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RESEARCH ARTICLE

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Herpes zoster in older adults: Impact on carbon footprint in the United States

Desmond Curran[a], Jacopo Bitetti[b], Imogen Catterall[b,c], and Stephen Wincott[d]

[a]Value Evidence, GSK, Wavre, Belgium; [b]Medical Affairs, GSK, Zug, Switzerland; [c]Corporate Sustainability, The Carbon Trust, London, UK; [d]Environment, Health & Safety, GSK, London, UK

ABSTRACT

We provide estimates for (I) annual herpes zoster (HZ) cases, (II) carbon costs related to healthcare utilization, and (III) annual carbon emissions due to HZ among ≥50 years of age (YOA) United States (US) population. We estimated the annual number of HZ cases in the US based on available incidence data and demographic data of individuals ≥50 YOA. Both the healthcare resource utilization (HCRU) associated with HZ cases and the unit carbon dioxide equivalent (i.e. CO_2e) costs associated with each type of HCRU in the US were estimated based on literature and studies available online. The carbon footprint associated with HZ annually among US adults ≥50 YOA was estimated by multiplying the unit carbon estimates by the HCRU. In the US population aged ≥50 YOA in 2020 (i.e. approximately 118 million), approximately 1.1 million cases of HZ occur annually assuming no vaccination. Based on 2 sources of HCRU the average $kgCO_2e$ per HZ patient ranged from 61.0 to 97.6 $kgCO_2e$, with values by age group ranging from 40.9 $kgCO_2e$ in patients aged 50–59 to 195.9 $kgCO_2e$ in patients ≥80 YOA. The total annual HZ associated carbon ranged between 67,000 and 107,000 tons of CO_2e in the US population aged ≥50 YOA. The impact of HZ on carbon footprint in the US results in considerable greenhouse gas (GHG)emissions. Assuming no vaccination, the burden of HZ is projected to rise over the coming years with the aging populations consequently worsening its impact on GHG emissions. (Figure 1)

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Introduction

Increasing scientific evidence shows that changes in the climate and the natural world are impacting human health.[1,2] The World Health Organization noted climate change as one of the biggest risks to human health and consequently addressing climate change as a key public health opportunity in improving human health.[3] Healthcare and the provision of healthcare also contribute to greenhouse gas (GHG) emissions and climate change, and as such, may contribute negatively to a population's health.[2] The health impacts of environmental change are well recognized,[4] however, the environmental footprint of the healthcare sector is less well documented.

Lenzen et al.[2] provided a global assessment of the environmental footprint of health care.[2] Several detailed country-specific reports suggest that the carbon footprint attributed to health care ranges from 2% in Indonesia to 10% in Russia, of the total national carbon footprint.[2] As such, the healthcare sector has a vital role to play in climate change mitigation efforts, which will not only result in substantial reductions in GHG emissions, but can often lead to enhanced patient care, staff satisfaction, and cost savings.[5]

Carbon footprints are traditionally measured in terms of global warming potential (GWP). GWP is the heat absorbed by any greenhouse gas in the atmosphere, and quantified as carbon dioxide equivalent (CO_2e), whereby for any other gas, CO_2e is the mass of CO_2 that would warm the earth as much as the mass of that gas. As such CO_2e emissions include the effects of greenhouse gases such as CO_2, methane (CH_4) and nitrous oxide (N_2O).[6] Hospitals and pharmaceuticals are considered to be major contributors to healthcare carbon footprints.[7] In particular, hospitals are highly energy intensive, consume large amounts of resources, and produce a large amount of waste.[8]

Very limited data is available on the impact of specific diseases on carbon footprints. Desterbecq et al. provide a summary of environmental impacts of various disease areas and healthcare products.[9] The number of studies included in their review increased from 1 in 2004 to 10 in 2022. Several studies were carried out on vaccine preventable disease including pertussis, influenza, respiratory syncytial virus and COVID-19.[10–13] In this manuscript we explore the carbon footprint associated with another vaccine-preventable disease, i.e. herpes zoster (HZ), focusing on adults aged ≥50 years of age (YOA) in the United States (US). HZ typically manifests as a unilateral, painful dermatomal rash (Figure 1).[14] In the US, approximately 30% of the population will develop HZ during their lifetime.[15] The median duration of HZ is approximately 30 days,[16] but up to 30% of HZ patients develop postherpetic neuralgia (PHN), a chronic condition of debilitating pain that may last for months or even years and is very difficult to treat.[17,18] HZ contributes annually to GHG emissions through healthcare visits and treatment (e.g., hospitalizations,

CONTACT Desmond Curran desmond.x.curran@gsk.com Value Evidence, GSK, Avenue Fleming, 20, Wavre 1300, Belgium.
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physician visits, HZ medication). We present estimates of (I) the annual number of HZ cases in the US, (II) the unit carbon costs associated with healthcare utilization in the US and (III) the carbon associated with HZ annually in the US in population aged ≥50 YOA.

