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Original Research

The carbon footprint of American Academy of Orthopaedic Surgeons and Pediatric Orthopaedic Society of North America national meetings

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ABSTRACT

Background: The health care sector contributes substantially to carbon emissions. Estimating the carbon emissions of an event can help determine its climate impact. This study calculates the carbon footprints of the 2019 American Academy of Orthopaedic Surgeons (AAOS) Annual Meeting and the 2019 Pediatric Orthopaedic Society of North America (POSNA) Annual Meeting.
Methods: Data regarding attendance volume, geographic origin of attendees and vendors, hotel room nights, event space, and duration of meetings were obtained from AAOS and POSNA. Data were entered into an online calculator designed to measure the carbon footprint of large events (www.terrapass.com).
Results: The AAOS 2019 annual meeting was attended by 29 448 people, requiring 66 000 hotel room nights and 2 308 800 ft2 of convention center space for 5 days. We estimated 7179 short, 8374 medium, and 13 421 long-haul round-trip flights. The POSNA 2019 annual meeting was attended by 1103 people, requiring 1932 hotel room nights and 52 100 ft2 of convention center space for 4 days. We estimated 501 short, 280 medium, and 280 long-haul round-trip flights. The AAOS 2019 meeting emitted 26 075 metric tonnes of carbon dioxide equivalents (CO_2e), while the POSNA 2019 meeting emitted 544 metric tonnes. Eighty-one percent of the carbon emissions from AAOS and 80% from POSNA came from flight travel alone. Carbon neutralization of in-person AAOS and POSNA annual meetings would require carbon-offset purchases of approximately $273 700 and $5700, respectively.
Conclusions: Annual orthopaedic meetings contribute to climate change through their large carbon footprint. Leaders in the field of orthopaedics should consider strategies to mitigate the impact of such meetings, examples of which include transitioning to hybrid formats when appropriate and by purchasing carbon offsets for essential in-person participation.
Key Concepts:

1) Calculating the carbon footprint of an event estimates its total carbon dioxide emissions to help determine how to reduce its climate impact.
2) The AAOS 2019 meeting emitted 26 075 metric tonnes (MT) of carbon dioxide equivalents (CO_2e), while the POSNA 2019 meeting emitted 544MT, with ~80% coming from air travel alone.
3) Carbon neutralization of in-person AAOS and POSNA annual meetings would require carbon-offset purchases of approximately $273 700 and $5700, respectively.

Level of Evidence: IV

Introduction

Climate change, caused by greenhouse gas (GHG) emissions, is an environmental crisis that is becoming increasingly recognized as a global health crisis [1–4]. Health effects of climate change include exacerbation of respiratory diseases from thermal stress, fires, and air pollution [3–8]. Record-breaking heat waves cause heat exhaustion and deaths [9,10]. Mental health has been shown to be negatively affected by climate change [11]. Illnesses associated with climate change have a disproportionate impact on vulnerable communities, amplifying health

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disparities [4,6,12]. The rising toll of climate change on health makes efforts to reduce modifiable contributions paramount to the health-care community.

One popular climate change mitigation strategy is calculating and reducing carbon footprint: a quantitative measure of total carbon dioxide emissions caused by an activity, or production and consumption of goods [13]. Carbon footprint analyses have been expanded to include equivalents of other GHG emissions that contribute to climate change, such as methane, nitrous oxide, and chlorofluorocarbons [14].

Given the sundry of diseases associated with climate change and the goal of physicians to reduce risk and restore health, the medical community has a responsibility to address this global health crisis. Many recognize the economic cost of health care in the United States (US), which accounts for 17.1% of the GDP in 2017, 5% greater than the second-highest world health spender, Switzerland [15]. Less familiar but no less important is the carbon cost of health care. In 2007, health care activities accounted for 8% of the total US GHG emissions, increasing to 9.8% in 2013 [14,16]. Many organizations, including universities and hospitals, now analyze their carbon footprints. A study to calculate the carbon footprint of a Norwegian University showed that the medical department had the greatest carbon footprint *per* student, due to the specific equipment and consumable resources required to teach medicine [17]. US hospitals have begun to implement measures to increase energy efficiency and sustainability as suggested by the World Health Organization [18].

