

## Research Article

# Environmental Impact of the American Board of Orthopaedic Surgery All-in-person Oral Board Examination

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Keywords: sustainability, carbon expenditure, board certification, greenhouse gas emissions

<https://doi.org/10.60118/001c.131729>

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## Journal of Orthopaedic Experience & Innovation

Vol. 6, Issue 1, 2025

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### Introduction

Climate change presents a significant threat to global health, with the healthcare sector contributing notably to greenhouse gas emissions. This study quantifies the carbon footprint associated with the 2019 all-in-person American Board of Orthopaedic Surgery Part II Oral Board examination and estimates the potential reduction in emissions associated with transitioning to a virtual format.

### Methods

Carbon emissions from attendee travel and lodging for the 2019 ABOS Part II Oral Board Examination in Chicago were estimated. In-person emissions calculations considered examinees, examiners, and ABOS staff. For virtual exam calculations, emissions from network data transfers and technology usage were estimated.

### Results

In total, 997 people attended the 2019 in-person examination. This event resulted in 600.8 tons of CO<sub>2</sub>e emissions, with the majority (89.6%) being from air travel. In contrast, an all-virtual examination was estimated to produce 12.2 tons CO<sub>2</sub>e, representing a 98% reduction compared to in-person examinations.

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## Conclusion

The 2019 ABOS all-in-person Part II Oral Board examination had a substantial carbon footprint. Transitioning to a virtual format appears to be a promising alternative to reduce the examination's environmental impact.

## INTRODUCTION

Experts have established that climate change is the greatest threat to global health this century (Costello et al. 2009; Romanello et al. 2022; Costello et al. 2023). Ironically, the healthcare sector produces sizable fractions of greenhouse gas emissions—10% of those in the US and 5% worldwide (Dupraz and Burnand 2021; Eckelman and Sherman 2016, 2018). Quantitation of greenhouse gasses is reported in metric tons of CO<sub>2</sub> equivalents (CO<sub>2</sub>e). Non-CO<sub>2</sub> emissions (including methane, nitrous oxide, and fluorinated gasses) are converted into CO<sub>2</sub>e amounts according to their global warming potential (US EPA, n.d.).

For the Paris Agreement goal of counteracting the current trajectory of anthropogenic climate change and limiting average global temperature rise to 1.5°C by 2050, climate experts recommend annual per capita emissions be reduced to no more than 2.5 tons of CO<sub>2</sub>e by 2030, 1.4 tons by 2040, and 0.7 tons by 2050 (Institute for Global Environmental Strategies 2019). In 2020, the United States per capita annual emissions were 16.0 tons CO<sub>2</sub>e (CLIMATEWATCH 2020). Limiting commercial airline travel is rated as one of the four highest-impact behaviors that can reduce an individual's greenhouse gas emissions in westernized societies (Wynes and Nicholas 2017). An example illustrating the effect air travel can have on CO<sub>2</sub>e is a round-trip flight from Los Angeles to New York. This journey produces approximately 1.3 tons CO<sub>2</sub>e per traveler, slightly exceeding 50% of the annual recommended per capita emissions. Examples such as this have spurred the medical community to evaluate its contribution to anthropogenic climate change via professional travel (Parker et al. 2023; Leddin et al. 2022; Milford et al. 2021; Parncutt et al. 2021; Smith, Sounderajah, and Darzi 2021; Wortzel et al. 2021; Callister and Griffiths 2007).

Medical board certification is defined as an “independent evaluation of a physician or medical specialist's knowledge and skills to practice safely and effectively” and provides “a trusted credential patients can rely upon when selecting a provider for their health care needs” (American Board of Medical Specialties 2024). In surgical specialties, the last step of initial board certification frequently takes the form of a centralized oral in-person examination to review the examinee surgeon's knowledge, skills, and management of their own or standardized patients. This examination paradigm was disrupted during the COVID-19 pandemic, necessitating the conduct of these board examinations in a virtual format (Bartley 2020; Chen et al. 2021; Huber et al. 2022; Pettit et al. 2021; Zemela et al. 2021; Shivraj et al. 2022). A number of studies have since been conducted evaluating the efficacy of the virtual board examinations. These studies have indicated that virtual examinations were as effective as in-person examinations in achieving the aforementioned goals (Chen et al. 2021; Huber et al. 2022; Shiv-

raj et al. 2022). For orthopaedic surgery in the US, the medical specialty board providing certification is the American Board of Orthopaedic Surgery (ABOS).