Methods

The carbon footprint of HZ was estimated using data from published literature and national data sources from the US. The US population estimates by age were taken from the United Nations Department of Economic and Social Affairs population estimates.[19] Incidence rates of HZ were based on the publication of Johnson et al.[20] and health care resource utilization for patients with HZ taken from 2 alternative sources (I) Table 2 of Johnson et al.[21] and (II) Table 2 of Meyers et al.[22] All 3 studies used claims data from the Truven Health Analytics MarketScan Commercial Claims and Encounters database and the Medicare Supplemental and Coordination of Benefits database. The annual number of HZ cases in the US was calculated by multiplying the US age-group specific population estimates by the annual incidence rates of HZ.

Unit carbon cost of all healthcare treatment steps that a typical patient affected by HZ undergoes was calculated, e.g., based on the average time spent in each facility apportioned to the area utilized per patient, energy consumption, and personal protective equipment (PPE). The facilities included in the analysis were: hospital inpatient, hospital outpatient, emergency department, primary care physician and pharmacy. The carbon cost of transport was calculated based on the average time taken to get to each facility split by type of facility, population density of a region and/or population density split by rural, suburban and urban. The carbon cost accounted for the type of transport, distance and mode of transport to the medical facility. The average distance to each facility was estimated as follows: hospital 5.62 miles (assuming 10% of patients arrived from the emergency department); emergency department 11.89 miles; pharmacy 5.36 miles, primary care physician 4.3 miles.

The calculations were based on average consumption data across the US. The analysis was conducted from a healthcare perspective (i.e., including direct and non-direct medical CO_2 e costs). Further details are provided in the supplementary material text.[23–53]

The per HZ patient CO_2e for each age group was estimated by summing over i the product of the healthcare resource utilization per HZ case for healthcare facility type i and age group a, from Johnson et al.[21] and Meyers et al.[22] respectively and the unit $kgCO_2e$ costs per healthcare facility type i for age group a:

$$\text{Per HZ patient } CO_2e_a = \sum_i (HCRU_{ia} \times CO_2e_{ia})$$

The total annual CO_2e was subsequently calculated by summing over a the product of the annual number of HZ cases for age group a, and the per patient CO_2e for age group a:

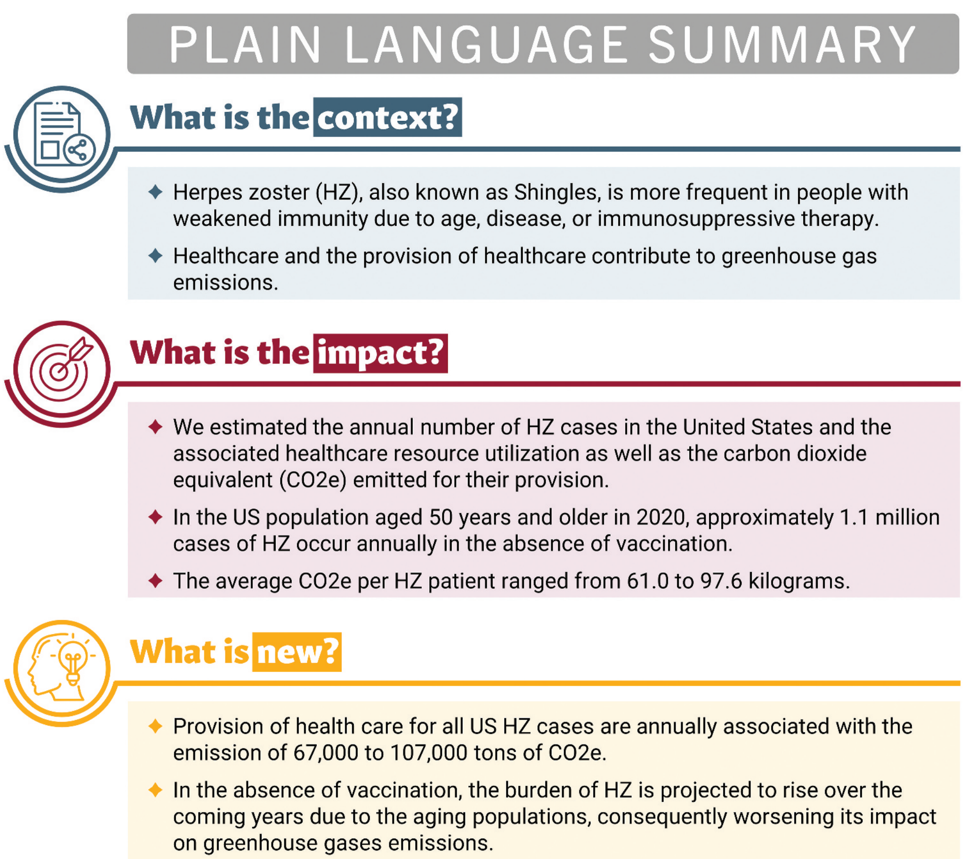

Figure 1. Plain language summary.

$$\text{Total annual } CO_2e = \Sigma_a \left(HZcases_a \times \text{Per HZ patient } CO_2e_a \right)$$

Results

Applying the annual incidence rates to the US population ≥50 YOA (i.e. approximately 118 million in 2020 (see Table 1)) yields an estimate of approximately 1.1 million cases of HZ in 2020 assuming no vaccination.

The estimated unit $kgCO_2e$ for each facility is presented in Table 2. Note, each day of hospitalization is associated with 110.82 $kgCO_2e$. It was estimated that on average the length of stay in hospital due to a HZ episode in individuals aged ≥50 years was 7.4 days (see text in Supplementary Material for more details).

Table 3 presents the estimated annual $kgCO_2e$ associated with HZ cases by age group and overall based on 2 alternative sources of healthcare resource utilization estimates. Based on the healthcare resource utilization (HCRU) estimates of Johnson et al.[21] the average $kgCO_2e$ per HZ patient was estimated as 61.0, ranging from 40.9 $kgCO_2e$ in patients aged 50–59 to 121.7 $kgCO_2e$ in patients aged 80 years and older. Similarly, based on the HCRU estimates of Meyers et al.[22] the average $kgCO_2e$ per HZ patient was estimated as 97.6, ranging from 63.6 $kgCO_2e$ in patients aged 50–59 to 195.9 $kgCO_2e$ in patients aged 80 and older. Based on these estimates, the overall emissions $kgCO_2e$ associated with HZ in the US in adults aged ≥50 years was approximately between 67,000 and 107,000 tons CO_2e.

Figure 2 presents the percent annual $kgCO_2e$ associated with HZ cases by healthcare resource. Based on both sources of HCRU estimates, hospitalization is associated with the largest contribution of CO_2e.

Table 1. Estimated number of annual herpes zoster cases by age group and overall.

Age	Population	Annual incidence	Annual cases
50–59 YOA	42,120,077	0.00674	283,889
60–64 YOA	20,669,143	0.00932	192,636
65–69 YOA	17,819,027	0.00932	166,073
70–79 YOA	24,082,597	0.01202	289,473
80+ YOA	13,147,182	0.01278	168,021
Total	117,838,026		1,100,093

YOA, years of age.

Discussion

In this manuscript, we describe the first estimates of the healthcare related carbon footprint associated with HZ in the US in adults aged 50 years and older. We estimated 1.1 million cases of HZ annually, in line with previous publications,[54–56] resulting in between 67,000 and 107,000 tons of CO_2e in the US, which is equivalent to between 41,000 return flights and 65,000 return flights from London to New York.[57]

Many decision-making bodies, such as the National Health Service (NHS) in the United Kingdom, are putting in place plans and targets to make the healthcare sector, including hospitals, more sustainable.[7] For example, several solutions are proposed to improve the environmental impact of hospitals, including engineering solutions to upgrade buildings; use of renewable energy and energy savings schemes; improved waste segregation

Table 2. Estimated unit of kgCo2e by facility.