Medical meetings contribute significantly to the carbon footprint of the health care sector, shining a spotlight on the necessity and scope of in-person meetings [19–23]. The American Thoracic Society International Conference (2006) and the Society for Neuroscience meeting (2014) generated estimated carbon footprints of 10 000MT of CO_2e emissions for 15 000 attendees and 22 000MT of CO_2e emissions for 30 000 attendees [24,25], respectively. Air travel was the largest contributor at both meetings.

This study expands upon previous findings by bringing carbon footprint calculation to orthopaedics, an area not previously studied, looking specifically at the 2019 annual meetings of the American Academy of Orthopaedic Surgeons (AAOS) and the Pediatric Orthopaedic Society of North America (POSNA). Our findings can inform the Orthopaedic community as it joins the broader effort to reduce or offset the carbon footprint of health care.

Methods

An online calculator, Terrapass (terrapass.com), was used to measure the carbon footprints of the 2019 meeting of the AAOS in Las Vegas, NV and the 2019 meeting of POSNA in Charlotte, NC. This online carbon footprint calculator, similar to other free, publicly available tools such as Myclimate.org and Greeneventstool.com among others, is designed for calculating the carbon footprint of large events. These tools use established emission factors (including location, venue, food, water, commute, travel, shipping, and accommodations) and protocols from expert sources to estimate carbon footprints. The calculator has been validated based on carbon standard (Verra) projects, a standard that determines rules and requirements for the verification of projects of carbon emissions calculations and reduction efforts [26–28].

Data collection and fitting to calculator

Event coordinators for the AAOS and POSNA meetings provided the venue ZIP code, the total number of attendees, the geographic distribution of attendees, the total actual number of hotel-room-nights, the venue square footage, the duration of the event, and the total number of meals served. Although POSNA but not AAOS served meals at the event, we assumed that each attendee ate 3 meals *per diem*. An estimate of 8% vegetarian meals was used in alignment with data regarding the US population of vegetarians [29].

The deidentified geographic distribution of attendees (including exhibitors) was used to estimate flight or drive distances. Both AAOS and POSNA provided a list of attendees' origin city, state, and country. Average round-trip flight time was calculated from each state or country of origin to Las Vegas, NV (AAOS) or Charlotte, NC (POSNA), using an online flight time calculator (https://flighttime-calculator.com/). Average flight times were grouped as short (< 2 hours), medium (2-4 hours), or long-haul (> 4 hours). This method of organizing flight data is the typical way of calculating carbon footprint as opposed to analyzing flight-hour data as a continuous variable since flight time and carbon footprint do not have a linear relationship. This is because of the disproportionate energy consumption during the takeoff and landing or commercial airline flights. In-state attendees were assumed to have driven to the conference. For these attendees, the average distance from cities of origin to Las Vegas or Charlotte was determined using an online distance calculator (https://www.mapdevelopers.com/mileage_calculator.php).

The raw data obtained from AAOS and POSNA included room square footage and the number of days each room was used for a 9-hour day.

A sample of four corporate partners for AAOS and POSNA provided estimates of the size, weight, and shipment methods of equipment and products used by exhibitors. For AAOS, the geographic distribution of vendor product shipments was estimated by locating the headquarters of a sample of 26 corporate partners (out of 777 vendors) and calculating the average flight distance to Las Vegas using the online distance calculator. For POSNA, geographic distributions of the 35 vendor product shipments were determined by locating the headquarters of each exhibitor and calculating the average flight distance from the headquarters to Charlotte using the online distance calculator. The estimated average shipment weights were 1600 lbs for each AAOS vendor and 1200 lbs for each POSNA vendor.