During the COVID pandemic, the ABOS recognized the imperative to arrange an alternative to the in-person Part II Oral Board examination promptly—trainees had spent years preparing and planning to take the exam, and the start of their careers depended on becoming fully board certified. Traditionally held in July in downtown Chicago, approximately 750 candidates take the Part II Oral Board examination in a normal year with the help of hundreds of examiners. Careful to uphold the same standards for assessing safe and effective surgical care, the ABOS developed a three-stage approach: The first stage involved a document-based practice examination, which had been tested over the past several years and was found to reliably evaluate most examinees' practices. The second stage was utilized for a subset of examinees who, after completing Stage 1, were deemed to need further scrutiny of their practice. This second stage consisted of virtual oral examinations conducted via video conferencing. The third stage involved a final evaluation of the Stage 2 examinees conducted by the ABOS Board of Directors, with examinees whose results were inconclusive being deferred to the next in-person examination. While the virtual option received positive anecdotal feedback from examinees and examiners (American Board of Orthopaedic Surgery 2020), the ABOS decided to fully return to the traditional all-in-person format in 2022.

Given the large number of examinees that must travel to take the oral test using a traditional model, we sought to quantitate the CO<sub>2</sub>e expenditure for the conduct of a single cycle of a traditional orthopaedic board examination. Specifically, we asked two questions: (1) What was the magnitude of greenhouse gas production resulting from the all-in-person 2019 ABOS Part II Oral board certification examination in Chicago, IL, USA? (2) How much reduction of greenhouse gas production could have been realized if this examination had been conducted virtually?

## METHODS

### STUDY DESIGN AND SETTING

To estimate the carbon footprint of the 2019 ABOS Part II Oral Board Examination taking place at the Palmer House in Chicago, IL, we concentrated on emissions associated with attendee travel and lodging as these contribute the vast majority of the carbon footprint of academic gatherings (Zotova et al. 2020). We chose to study the 2019 certifying examination because it was the last pre-COVID meeting and thus was more likely to represent attendance at current all-in-person examinations. We studied the carbon emissions associated with three groups of attendees: examinees, examiners, and ABOS staff. Examinees were defined

as surgeons who traveled to the Palmer House in Chicago to sit for the certifying examination in 2019. Examiners were defined as those who volunteered to help administer and grade the examination, including ABOS Board Members. ABOS staff were defined as administrative and support staff who attended in order to help with administering the examination. The examination period spans four days, during which examiners and ABOS staff are present throughout, while examinees are only required to attend for one day.

#### CALCULATION OF CO<sub>2</sub>E EMISSIONS ASSOCIATED WITH ATTENDEE TRAVEL AND LODGING

The ABOS website lists all ABOS certified surgeons along with their ZIP code and year of initial certification (American Board of Orthopaedic Surgery, n.d.-a). Using this database, we recorded the ZIP codes of all surgeons initially certified in 2019. We identified a 22-person discrepancy between the number of surgeons listed as initially certified in 2019 on the ABOS website (733) and the actual number reported by the ABOS as having passed in 2019 (755). We proceeded with calculations for examinees listed as having become successfully board certified in 2019 on the ABOS website, as this gives a more conservative estimate of expenditure.

According to the ABOS website (“American Board of Orthopaedic Surgery: Part II Examination Statistics,” n.d.), 34 examinees failed the examination in 2019, and ZIP codes were not available for these examinees. We assumed 225 examiners and 5 ABOS staff members attended the examination (American Board of Orthopaedic Surgery, n.d.-b). Because ZIP codes were not available for examiners and examinees who failed, we utilized the average travel-related carbon expenditure of examinees for whom ZIP codes were available. ABOS staff were assumed to travel from Chapel Hill, NC, where the ABOS headquarters are located.

