younger ages, can negatively affect the healthy aging process. Moreover, unclean cooking fuel use is common in low- and middle-income countries; (1) and undernutrition is also common in this setting (68). Therefore, low- and middle-income country status could be a potential confounding factor in the relationship between unclean cooking fuel and undernutrition.

Public health implications

Findings from existing literature on the association between unclean cooking fuel use and health outcomes support the adoption of the United Nations Sustainable Development Goal (SDG) 7 “ensure access to affordable, reliable, sustainable and modern energy for all” (69) and highlights the importance of applying SDG7 and directing resources towards the elimination of unclean cooking fuel use. The following is currently being suggested by key international bodies such as the World Health Organization to address the common use of unclean cooking fuel in LMICs: 1) Governments must prioritize clean-cooking solutions (i.e., access to clean and modern cooking energy), via evidence-based policies and strategies. 2) Mobilization of funds to scale up promising enterprises, so they become profitable, increase consumer choice and financing, and stimulate additional private investment. 3) Successful clean-cooking solutions should engage diverse public and private stakeholders. 4) Moving people towards cleaner and more efficient cooking solutions that meet local cultural, social and gender needs should be prioritized. 5) Improved monitoring of household energy use to track, measure impact, and assess progress towards achieving universal access.

Interestingly, there is a growing body of literature to suggest that the presence of chimneys or hoods when using unclean cooking fuel may mitigate against some of the detrimental health outcomes. For example, in one study including a large representative sample of older adults from six low- and middle-income countries, unclean cooking fuel (vs. clean cooking fuel) was associated with a significant 1.48 (95% CI = 1.08, 2.03) times higher odds for mild cognitive impairment (MCI). However, when investigating cooking ventilation, the absence of chimney or hood (compared to having a chimney or hood) was associated with significantly higher odds for MCI (OR = 1.88; 95% CI = 1.25, 2.84) (10). Thus the installation of appropriate cooking ventilation devices (i.e., chimney or hood) should be considered among those using solid fuels for cooking as this can remove a greater quantity of pollutants (70).

Limitations of the existing literature

While existing literature has significantly advanced knowledge on the association between unclean cooking fuel use and health outcomes, several limitations of this literature need to be addressed in future research. First, the vast majority of the literature on this topic is of a cross-sectional nature. Thus, it is often not confirmed whether unclean cooking fuel use is associated with poor health outcomes or vice versa. For example, it is well known that chronic conditions are associated with unemployment (71) and thus may drive poverty and subsequently unclean cooking fuel use. Future research of a longitudinal cohort nature is needed on unclean cooking fuel use and health outcomes. Second, the majority of literature on this topic has relied on self-reported measures of cooking fuel use and has not directly measured levels of pollutants in relation to unclean cooking fuel use in the home environment and its impact on health outcomes; such studies would allow for a more accurate understanding of observed associations and provide the development of robust hypothesises on the mechanistic pathways between unclean cooking fuel use and health outcomes that could be further studied in experimental lab based trials. Finally, there is an uneven distribution between number of studies looking at varying health outcomes. For example, very few studies exist on the relationship between cooking fuel use and gait speed, a key criterion in epidemiology to strive towards cause and effect is consistency in associations between different populations. Thus, we encourage more epidemiological investigation into the relationship between unclean cooking fuel use and all health outcomes.

Conclusion and future directions

There is now a relatively large and expanding body of literature to demonstrate the association between unclean cooking fuel use and a plethora of mental and physical health outcomes in older adults. Several plausible mechanisms exist that likely explain such associations with key mechanisms likely being inflammation and oxidative stress. Considering that inflammation and oxidative stress have been implicated in multiple other mental and physical health conditions in addition to those investigated to date on this topic, such as, arthritis, osteoporosis, and psychotic episodes, it would be prudent to continue investigation of unclean cooking fuel use and with yet to be studied health outcomes. Future research is indeed now required to identify plausible pathways to eliminating unclean cooking fuel globally to better the health of an aging global population and to support the implementation of SDG7.

References

1. Twumasi MA, Jiang Y, Addai B, Asante D, Dan L, Ding Z. Determinants of household choice of cooking energy and the effect of clean cooking energy consumption on household members' health status: The case of rural Ghana. *Sustain Prod Consum*. 2021. https://doi.org/10.1016/j.spc.2021.06.005

2. World Health Organization. WHO publishes new global data on the use of clean and polluting fuels for cooking by fuel type. https://www.who.int/news/item/20-01-2022-who-publishes-new-global-data-on-the-use-of-clean-and-polluting-fuels-for-cooking-by-fuel-type. Published 2022. Accessed June 27, 2023.