	Energy				Equipment (PPE)	Diagnostic procedures	Return transport
	Energy Type	Consumption (kWh/ patient)	Emissions factor (kgCO2e/unit)	Emissions (kgCO2e)			
Hospitalisation per day	Natural Gas	194.653	0.181	35.278	3.37	0.73	4.18
	Electricity	182.995	0.413	75.541			
	Total			110.82			
Emergency department	Natural Gas	3.633	0.181	0.658	1.20	0.73	7.82
	Electricity	3.368	0.413	1.390			
	Total			2.05			
Primary care physician	Natural Gas	0.089	0.181	0.016			2.87
	Electricity	0.146	0.413	0.060			
	Total			0.08			
Outpatient	Natural Gas	0.213	0.181	0.039			4.18
	Electricity	0.303	0.413	0.125			
	Total			0.16			
Pharmacy	Natural Gas	0.097	0.181	0.018			
	Electricity	0.156	0.413	0.065			
	Total			0.08			3.57

CO2e, carbon dioxide equivalent; PPE, personal protective equipment. See supplementary text for further details

Table 3. Estimated annual kgCo2e associated with herpes zoster cases by age group and overall.

		Based on Johnson et al.[21]		Based on Meyers et al.[22]	
Age	HZ cases	Per patient $kgCO_2e$	Total tons CO_2e	Per patient $kgCO_2e$	Total tons CO_2e
50–59 YOA	283,889	40.9	11,602	63.6	18,052
60–64 YOA	192,636	46.5	8,959	62.0	11,951
65–69 YOA	166,073	51.4	8,538	73.2	12,159
70–79 YOA	289,473	60.6	17,536	111.5	32,278
80+ YOA	168,021	121.7	20,450	195.9	32,921
Total	1,100,093	61.0	67,085	97.6	107,362

CO2e, carbon dioxide equivalent; HZ, herpes zoster; kg, kilogram; YOA, years of age.

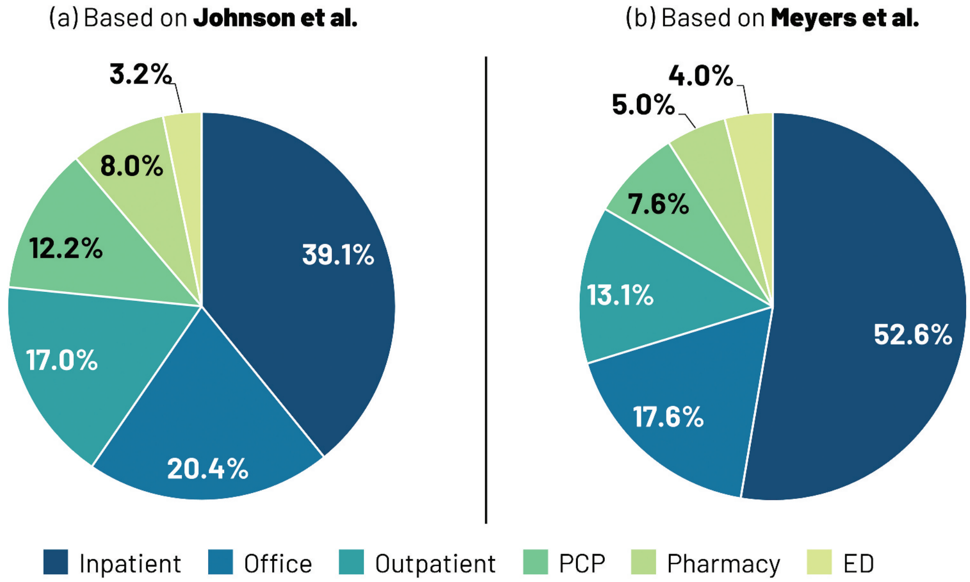

Figure 2. Annual total kgCo2e associated with herpes zoster cases by healthcare resource based on (a) Johnson et al.[21] (b) Meyers et al.[22] Note. ED, emergency department; PCP, primary care physician

facilities and recycling rates; travel and transport (e.g., use of public transport and cycle to work and lift-share schemes for staff); education on sustainability and waste management.

Given that transport is one of the main contributors to carbon emissions associated with HZ visits, alternative solutions such as telehealth could circumvent the need for face-to-face visits including emergency department, outpatient and/or primary care physician visits. It may be feasible for diagnosis and monitoring of HZ patients to be performed remotely thus reducing the carbon footprint associated with face-to-face visits.

