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ORIGINAL ARTICLE

Carbon Footprint of Medical Education: Preclerkship and Clerkship Considerations

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Abstract

Climate change is putting immense pressure on healthcare systems, which are already responsible for significant global greenhouse gas emissions, contributing 4.4 % of worldwide emissions. Medical education, as an integral part of the healthcare system, also plays a role in this environmental impact, particularly through energy-intensive preclerkship learning spaces and carbon-heavy clerkship travel. However, innovative strategies such as digital and hybrid learning, telemedicine, and longitudinal integrated clerkships (LICs) present opportunities for emission reductions. This commentary explores the carbon footprint of medical education, assesses the impact of traditional practices, and proposes practical solutions to integrate sustainability into future medical training..

Keywords Clerkship Education, Climate Change, Curriculum Development, Preclerkship Education.

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INTRODUCTION/BACKGROUND

Climate change is increasingly straining health care systems that are already under pressure in many parts of the world. In some regions, such as OECD countries, China and India, studies estimate that health care contributes about 5 % to national CO_2 emissions, placing it on par with the food sector in terms of its environmental impact[1]. In terms of worldwide emissions, healthcare sector is a significant contributor to global greenhouse gas emissions, responsible for approximately 4.4 % emissions[2]. The emissions from the healthcare sector are result of a wide range of activities, including direct patient care and research, education and waste management from patient care and research activities. With the Paris agreement requiring rapid emission reductions in all sectors of the global economy to stay well below the 2 °C targe, the healthcare industry faces increasing pressure to contribute its fair share towards this solution. Medical education, as an integral part of the healthcare system, shares the obligation to address this challenge.

Medical schools play a critical role in preparing future physicians, but they also contribute to the healthcare sector's environmental impact. From the energy consumption of academic buildings to the carbon-intensive travel associated with attending lectures, labs, clinical rotations, medical education is directly responsbile for a significant amount of emissions. This paper examines the carbon footprint of medical schools, focusing on both the preclerkship and clerkship phases of education. By analyzing the environmental impact of traditional education models and exploring innovative strategies for reducing emissions, this commentary offers a balanced perspective on how medical schools may be able to adapt to the sustainability challenges of the 21st century.

The preclerkship phase of medical education typically involves classroom-based learning, often delivered in large lecture halls, small group settings or laboratories. In addition, students may be engaging in assigned online learning requring use of internet and computer devices. These settings require substantial energy for lighting, heating, cooling and powering electronic equipment. In contrast, the clerkship phase involves students rotating through various clinical sites, often necessitating travel between hospitals, clinics and outpatient facilities. Both phases contribute to the carbon footprint of medical education, but they also offer opportunities for reducing emissions through digital learning, telemedicine and other innovative approaches.

Given the urgency of addressing climate change, medical schools must begin thinking about balancing the need to maintain high-quality education with the imperative to reduce their environmental impact. This exercise can be guided and informed by the emerging findings from the Science of Learning and Cognitive Learning Theories. This following sections will explore the specific environmental challenges associated with preclerkship and clerkship education, assess the potential for carbon reduction and propose a few practical solutions for integrating sustainability into medical education.

Preclerkship Education: Digital Learning and Carbon Reduction

The traditional model of preclerkship education is resource-intensive. Large lecture halls, anatomy labs and other educational spaces consume vast amounts of energy for heating, cooling and powering equipment. There are emissions associated with each of these activities. For e.g., the activties related to the anatomy labs such as transporting donor bodies for dissections, storing them in freezers and cremating the human remains can be an enormous contributor to carbon emissions. A significant portion of a medical school's carbon footprint can be attributed to its buildings, which require constant maintenance to ensure that temperature, air quality and lighting meet the necessary standards for education[3, 4]. For example, laboratories where students conduct dissections or simulations often need to be maintained at specific temperatures to ensure proper storage of biological materials. These energy-intensive environments contribute to a medical school's carbon footprint.

However, the COVID-19 pandemic prompted a rapid shift to online learning, which revealed the potential for reducing emissions associated with preclerkship education. Moving lectures and assessments online reduced the carbon footprint of preclerkship education by up to 30 %, primarily by eliminating the need for students to commute to campus and reducing the demand for physical classroom space[4]. This shift has opened new possibilities for reducing emissions in medical education.

Digital and hybrid learning models offer several advantages in terms of sustainability. By delivering lectures, tutorials and assessments online, medical schools can significantly reduce their energy consumption. A study conducted at Case Western Reserve University evaluated the effectiveness of the HoloAnatomy® mixed-reality application compared to traditional cadaveric dissection in teaching musculoskeletal anatomy. The randomized controlled trial found that students achieved comparable learning outcomes with both methods, suggesting that mixed-reality technology can serve as an effective alternative to cadaveric dissection[5]. Moreover, online learning platforms can facilitate the use of virtual simulations and other digital tools, further decreasing the need for resource-intensive physical environments. Additionally, for didactic lectures, students can participate in synchronous live sessions from various locations, reducing the need for commuting and minimizing transportation-related emissions.

However, the transition to digital learning is not without environmental costs. The production, maintenance and disposal of electronic devices, such as laptops, tablets and smartphones, contribute to e-waste and carbon emissions. Moreover, the data centers that power online learning platforms consume large amounts of energy. Data centers account for approximately 1 % of global electricity demand, a figure that is expected to grow as more educational institutions move online[6]. Therefore, while digital learning can reduce the carbon footprint of preclerkship education, it is important to consider the environmental costs associated with increased reliance on technology.

To mitigate these costs, medical schools can adopt strategies such as using energy-efficient devices, encouraging recycling and proper disposal of electronic waste and selecting online platforms that are powered by renewable energy sources. By carefully considering the environmental impact of digital education, medical schools can make informed decisions about how to reduce their carbon footprint while maintaining high standards of education.