3. Wolfson JA, Ishikawa Y, Hosokawa C, Janisch K, Massa J, Eisenberg DM. Gender differences in global estimates of cooking frequency prior to COVID-19. *Appetite*. 2021;161:105117. https://doi.org/10.1016/j.appet.2021.105117

4. Smith L, Veronese N, Sánchez GFL, et al. The association of cooking fuels with depression and anxiety symptoms among adults aged≥ 65 years from low-and middle-income countries. *J Affect Disord*. 2022;311:494-499. https://doi.org/10.1016/j.jad.2022.05.103

5. Banerjee M, Siddique S, Dutta A, Mukherjee B, Ray MR. Cooking with biomass increases the risk of depression in pre-menopausal women in India. *Soc Sci Med*. 2012;75(3):565-572. https://doi.org/10.1016/j.socscimed.2012.03.021

6. Chen H, Chen L, Hao G. Sex difference in the association between solid fuel use and cognitive function in rural China. *Environ Res*. 2021;195:110820. https://doi.org/10.1016/j.envres.2021.110820

7. Liu Y, Chen X, Yan Z. Depression in the house: the effects of household air pollution from solid fuel use among the middle-aged and older population in China. *Sci Total Environ*. 2020;703:134706. https://doi.org/10.1016/j.scitotenv.2019.134706

8. Shao J, Ge T, Liu Y, Zhao Z, Xia Y. Longitudinal associations between household solid fuel use and depression in middle-aged and older Chinese population: A cohort study. *Ecotoxicol Environ Saf*. 2021;209:111833. https://doi.org/10.1016/j.ecoenv.2020.111833

9. Deng Y, Zhao H, Liu Y, et al. Association of using biomass fuel for cooking with depression and anxiety symptoms in older Chinese adults. *Sci Total Environ*. 2021:152256. https://doi.org/10.1016/j.scitotenv.2021.152256

10. Smith L, Pizzol D, López Sánchez GF, et al. Association between cooking fuels and mild cognitive impairment among older adults from six low-and middle-income countries. *Sci Rep*. 2022;12(1):1-8. https://doi.org/10.1038/s41598-022-17216-w

11. Cao L, Zhao Z, Ji C, Xia Y. Association between solid fuel use and cognitive impairment: a cross-sectional and follow-up study in a middle-aged and older Chinese population. *Environ Int*. 2021;146:106251. https://doi.org/10.1016/j.envint.2020.106251

12. Du M, Tao L, Zhu L, Liu J. Association between biomass fuel use and the risk of cognitive impairment among older populations in China: a population-based cohort study. *Environ Heal*. 2021;20(1):1-11. https://doi.org/10.1186/s12940-021-00706-1

13. Štorkánová H, Oreská S, Špiritović M, et al. Plasma Hsp90 levels in patients with systemic sclerosis and relation to lung and skin involvement: a cross-sectional and longitudinal study. *Sci Rep*. 2021;11(1):1. https://doi.org/10.1038/s41598-020-79139-8

14. Luo Y, Zhong Y, Pang L, Zhao Y, Liang R, Zheng X. The effects of indoor air pollution from solid fuel use on cognitive function among middle-aged and older population in China. *Sci Total Environ*. 2021;754:142460. https://doi.org/10.1016/j.scitotenv.2020.142460

15. Saenz JL. Solid cooking fuel use and cognitive decline among older Mexican adults. *Indoor Air*. 2021. https://doi.org/10.1111/ina.12844

16. Smith L, López Sánchez GF, Pizzol D, et al. Unclean cooking fuel use and slow gait speed among older adults from six countries. *Journals Gerontol Ser A*. 2023:glad109. https://doi.org/10.1093/gerona/glad109

17. Liu Y, Chang Q, Xia Y, Zhao Y. Longitudinal Associations Between Household Solid Fuel Use and Handgrip Strength in Middle-Aged and Older Chinese Individuals: The China Health and Retirement Longitudinal Study. *Front Public Heal*. 2022:1942. https://doi.org/10.3389/fpubh.2022.881759

18. Yu H, Luo J, Chen K, Pollitt KJG, Liew Z. Solid fuels use for cooking and sleep health in adults aged 45 years and older in China. *Sci Rep*. 2021;11(1):1-9. https://doi.org/10.1038/s41598-021-92452-0