If the listed ZIP code was more than 250 miles from the examination venue ZIP code, examinees were assumed to have flown to Chicago. The threshold for driving versus flying was established following guidelines provided by the United States Environmental Protection Agency for estimating emissions from events and conferences. These guidelines outline the typical mode of transportation for business travel based on distance (US EPA 2018). The largest airport closest to the specified zip code was utilized with the Myclimate flight calculator, an openly accessible online tool for estimating carbon emissions, to determine the CO<sub>2</sub>e emissions in metric tons from round-trip air travel to Chicago O’Hare airport ([https://co2.myclimate.org/en/flight\\_calculators/new](https://co2.myclimate.org/en/flight_calculators/new)). The Myclimate flight calculator assesses both direct and indirect CO<sub>2</sub>e emissions per passenger for a given flight distance, accounting for cabin class and incorporating a conservative radiative forcing index of 2 (a multiplier that adjusts for the warming effects of non-CO<sub>2</sub> emissions). Fuel consumption data utilized in the calculator are based on a weighted average of fuel consumption rates during cruising, landing, and take-off cycles for the most commonly utilized short and long-haul aircrafts (Myclimate, n.d.-b). Economy-class travel and non-stop flights were assumed for all calculations.

If the listed ZIP code was within 250 miles of the examination venue, attendees were assumed to have driven to the exam. To calculate emissions associated with car travel, we used the straight-line distance between the ABOS-listed surgeon ZIP code and the examination venue ZIP code.

The driving and commuter rail distance from Chicago O’Hare International Airport to the hotel was determined using Google maps (<https://www.google.com/maps>). To estimate the total emissions of fliers commuting to the hotel and back from Chicago O’Hare International Airport, we averaged the emissions associated with driving and taking the commuter rail, given it was unknown what proportion of travelers would have chosen each mode of transport.

We assumed all examinees stayed at the hotel hosting the examination for one night. Examiners and ABOS staff were assumed to stay for 4 nights. Information regarding which venues within the Palmer House were used for the examination was obtained and the publicly listed dimensions were utilized to estimate emissions associated with utilizing the event spaces (Palmer House Hilton, n.d.). To calculate emissions produced by the examination venue, car travel, and hotel stays, we used published Environmental Protection Agency emission factors and the Environmental Protection Agency Greenhouse Gas Equivalencies Calculator (Appendix) (US EPA 2018; Palmer House Hilton, n.d.; Faber 2021; US EPA, O 2015).

The total estimated CO<sub>2</sub>e emissions from the 2019 in-person certifying examination were calculated by summing the emissions of round-trip air travel, fliers commuting round-trip from Chicago O’Hare Airport to the hotel, venue electricity and fuel consumption, hotel stays, and drivers commuting from within 250 miles.

#### ESTIMATION OF CO<sub>2</sub>E PRODUCED BY AN ALL-VIRTUAL EXAMINATION

To estimate emissions produced if the ABOS Part II Oral Board Examination was conducted entirely virtually, we adapted the techniques outlined by Faber et al. and summed the estimated emissions from network data transfers, personal computer and monitor usage, as well as server-related emissions from the life cycles of these technologies and their associated electrical energy consumption (Faber 2021). For these calculations, we used the same number of attendees as at the 2019 exam and assumed virtual participation for 8 hours for 4 days for examiners and ABOS staff, and 6 hours for one day for examinees.

#### ETHICAL APPROVAL

This study was deemed to be exempt from institutional review board approval by the Mass General Brigham IRB because there were no human participants, and all information was deidentified.