Simulation-Based Learning and Its Environmental Footprint

Simulation-based education has become a cornerstone of modern medical training, offering students the opportunity to practice clinical skills in a controlled environment before interacting with real patients. However, simulation centers can be energy-intensive, requiring climate control, lighting

and the use of high-tech equipment such as manikins, which need regular maintenance and sometimes single-use components. For example, some manikins and simulation devices require disposable parts such as needles, syringes and gloves, which contribute to medical waste[7].

Nevertheless, virtual simulations offer a promising alternative that can reduce the environmental impact of simulation-based education. Virtual simulations allow students to engage in realistic clinical scenarios using software rather than physical equipment. This eliminates the need for many disposable materials and reduces the energy consumption associated with maintaining simulation centers. Additionally, virtual simulations can be accessed remotely, allowing students to practice clinical skills without traveling to a physical location. This can be used for students during their early preclerkship phase and has the potential to repalce some of the in-person clinical skills sessions.

However, like digital learning, virtual simulations have their own environmental costs. The development and maintenance of virtual simulation platforms require significant computing power and the energy consumption of data centers must be taken into account. To minimize the environmental impact of virtual simulations, medical schools should prioritize the use of energy-efficient technologies and renewable energy sources for their digital infrastructure. By incorporating sustainability into the design and implementation of simulation-based education, medical schools can reduce their carbon footprint while continuing to provide high-quality training.

Clerkship Education: Transportation and Carbon Costs of Clinical Environments

Clerkship education is a critical phase of medical training, during which students apply their knowledge in real clinical settings and learn from real patient experiences. However, the traditional model of clerkship education often involves frequent travel between different clinical sites, resulting in substantial carbon emissions. Medical students often need to travel significant distances between various healthcare facilities during their clinical rotations. In some cases, this includes air travel to reach remote clinical sites. For instance, a study published in BMC Medical Education discusses how pre-final year medical students at Stellenbosch University were distributed across a widespread training platform in two provinces of South Africa, utilizing a range of healthcare facilities in both rural and urban areas, rather than the central academic hospital. This distribution required students to commute long distances and in some instances, travel by plane to reach remote clinical sites[8]. Transportation accounts for nearly 30 % of the carbon footprint of clerkships, with air travel being a particularly significant contributor[9].

One solution to the carbon emissions associated with clerkship travel is the adoption of Longitudinal Integrated Clerkships (LICs). LICs allow students to stay at a single clinical site for an extended period, rather than rotating between different locations. This model not only reduces the need for travel but also provides students with a more cohesive and continuous learning experience. LICs can reduce carbon emissions by up to 40 % compared to traditional clerkship models, while also promoting stronger relationships between students and clinical teams[10].

Telemedicine offers another opportunity to reduce the carbon footprint of clerkship education. As telemedicine becomes increasingly integrated into healthcare, students can participate in virtual patient consultations and other remote clinical activities without the need for in-person visits. Incorporating telemedicine into clerkship education could reduce transportation-related emissions by as much as 25 %, particularly for outpatient services[9]. Additionally, telemedicine allows students to gain experience with the technologies and workflows that are likely to become more prevalent in their future practice.

The Environmental Costs of Clinical Training Environments

In addition to the transportation-related emissions associated with clerkships, clinical training environments themselves can be significant sources of carbon emissions. Hospitals, in particular, are energy-intensive institutions that require large amounts of power for lighting, heating, cooling and operating medical equipment. Hospitals are among the most energy-intensive buildings in the healthcare sector and their carbon footprint is exacerbated by the use of single-use medical supplies, which generate substantial waste[2].

Reducing the environmental impact of clinical training environments requires collaboration between medical schools and healthcare institutions. Hospitals and clinics can adopt sustainable practices such as using renewable energy sources, reducing waste and implementing energy-efficient building designs. For example, some hospitals have begun to use solar panels and energy-efficient lighting to reduce their carbon footprint. Additionally, efforts to reduce the use of single-use medical supplies and promote recycling can help to minimize waste in clinical settings.

Medical schools can also play a role in promoting sustainability within clinical training environments. By integrating sustainability education into the curriculum,

medical schools can raise awareness among students about the environmental impact of healthcare practices. For example, students can be encouraged to consider the environmental implications of their clinical decisions, such as choosing reusable medical instruments when appropriate. By fostering a culture of sustainability in clinical education, medical schools can contribute to the broader effort to reduce the carbon footprint of the healthcare sector.

CONCLUSION

The carbon footprint of medical education, particularly in the preclerkship and clerkship phases, presents a significant challenge for medical schools. However, this challenge also offers an opportunity for innovation and sustainability. Digital and hybrid learning models, virtual simulations, longitudinal integrated clerkships and telemedicine all present viable strategies for reducing the environmental impact of medical education. Additionally, hospitals and clinics can adopt sustainable practices that contribute to the overall reduction of healthcare emissions.

While the transition to more sustainable models of medical education requires careful planning and consideration, it is essential for medical schools to take proactive steps toward reducing their carbon footprint. By balancing educational quality with environmental responsibility and adopting the emerging findings from the science of learning, medical schools can continue to provide high-quality education while contributing to the global effort to combat climate change.

Future research should delve deeper into understanding the carbon footprint of different educational activities in medical training while also exploring how proposed changes impact student learning experiences and outcomes. Additionally, uncovering new ways to minimize environmental impact while maintaining educational quality is essential. Collaboration between medical schools, healthcare institutions and other stakeholders is vital for creating robust sustainability plans that address both education and clinical practice. By leading these efforts, medical schools have a unique opportunity to shape a healthcare future that is not only environmentally sustainable but also equitable and socially responsible.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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