19. Chen C, Liu GG, Sun Y, et al. Association between household fuel use and sleep quality in the oldest-old: Evidence from a propensity-score matched case-control study in Hainan, China. *Environ Res*. 2020;191:110229. https://doi.org/10.1016/j.envres.2020.110229

20. Wei F, Nie G, Zhou B, et al. Association between Chinese cooking oil fumes and sleep quality among a middle-aged Chinese population. *Environ Pollut*. 2017;227:543-551. https://doi.org/10.1016/j.envpol.2017.05.018

21. Patel M, Shrestha MK, Manandhar A, et al. Effect of exposure to biomass smoke from cooking fuel types and eye disorders in women from hilly and plain regions of Nepal. *Br J Ophthalmol*. 2022;106(1):141-148. http://dx.doi.org/10.1136/bjophthalmol-2020-316766

22. Chan KH, Yan M, Bennett DA, et al. Long-term solid fuel use and risks of major eye diseases in China: A population-based cohort study of 486,532 adults. *PLoS Med*. 2021;18(7):e1003716. https://doi.org/10.1371/journal.pmed.1003716

23. Smith KR, Bruce N, Balakrishnan K, et al. Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annu Rev Public Health*. 2014;35:185-206. https://doi.org/10.1146/annurev-publhealth-032013-182356

24. Hemant K, Narlawar UW, Sukhsohale ND, Sushama T, Ughade SN. Biomass fuel use and risk of cataract: systematic review and meta-analysis. *Br J Med Med Res*. 2014;4(1):382-394. https://doi.org/10.9734/BJMMR/2014/5297

25. Ravilla TD, Gupta S, Ravindran RD, et al. Use of cooking fuels and cataract in a population-based study: the India Eye Disease Study. *Environ Health Perspect*. 2016;124(12):1857-1862. https://doi.org/10.1289/EHP193

26. Li X, Guo Y, Liu T, et al. The association of cooking fuels with cataract among adults aged 50 years and older in low-and middle-income countries: results from the WHO Study on global AGEing and adult health (SAGE). *Sci Total Environ*. 2021:148093. https://doi.org/10.1016/j.scitotenv.2021.148093

27. Liu T, Chen R, Zheng R, Li L, Wang S. Household air pollution from solid cooking fuel combustion and female breast cancer. *Front Public Heal*. 2021;9:677851.

https://doi.org/10.3389/fpubh.2021.677851

28. Sheikh M, Poustchi H, Pourshams A, et al. Household fuel use and the risk of gastrointestinal cancers: the Golestan cohort study. *Environ Health Perspect*. 2020;128(6):67002. https://doi.org/10.1289/EHP5907

29. Bruce N, Dherani M, Liu R, et al. Does household use of biomass fuel cause lung cancer? A systematic review and evaluation of the evidence for the GBD 2010 study. *Thorax*. 2015;70(5):433-441. http://dx.doi.org/10.1136/thoraxjnl-2014-206625

30. Faizan MA, Thakur R. Association between solid cooking fuels and respiratory disease across socio-demographic groups in India. *J Heal Pollut*. 2019;9(23). https://doi.org/10.5696/2156-9614-9.23.190911

31. Mbatchou Ngahane BH, Afane Ze E, Chebu C, et al. Effects of cooking fuel smoke on respiratory symptoms and lung function in semi-rural women in Cameroon. *Int J Occup Environ Health*. 2015;21(1):61-65. https://doi.org/10.1179/2049396714Y.0000000090

32. Chan KH, Kurmi OP, Bennett DA, et al. Solid fuel use and risks of respiratory diseases. A cohort study of 280,000 Chinese never-smokers. *Am J Respir Crit Care Med*. 2019;199(3):352-361. https://doi.org/10.1164/rccm.201803-0432OC

33. Ji H, Chen Q, Wu R, et al. Indoor solid fuel use for cooking and the risk of incidental non-fatal cardiovascular disease among middle-aged and elderly Chinese adults: a prospective cohort study. *BMJ Open*. 2022;12(5):e054170. http://dx.doi.org/10.1136/bmjopen-2021-054170

34. Juntarawijit C, Juntarawijit Y. Cooking with biomass fuel and cardiovascular disease: a

cross-sectional study among rural villagers in Phitsanulok, Thailand. *F1000Research*. 2020;9. https://doi.org/10.12688%2Ff1000research.23457.2

35. Yu K, Qiu G, Chan K-H, et al. Association of solid fuel use with risk of cardiovascular and all-cause mortality in rural China. *Jama*. 2018;319(13):1351-1361. https://doi.org/10.1001/jama.2018.2151