**Table 1. ABOS 2019 Oral Board Exam Attendees**

|                          |            |
|--------------------------|------------|
| Examinees                | 767        |
| Initially certified 2019 | 733        |
| Failed certification     | 34         |
| Examiners                | 225        |
| ABOS Staff               | 5          |
| <b>Total</b>             | <b>997</b> |

**Table 2. Estimated Metric Tons of CO<sub>2</sub>e Emissions Resulting from the 2019 ABOS Part II Oral Board Exam**

|                         |              |
|-------------------------|--------------|
| Examinee Travel (n=767) | 414.2        |
| Examiner Travel (n=225) | 121.5        |
| Staff Travel (n=5)      | 2.8          |
| Hotel Stays             | 43.9         |
| Event Space             | 18.4         |
| <b>Total</b>            | <b>600.8</b> |

## RESULTS

### MAGNITUDE OF GREENHOUSE GAS PRODUCTION RESULTING FROM THE 2019 ABOS PART II ORAL BOARD EXAMINATION

In total, 997 people attended the 2019 ABOS Part II Oral Board Examination in Chicago, IL; 733 examinees were listed as initially certified in 2019, 34 examinees were reported to have failed the exam, and 225 examiners and 5 ABOS staff members were reported to have attended (Table 1). The total estimated emissions of attendance at the 2019 examination were 600.8 tons CO<sub>2</sub>e (median 0.58 tons per attendee; range 0.05 to 2.25 tons) (Table 2). Forty-five percent of attendees used over 25% of their annual allotted carbon budget according to the goals outlined by the Paris Agreement to attend this single event in person.

Of examinees who became initially certified in 2019, 89.5% (n=656) traveled from an address greater than or equal to 250 miles from the examination. Passing examinees from California and Texas collectively contributed the largest proportions of travel-related emissions, 20.9% and 9.3% respectively (Figure 1). The total estimated CO<sub>2</sub>e production from round-trip travel was 539 tons (89.6% of total emissions).

Upon arrival at Chicago O'Hare International Airport, attendees needed to travel 18.2 miles to the Palmer House hotel in downtown Chicago. If we assume 892 attendees flew to the exam (656 passing examinees, 5 ABOS staff, and 90%, or 231, of remaining attendees) and traveled from the airport to the hotel by car, this would result in 11.1 tons of CO<sub>2</sub>e emissions. If registrants instead took the commuter rail, this would decrease the CO<sub>2</sub>e total emissions for the O'Hare to Palmer House trip by 57.9% to 4.7 tons of CO<sub>2</sub>e.

For the Palmer House hotel, an "upper upscale hotel" according to the Environmental Protection Agency, we calcu-

lated the total electricity and natural gas consumption of hotel stays to be 43.9 tons CO<sub>2</sub>e. Estimated emissions from fuel and electricity needed for operating the event spaces (such as lighting, cooling, and heating) was 18.4 tons CO<sub>2</sub>e.

### MAGNITUDE OF GREENHOUSE GAS PRODUCTION RESULTING FROM THE 2020 VIRTUAL MEETING

The total estimated emissions of attendance at an all-virtual ABOS Oral Board examination, assuming the same number of attendees as the 2019 examination, was 12.2 tons CO<sub>2</sub>e. This corresponds to a 98% decrease in CO<sub>2</sub>e emissions compared with the in-person examination (Figure 2). The estimated network data transfer emissions, personal computer and monitor emissions, and server-related emissions were 8.2 tons, 4.0 tons, and 0.010 tons CO<sub>2</sub>e, respectively.

## DISCUSSION

The climate crisis is thought to be one of the greatest risks to human well-being in the 21st century (Costello et al. 2023). We as medical professionals can choose to adapt and create solutions to minimize healthcare's carbon footprint and avoid worsening the health and environmental effects of climate change. The carbon footprint of the ABOS in-person Part II certification examination has previously not been quantified. Knowledge of the magnitude of components of our specialty's educational, governance and self-regulatory activities to the climate crisis is important in helping to identify strategies to minimize the carbon footprint of such necessities. The findings we report here demonstrate that in-person board certification testing can have a large carbon footprint, resulting in many individuals depleting much of their annual allotted carbon budget set by the Paris Agreement to counteract the current trends in climate change. We found that pivoting to a virtual format for the ABOS Part II examination could substantially decrease greenhouse gas emissions. These data may help our specialty weigh the advantages and disadvantages of in-person board certification testing and encourage careful consideration of sustainable alternatives.