Carbon footprint calculator

Carbon footprint was measured using the following factors [30]:

1. Air travel: World Resources Institute, Environmental Protection Agency (EPA), and Bureau of Transportation GHG protocols for common modes of transportation and vehicle efficiency are used to calculate CO_2 emissions for short (< 2 hours), medium (2-4 hours), and long-haul flights (> 4 hours).
2. Hotel accommodations: EPA and the Department of Energy provide data for the carbon intensity of electricity and other energy production required for hotel room operation, which is used to determine CO_2 emissions for the number of hotel room nights.
3. Commute: World Resources Institute, EPA, and Bureau of Transportation GHG protocols for common modes of transportation and vehicle efficiency are used to calculate CO_2 emissions of non-aviation modes of commuting.
4. Venue: data from the Commercial Buildings Energy Consumption survey conducted by the Energy Information Administration is used to calculate CO_2 emissions from using a determined square footage of venue space for the number of days of the event.
5. Meals: information from the Johns Hopkins Center for a Livable Future is used to measure CO_2 emissions from food consumption.

Data for the above five factors gathered from AAOS and POSNA coordinators were entered into the “Event” carbon footprint calculator. Shipping data, extrapolated from information given by a sample of corporate partners, was entered into the shipping section of the “Business” carbon footprint calculator. Each calculation resulted in a value for the estimated carbon footprint in MT of CO_2e. Calculated values for the event and shipping were added to give the total carbon footprint for each meeting.

Table 1
AAOS and POSNA event and shipping data used by category for Terrapass calculation.

			Total carbon footprint (MT CO_2e)	
Category	AAOS	POSNA	AAOS	POSNA
Number of attendees	29 448	1103	26 075	544
ZIP code	89 169	28 202		
Number of long-haul flights	13 421	280	21 173	437
Number of medium-haul flights	8374	280		
Number of short-haul flights	7179	501		
Total hotel-room-nights	66 000	1932	2373	47
Number of commuters	474	32	7	2
Average commute distance (miles)	20	76		
Square feet used per day	2 308 800	52 116	232	4
Number of meals	441 720	13 236	1039	32
Shipping distance (miles)	1697	854	1251	22
Shipping weight (lbs)	1600	1200		

AAOS, American Academy of Orthopaedic Surgeons; POSNA, Pediatric Orthopaedic Society of North America.

Results

Information gathered from AAOS and POSNA was organized to fit the data categories for the Terrapass calculator (Table 1).

For the 2019 AAOS meeting in Las Vegas, the calculated total of CO_2e emissions was 26 075MT, or 0.88MT *per* attendee. 24 824MT of CO_2e were emitted from the event itself (21 173MT from flight travel, 2373MT from hotel accommodations, 7MT from at location commuting, 232MT from the venue space, 1039fMT from meals), and 1251MT were emitted by shipping to and from vendor headquarters (Fig. 1).

Flight travel accounted for 81.2% of the total CO_2e emissions, hotel accommodations accounted for 9.1%, meals served accounted for 4%, shipping accounted for 4.8%, venue space accounted for 0.88%, and commuting accounted for 0.02% (Fig. 2).

For the 2019 POSNA meeting in Charlotte, the calculated total carbon equivalent emissions was 544MT, or 1.37MT *per* attendee. 522MT CO_2e were emitted from the event itself (437MT from flight travel, 47MT from hotel accommodations, 2MT from driving commutes, 4MT from the venue space, 32MT from meals), and 22MT were emitted by shipping to and from vendor headquarters (Fig. 3).

Flight travel accounted for 80.4% of the total CO_2e emissions, hotel accommodations accounted for 8.6%, meals served accounted for 5.9%, shipping accounted for 4%, venue space accounted for 0.7%, and commute accounted for 0.4% (Fig. 4).

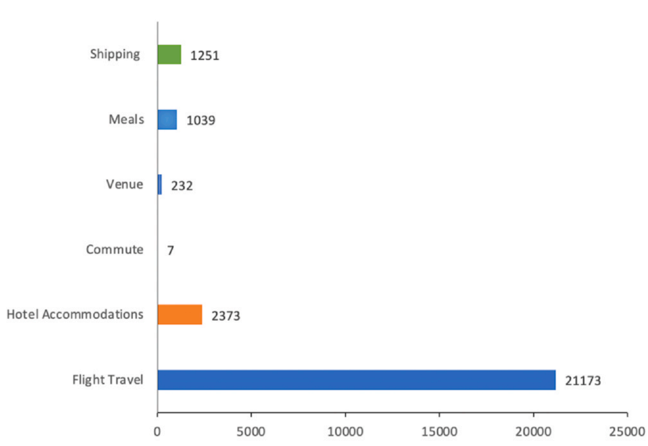

Figure 1. CO_2 equivalent emissons (MT) by category for AAOS 2019 meeting. Values generated from the Terrapass carbon footprint calculator.