The United Nations has developed 17 Sustainable Development Goals many of which are directly applicable to the health sector including: Good Health and Well-being, Affordable and Clean Energy, Industry, Innovation and Infrastructure, Sustainable Cities and Communities, Responsible Consumption and Reduction, Climate Action, Life on Land, and Partnerships for the Goals.[58]

As in other sectors and industries, progress needs to be tracked in the healthcare sector by integrating sustainability indices into existing forms of reporting (e.g., financial and healthcare outcomes reports). Integrated reporting allows better monitoring of progress and identification of areas of improvement. Life cycle analyses, e.g., of medical interventions, which provide in-depth reports of the energy and resources needed to create, package, ship, administer and dispose of an item, are substantially lacking for products in the medical field.[59] The lack of measurable information often limits potential approaches to guide future improvements in the carbon footprint associated with an intervention.

In 2022 the United States signed into law the Inflation Reduction Act (IRA), which directs new federal spending toward reducing carbon emissions, including grants and incentives for lowering emissions.[60] The IRA is projected to reduce US GHG emissions by 42% (3.3 Gigatons) by 2030, compared to 2005. A consequence of the legislation and ambitious targets is that evaluation of environmental impacts of disease and healthcare products is likely to be incorporated into future health technology assessment (HTA). Some HTA bodies, including Canada's Drug and Health Technology Agency (CADTH) and the National Institute for Health and Care Excellence (NICE) in England, have developed guidance on how this may be achieved.[61,62]

HZ and related complications are estimated to result in approximately $1.3 billion in medical care costs annually in adults ≥50 YOA.[63] HZ healthcare medical costs therefore represent approximately 0.03% of the total US national health expenditures (i.e.: $3.8 trillion).[64] Given that US national health GHG emissions represents 7.9% of the total GHG emissions in the US (i.e. 5,981 million tons), our estimates of overall tons of CO_2e associated with HZ in adults ≥50 YOA range from 0.01% to 0.02% of the total US national health GHG emissions (see text in Supplementary Material for more details).[65,66] Assuming healthcare financial costs and healthcare environmental costs are correlated, this would suggest that our estimates are conservative, especially considering that the latter includes travel to healthcare facilities.

Assuming no vaccination, the burden of HZ is projected to rise over the coming years due to the aging populations.[67] Zoster vaccines that substantially reduce the risk of HZ in older adults could be carbon saving given the small number of subjects (i.e., less than 10) who need to be vaccinated to prevent 1 HZ case.[68,69]

One limitation of our study is that calculations are based on average consumption data across the US, and may not be specific to a HZ patient, i.e., a HZ patient may have higher or lower CO2e consumption. A limitation of carbon footprint analyses is that although data is available overall for healthcare facilities, it is not always possible to separate out the carbon footprint for different disease types in particular where areas are shared for multiple disease types, e.g. where HZ, cardiovascular, diabetic, rheumatology patients share the same facilities (e.g. waiting areas/emergency rooms/wards, GP offices, clinics). In addition, we have not provided estimates broken down by health status, e.g. HZ patients without PHN/complications versus HZ patients with PHN or with other non-pain complications. The carbon footprint is likely to be 4 to 5 times higher in HZ patients with PHN/complications compared to HZ patients without PHN/complications, given the relative differences in healthcare resource utilization observed between those two groups.[70]

Another limitation of our study is that we focused on CO_2e. Our study did not comprise a wider range of environmental indicators known to harm human health, e.g., scarce water use, air pollution, reactive nitrogen in water. On the rare occasions that US data was not available (e.g. waiting times) we used global or other country information (see text in Supplementary Material).

Conclusions

The impact and complications of HZ are substantial, particularly in older adults resulting in substantial greenhouse gas emissions. Assuming no vaccination, the burden of HZ is projected to rise over the coming years due to the aging populations, consequently worsening its impact on greenhouse gas emissions. Human health is intricately linked to the health of the planet we all share.

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Disclosure statement

DC, JB and SW are employed by/hold shares in GSK. JB declares participation on a Data Safety Monitoring Board/Advisory Board and financial services from GSK, outside of the submitted work. IC is an employee of Carbon Trust, who was engaged by GSK to complete part of the work related to this manuscript. All authors declare no other financial and non-financial relationships and activities.

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ORCID

Desmond Curran http://orcid.org/0000-0002-7423-0111
Jacopo Bitetti http://orcid.org/0000-0002-1875-3305

Role of the sponsor

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Author contributions

DC, JB and SW were involved in the conception and/or the design of the study and participated in the collection/generation of the study data. All authors had full access to the data and gave approval before submission. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The work described was carried out in accordance with the recommendations of the International Committee of Medical Journal Editors for conduct, reporting, editing, and publication of scholarly work in medical journals.

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