36. Shen S, Luo M, Meng X, Deng Y, Cheng S. All-cause mortality risk associated with solid fuel use among Chinese elderly people: a national retrospective longitudinal study. *Front public Heal*. 2021;9:741637. https://doi.org/10.3389/fpubh.2021.741637

37. Yang Y, Liu Y, Peng L, et al. Cooking or heating with solid fuels increased the all-cause mortality risk among mid-aged and elderly People in China. *Environ Heal*. 2022;21(1):91. https://doi.org/10.1186/s12940-022-00903-6

38. Yu K, Lv J, Qiu G, et al. Cooking fuels and risk of all-cause and cardiopulmonary mortality in urban China: a prospective cohort study. *Lancet Glob Heal*. 2020;8(3):e430-e439. https://doi.org/10.1016/S2214-109X(19)30525-X

39. Calderón-Garcidueñas L, Franco-Lira M, Henríquez-Roldán C, et al. Urban air pollution: influences on olfactory function and pathology in exposed children and young adults. *Exp Toxicol Pathol*. 2010;62(1):91-102. https://doi.org/10.1016/j.etp.2009.02.117

40. Calderón-Garcidueñas L, Solt AC, Henríquez-Roldán C, et al. Long-term air pollution exposure is associated with neuroinflammation, an altered innate immune response, disruption of the blood-brain barrier, ultrafine particulate deposition, and accumulation of amyloid β-42 and α-synuclein in children and young adults. *Toxicol Pathol*. 2008;36(2):289-310. https://doi.org/10.1177/0192623307313011

41. Wood SK. The role of inflammation and oxidative stress in depression and cardiovascular disease. In: *Cardiovascular Implications of Stress and Depression*. Elsevier; 2020:175-209. https://doi.org/10.1016/B978-0-12-815015-3.00008-8

42. Greten FR, Grivennikov SI. Inflammation and cancer: triggers, mechanisms, and consequences. *Immunity*. 2019;51(1):27-41. https://doi.org/10.1016/j.immuni.2019.06.025

43. Masuda T, Shimazawa M, Hara H. Retinal diseases associated with oxidative stress and the effects of a free radical scavenger (Edaravone). *Oxid Med Cell Longev*. 2017;2017. https://doi.org/10.1155/2017/9208489

44. National Eye Institute. Cataracts. https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/cataracts. Published 2023. Accessed June 27, 2023.

45. National Eye Institute. Age-Related Macular Degeneration (AMD). https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/age-related-macular-degeneration. Published 2021. Accessed June 27, 2023.

46. Soysal P, Isik AT, Carvalho AF, et al. Oxidative stress and frailty: A systematic review and synthesis of the best evidence. *Maturitas*. 2017;99:66-72. https://doi.org/10.1016/j.maturitas.2017.01.006

47. Soysal P, Stubbs B, Lucato P, et al. Inflammation and frailty in the elderly: a systematic review and meta-analysis. *Ageing Res Rev*. 2016;31:1-8. https://doi.org/10.1016/j.arr.2016.08.006

48. Pinto M, Moraes CT. Mechanisms linking mtDNA damage and aging. *Free Radic Biol Med*. 2015;85:250-258. https://doi.org/10.1016/j.freeradbiomed.2015.05.005

49. Derbré F, Gratas-Delamarche A, Gómez-Cabrera MC, Viña J. Inactivity-induced oxidative stress: a central role in age-related sarcopenia? *Eur J Sport Sci*. 2014;14(sup1):S98-S108. https://doi.org/10.1080/17461391.2011.654268

50. Agostini F, Libera LD, Rittweger J, et al. Effects of inactivity on human muscle glutathione synthesis by a double- tracer and single- biopsy approach. *J Physiol*. 2010;588(24):5089-5104. https://doi.org/10.1113/jphysiol.2010.198283

51. Ferrucci L, Fabbri E. Inflammageing: chronic inflammation in ageing, cardiovascular disease, and frailty. *Nat Rev Cardiol*. 2018;15(9):505-522. https://doi.org/10.1038/s41569-018-0064-2

52. Jankowska-Kieltyka M, Roman A, Nalepa I. The air we breathe: air pollution as a prevalent proinflammatory stimulus contributing to neurodegeneration. *Front Cell Neurosci*. 2021;15:239. https://doi.org/10.3389/fncel.2021.647643

53. Cham R, Studenski SA, Perera S, Bohnen NI. Striatal dopaminergic denervation and gait in healthy adults. *Exp brain Res*. 2008;185(3):391-398. https://doi.org/10.1007/s00221-007-1161-3

54. Zarrindast M-R, Khakpai F. The modulatory role of dopamine in anxiety-like behavior. *Arch Iran Med*. 2015;18(9):0.

55. Belujon P, Grace AA. Dopamine system dysregulation in major depressive disorders. *Int J Neuropsychopharmacol*. 2017;20(12):1036-1046. https://doi.org/10.1093/ijnp/pyx056

56. Li H, Cai J, Chen R, et al. Particulate matter exposure and stress hormone levels: a randomized, double-blind, crossover trial of air purification. *Circulation*.