Other surgical specialties (e.g., Obstetrics and Gynecology, Plastic and Reconstructive, Cardiothoracic) have also returned to the traditional in-person certification format, while some (e.g., General Surgery, Ophthalmology, Vascular Surgery) have continued with remote examinations. A survey conducted by the American Board of Surgery (ABS) after adopting their virtual certifying examination found that 78% of examinees preferred the virtual examination, and the pass rate did not differ from in-person examinations (Chen et al. 2021). According to the ABOS website, the ABOS Part II oral boards held largely virtually also resulted in similar pass rates to prior in-person years (2020-2021, 92%; 2019, 96%; 2018, 93%) ("American Board of Orthopaedic Surgery: Part II Examination Statistics," n.d.). While the ABOS did not release the results of their formal survey after transitioning the 2020 ABOS Part II and Oral Recertification Examinations to the 2020 ABOS Case Based

Examinations, they described the adapted program as a “major accomplishment” in the diplomate e-newsletter and reported hearing positive reviews from both examiners and examinees (American Board of Orthopaedic Surgery 2020).

Interestingly, the ABS survey found that 78% of examiners preferred the in-person exam (Chen et al. 2021). This finding was mirrored in a study of the virtual Vascular Surgery Board certifying examination which found that only 32% of examiners preferred the virtual format. This was in contrast to 87% of examinees favoring the virtual examination (Huber et al. 2022). Despite differing preferences for future examinations among examiners and examinees in the ABS survey, 86.1% of examinees and 96.4% of examiners were either ‘satisfied’ or ‘very satisfied’ with the remote delivery of the certifying examination. Both the ABS and Vascular Surgery Board studies discussed the advantages of reduced travel costs and convenience to the examinees, while also acknowledging concerns with the virtual format, including test security, technology-related stress, and lacking interpersonal interactions.

One advantage of in-person examinations is their ability to assess professionalism and communication skills under pressure. These elements are less easily evaluated in a virtual setting, where examiners may not have the same ability to observe subtle non-verbal cues, body language, and interpersonal interactions that are critical components of physician assessment. To balance sustainability with the need for robust evaluation, a hybrid model may offer a feasible solution. Such a model could involve virtual exams for most examinees while retaining in-person assessments for candidates requiring further evaluation, similar to the multi-stage approach implemented by ABOS during the COVID-19 pandemic. This hybrid approach would significantly reduce travel-associated emissions while ensuring that candidates who require additional scrutiny undergo comprehensive in-person evaluation.

Although a cost analysis was outside the scope of this study, the virtual format could yield cost savings relative to the in-person examination. We would expect travel expenses related to the virtual examination to be substantially lower than costs associated with travel and accommodations for in-person staff and examiners. With a virtual format, examinees are relieved of the financial burdens related to flights to and lodging in Chicago. And, examiners would experience fewer losses in clinical time, and thus compensation, associated with travel to the examination site. While expenses for the ABOS related to technology, IT support, and proctoring are undoubtedly significant, it is unclear whether these virtual expenses would be substantially different from the information technology expenses required for the in-person examination.

The amount of total CO<sub>2</sub>e produced from the in-person ABOS Part II examination is small relative to other professional activities such as professional conference attendance. This is largely due to differences in numbers of attendees. The estimated ABOS Part II examination CO<sub>2</sub>e (n attendees=997) was 38.3%, 3.6%, and 1.6% of the emissions estimated to be produced by conferences of the American Orthopaedic Foot and Ankle Society (n=1,271), the Amer-

ican Psychiatric Association (n=13,335), and the American Society of Clinical Oncology (n=33,562) (Parker et al. 2023; Wortzel et al. 2021; Lichter et al. 2024). Yet the emissions produced by the ABOS Part II examination should not be overlooked as, unfortunately, there is no “silver bullet” that will correct anthropogenic climate change. A coordinated, concerted effort by many facets of society will be needed to halt or reverse climate change.