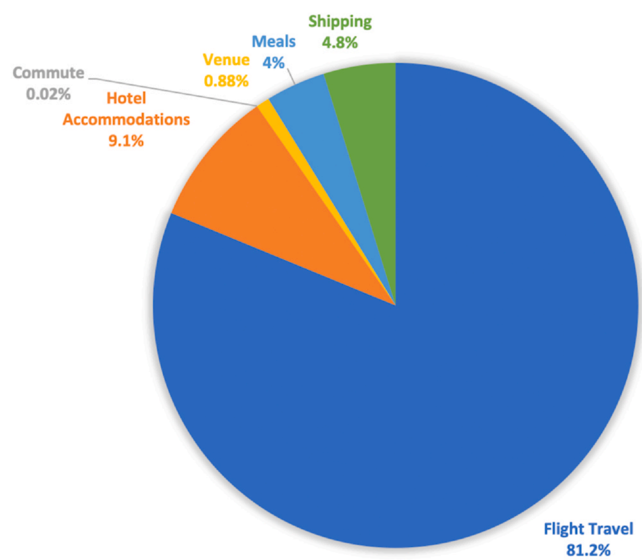

Figure 2. Distribution of carbon equivalent emissions by category as a percent of total emissions for the AAOS 2019 meeting.

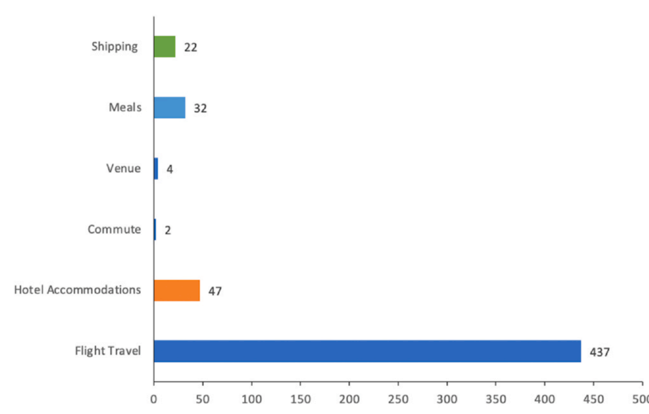

Figure 3. Carbon equivalent emissions (MT) by calculator category for the POSNA 2019 meeting. Values generated from the Terrapass carbon footprint calculator.

Discussion

In this analysis of the carbon footprint of orthopaedic meetings, we chose a comprehensive meeting and a subspecialty meeting as examples upon which to base estimates of carbon emissions more universally. The

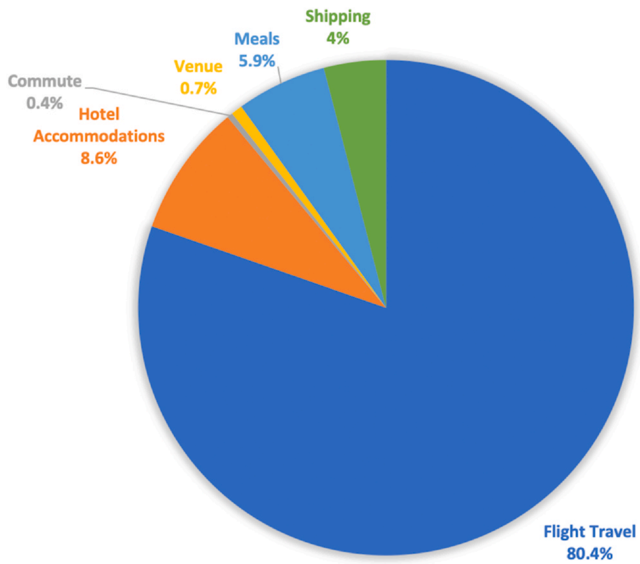

Figure 4. Distribution of carbon equivalent emissions by category as a percent of total emissions for the POSNA 2019 meeting.