2017;136(7):618-627. https://doi.org/10.1161/CIRCULATIONAHA.116.026796

57. Varghese FP, Brown ES. The hypothalamic-pituitary-adrenal axis in major depressive disorder: a brief primer for primary care physicians. *Prim Care Companion J Clin Psychiatry*. 2001;3(4):151.

58. Muntsant A, Giménez-Llort L. Crosstalk of Alzheimer's disease-phenotype, HPA axis, splenic oxidative stress and frailty in late-stages of dementia, with special concerns on the effects of social isolation: A translational neuroscience approach. *Front Aging Neurosci*. 2022;14:969381. https://doi.org/10.3389/fnagi.2022.969381

59. Qin D, Rizak J, Feng X, et al. Prolonged secretion of cortisol as a possible mechanism underlying stress and depressive behaviour. *Sci Rep*. 2016;6(1):1-9. https://doi.org/10.1038/srep30187

60. De Nys L, Anderson K, Ofosu EF, Ryde GC, Connelly J, Whittaker AC. The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis. *Psychoneuroendocrinology*. 2022:105843. https://doi.org/10.1016/j.psyneuen.2022.105843

61. Humans IWG on the E of CR to. Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. *IARC Monogr Eval Carcinog risks to humans*. 2010;92:1.

62. Shen H, Huang Y, Wang R, et al. Global atmospheric emissions of polycyclic aromatic hydrocarbons from 1960 to 2008 and future predictions. *Environ Sci Technol*. 2013;47(12):6415-6424.

63. Lin C-C, Chiu C-C, Lee P-Y, et al. The Adverse Effects of Air Pollution on the Eye: A Review. *Int J Environ Res Public Health*. 2022;19(3):1186. https://doi.org/10.3390/ijerph19031186

64. Li J, Xu X, Li J, Li D, Liu Q, Xue H. Association between household fuel types and undernutrition status of adults and children under 5 years in 14 low and middle income countries. *Environ Res Lett*. 2021;16(5):54079. https://doi.org/10.1088/1748-9326/abf005

65. Hosick PA, AlAmodi AA, Storm M V, et al. Chronic carbon monoxide treatment attenuates development of obesity and remodels adipocytes in mice fed a high-fat diet. *Int J Obes*. 2014;38(1):132-139. https://doi.org/10.1038/ijo.2013.61

66. Wen L, Ben X, Yang Z, et al. Association between co-exposure of polycyclic aromatic hydrocarbons and chronic obstructive pulmonary disease among the US adults: results from the 2013–2016 National Health and Nutrition Examination Survey. *Environ Sci Pollut Res*. 2023:1-12. https://doi.org/10.1007/s11356-023-26413-7

67. Soysal P, Koc Okudur S, Kilic N, Ipar O, Smith L. The prevalence of undernutrition and associated factors in older obese patients. *Aging Clin Exp Res*. 2022;34(9):2023-2030. https://doi.org/10.1007/s40520-022-02143-7

68. World Health Organization. More than one in three low- and middle-income countries face both extremes of malnutrition. https://www.who.int/news/item/16-12-2019-more-than-one-in-three-low--and-middle-income-countries-face-both-extremes-of-malnutrition. Published 2019. Accessed June 27, 2023.

69. United Nations. Goals 7 Ensure access to affordable, reliable, sustainable and modern energy for all. https://sdgs.un.org/goals/goal7. Published 2021.

70. Hartinger SM, Commodore AA, Hattendorf J, et al. Chimney stoves modestly improved Indoor Air Quality measurements compared with traditional open fire stoves: results from a small- scale intervention study in rural Peru. *Indoor Air*. 2013;23(4):342-352. https://doi.org/10.1111/ina.12027

71. Yildiz B, Burdorf A, Schuring M. The influence of chronic diseases and multimorbidity on entering paid employment among unemployed persons–a longitudinal register-based study. *Scand J Work Environ Health*. 2021;47(3):208. https://doi.org/10.5271%2Fsjweh.3942