Investigations such as this one may provoke questions about how changing the format of a certifying examination can impact climate change. Some argue that “the planes are going to fly anyway,” or perceive that our own impact is insignificant. These thoughts may mislead us into believing that each of our individual behaviors, and consequently our collective impact, carries no carbon footprint. Commercial air carriers are subject to the law of supply and demand and thus decreased air travel demand does change airline routing behavior. For example, in response to the drop in travel demand due the COVID-19 pandemic during the second week of April, 2020, scheduled flights in the U.S. decreased by 58% compared to the same week in April the year prior (“How the Coronavirus Is Disrupting US Air Travel, in 2 Charts,” n.d.).

Importantly, this investigation should not be construed as an argument against board certification or recertification. Board evaluation and certification by the ABOS are well-established and critical components of our profession. We believe that this process has immeasurable value to patients, clinicians, and society as a whole. We are thus not looking to diminish or eliminate the process of any board certification and certainly not that of orthopaedic surgery. In fact, the senior author has been and continues to be involved in the Part II ABOS board certification process. This investigation provides an analysis of the broader climate impact of the board certification process.

## LIMITATIONS

The methods used for our calculations are estimates. Direct measurement of vehicle emissions is not possible. Calculators used for determining carbon emissions all incorporate assumptions that lead to variability. Our calculations used the Myclimate flight emissions calculator because it is acknowledged by emissions and environmental experts as one of the most accurate available (Iken and Aguessy 2022; Ltd, Jungbluth, and Meili, n.d.). The evidence-based rationale for all included elements as well as their publicly available methods are reasons for its wide-spread use (Myclimate, n.d.-a).

There are several potential areas of inaccuracy with our estimates, yet in total we believe our calculations may underestimate the actual CO<sub>2</sub>e emissions for the 2019 ABOS in-person Part II licensure examination. For one, our calculations did not incorporate emissions produced by travel between the departure site and the attendee’s home. Secondly, all automobile travel was calculated using straight-line distance. This method results in an underestimation of fuel consumption. Additionally, calculations were based on average gasoline-powered automobiles. While some delegates may travel in hybrid or electric vehicles or carpool,

others may have driven in vehicles with less efficient miles-per-gallon ratings than the utilized “average” vehicle. Furthermore, we suspect a proportion of examiners living within 250 miles of the venue may have preferred to stay at the venue versus commuting each day, which would result in overestimated driving emissions and underestimated hotel emissions. For examinees, this would only result in underestimated hotel emissions. Because driving and hotel emissions were a relatively small portion of the carbon footprint, these uncertainties are unlikely to change the overall implications of the study findings. Also, we utilized direct routes and economy class for all attendees assumed to fly, which likely underestimated air travel emissions for some travelers. In addition, we did not factor in those who took the in-person ABOS Part II Examination for recertification purposes. This number has been historically very low, and we expect it to contribute very little to the overall exam carbon expenditure. Lastly, the listed square footage for the event spaces at the Palmer House on which our estimations are based were the “usable square footage” and thus necessarily resulted in an underestimation for the energy use associated with using the spaces.

## CONCLUSION

Confronting the threat of climate change and its health impacts requires a deliberate effort. Given its large carbon footprint, the medical profession bears a particularly profound responsibility to adapt; we must seek innovative solutions to reduce our environmental impact while upholding our commitment to patient care. This investigation underscores the substantial carbon footprint of a singular orthopaedic in-person certifying examination. While various strategies exist for physicians to mitigate their carbon emissions, reducing air travel is a particularly expedient and impactful means to do this. Although our study solely quantifies the carbon emissions associated with the ABOS Part II certifying examination and does not constitute a comprehensive cost-benefit analysis comparing in-person versus virtual formats, we believe that our findings warrant consideration as orthopaedics as a specialty looks to reduce its carbon footprint and contribute to the reduction of anthropogenic climate change.

Submitted: January 23, 2025 EDT. Accepted: March 02, 2025 EDT. Published: July 17, 2025 EDT.



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