2019 AAOS meeting in Las Vegas emitted approximately 26 075MT CO_2e, more than 47 times the 544MT emitted by the 2019 POSNA meeting. Emissions *per* attendee were 55% higher for the POSNA meeting (1.37MT) compared with the AAOS meeting (0.88MT), likely reflecting economy of scale. In comparison, the daily carbon footprint of an average American is about 0.04MT (or 16MT per year) [31], which represents about 1/20th of the daily emissions of each attendee during the AAOS meeting.

The distributions of carbon emissions by category as a percent of total emissions were roughly equivalent for both meetings. Similar proportions between two meetings of significantly different size and scope suggest that our findings may be broadly applicable to a range of meetings.

We present data in categories—flight travel, hotel accommodations, commute, venue, meals, and shipping—to allow focused efforts at the curtailment of carbon emissions. Flight travel is the most significant single opportunity for reduction, representing more than 80% of the total and being an order of magnitude greater than the next category.

The CO_2e emissions for AAOS and POSNA annual meetings are approximately equivalent to 5548 and 116 average passenger vehicles, respectively, being driven for one year, and to the annual emissions of about 550 and 11 households, respectively [32]. For comparison to a generally well-known event, the emissions for the AAOS annual meeting were approximately 15 times the estimated carbon emissions of the 2013 Super Bowl in New Orleans LA (1700MT carbon emissions for the event itself not including travel/flights), while the emissions for the POSNA annual meeting were approximately one third as great as the emissions from the 2013 Super Bowl [33]. An individual surgery has been estimated to emit between 6 and 814 kg of CO_2e, meaning that the AAOS event was equivalent to the emissions of roughly 50 000 surgeries and roughly 1000 surgeries for POSNA (assuming 500 kg CO_2e for a single surgery) [34].

Despite the multiple factors used in the carbon footprint calculations, our calculations are likely an underestimate. Estimates made for flight travel distances were extrapolated from deidentified geographic data but did not account for differences in airlines or ticket types. Regarding the latter, business and first-class seats result in 2 to 9 times more CO_2e emissions *per* person compared with economy class [35,36], which we assumed for every attendee. Additionally, our estimate of 3 daily meals does not take into account snacking or the impact of banquets and other disproportionately carbon-intensive meals such as those sponsored by vendors.

One overestimate in our methodology is the ascribing of meals *in toto* to each meeting when attendees would otherwise be consuming meals at home. Offsetting this overestimate is the fact that formalized meals such as those at medical meetings are associated with greater carbon footprints than at-home eating [37]. In addition, meals represented a small percentage of the total carbon footprint.

Other factors contributing to an underestimate of the carbon footprint include attendees' participation in social events and sightseeing. These activities were not included in our calculation because they are difficult to quantify, highly variable, and not reliably registered. Participants are often accompanied by family members, who were not counted as attendees but who would multiply the calculated carbon footprint for all categories except the smallest, namely, venue.

The value of carbon emissions from shipments to and from vendor headquarters was the least reliable category. Many vendors were unable to disclose information detailing their products. As a result, shipment data were extrapolated from a small sample size, increasing the potential for error. Balancing error is the fact that this category represents only 5% of the total carbon emissions.

As AAOS itself promotes, face-to-face contact and communication are essential benefits of in-person meetings, reflecting the assumption that the professional and social benefits cannot be replicated through a virtual format [38]. In-person attendance extracts participants from other professional obligations, allowing them to focus and maximize the benefits of a meeting. Video conferencing introduces the pressure to multitask with other work requirements. Such split participation could potentially detract from the quality of virtual meetings.

Today, knowledge can be disseminated, and interaction can occur live and in multiple forms, including video that is easy to use, inexpensive, and nearly universal. The COVID-19 pandemic expedited innovation in medical practice, including telemedicine. Indeed, early evidence from studies on telemedicine with patients during the COVID-19 pandemic suggests that virtual appointments are associated with high satisfaction and diagnostic accuracy [39]. Another example is virtual learning, which enhanced the quality of surgical training during the pandemic, offering benefits such as decreased resident burnout, facilitating access to learning sources and elimination of travel time [40].

The COVID-19 pandemic has accelerated what many believe were inevitable social changes, such as remote work. Consistent with this, in addition to responding to the climate crisis, we recommend a virtual component to medical meetings where possible and valuable. Virtual medical meetings offer the ability to tailor meetings temporally, reduce attention fatigue, and eliminate the toll of travel, including financial burden and jetlag. This hybrid format can be titrated according to meeting and activity type. Most presentations may be delivered remotely without a significant reduction in quality. Most participants can adapt to meet their goals of learning and updating remotely while still having the opportunity to engage in questions to presenters real time. Many administrative meetings could likewise have a hybrid component, inviting remote participants via video conference platform. Virtual attendance at an academic meeting has been shown to reduce carbon footprint by 2 orders of magnitude per person [41].

Although the potential environmental benefits of transitioning away from in-person meetings have been outlined above, what is difficult to determine and likely to be lost are the intangible gains from physical presence during annual meetings. We recognize that the organic, spontaneous, exchanges that come from physically interacting with other members of the Orthopaedic community are unique and difficult to replace. It is unclear how a move to hybrid-virtual would affect research collaboration, industry support, and the fiscal health of the organizing bodies. Incorporation of the virtual format will no doubt evolve with time as we gain more experience and technological advantage with this new approach. Other strategies in addition to the use of virtual meeting technology include organizing satellite meetings to engage members at the local level without the need for air travel.

National meetings could be directed to cities with Leadership in Energy and Environmental Design-certified or otherwise ecofriendly hotels, venues, public transportation, airports, and conference centers [42]. Single-use items such as plastic bottles should be minimized. The program planning committees should have designated roles in charge of sustainability, with the goal of a carbon neutral meeting [43].

For those parts of national meetings that will remain in-person, we recommend the implementation of a carbon offset program, as is done in other industries [44]. Carbon offsetting is the action of compensating for carbon dioxide emissions that result from industrial or other human activity by participating in processes to effect equivalent reductions of carbon dioxide in the atmosphere [45]. Carbon offsets fund local or global projects that reduce GHG emissions (e.g., planting trees). While the concept of carbon offsets may be new to a medical audience, they are a mainstream, validated part of international markets and a billion-dollar industry [46,47,44]. Etsy, for example, a popular company that relies on shipping products around the world, pays for carbon offsets for shipping [48]. However, it is worth noting that there are criticisms of the validity and efficacy of carbon offset programs due to a lack of formal (i.e. government) oversight, yet offsets remain a major component of achieving carbon-neutral operations for industries that have carbon-intensive needs [44]. The carbon footprint calculator used in our estimates generates an estimated offset value and provides the option to purchase offsets for a meeting. Completely in-person AAOS 2019 and POSNA 2019 meetings would require offset purchases of approximately $273,700 and $5700, respectively. This financial burden should likely be shared between the organization, vendors, and attendees, who should be incentivized to purchase carbon offsets for their flights.

We recognize that our study differs from mainstream Orthopaedic research. However, we believe that the topic is of universal importance, including to the medical community, which is participating in the environmental crisis by its large carbon footprint. Specifically, a recent study of waste production places orthopaedic surgery at the top of a list of 18 specialties, 13 of which were surgical [49]. That our profession is a large carbon emitter obligates us to study this topic even if unfamiliar. We do not recommend abandoning meetings, which are invaluable to our profession. We suggest finding opportunities to make them better by reducing—where possible and beneficial—their deleterious impact on the environment by decreasing and offsetting their carbon footprint. In this vein, we hope the Orthopaedics profession will lead in this vital discussion.

Author contributions

Livingston Kristin S: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Jackert Ella Prebel:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Diab Mohammad:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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