English

Telehealth and Decarbonization: A perspective for Porto Alegre's metropolitan region

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Abstract

The healthcare sector is a significant contributor to global emissions, with Brazil accounting for a notable share. Telehealth, using information technologies for remote care, helps reduce patient travel and its associated environmental impact. This study explores the role of telehealth in decarbonization within the metropolitan region of Porto Alegre, focusing on its potential to reduce greenhouse gas (GHG) emissions. **Objective**: To evaluate how telehealth can support decarbonization by reducing GHG emissions in Porto Alegre's healthcare sector. **Methodology**: An integrative literature review of 21 studies from the past five years was conducted, along with a simulation of the carbon emissions avoided by the TelessaúdeRS program in the region. **Results:** The findings show a strong relationship between reduced travel via telehealth and decreased GHG emissions. The simulation estimated that 199,492 consultations avoided over 14 million kilometers of travel, saving 1.8 million liters of fuel and reducing costs by 6 million reais. This resulted in a 1.9-ton reduction in CO2e emissions, equivalent to the carbon sequestered by 32,800 tree seedlings over 10 years. **Conclusion**: Telehealth demonstrates significant potential for decarbonizing healthcare, particularly in Porto Alegre, by reducing emissions and promoting sustainability.

Key-words: Telehealth, Carbon Footprint, Greenhouse effect, information technologies, environmental impact.

Resumen

Telesalud y Descarbonización: Una perspectiva para la región metropolitana de Porto Alegre

El sector de la salud contribuye significativamente a las emisiones globales, con una parte importante proveniente de Brasil. La Telemedicina, al usar tecnologías para ofrecer atención remota, ayuda a reducir los desplazamientos de los pacientes y el impacto ambiental asociado. Este estudio analiza el papel de la Telemedicina en la descarbonización del sector salud en la región metropolitana de Porto Alegre, centrándose en la reducción de emisiones de gases de efecto invernadero (GEI). **Objetivo**: Evaluar cómo la Telemedicina puede reducir las emisiones de GEI en el sector salud de Porto Alegre**. Metodología**: Se realizó una revisión de 21 estudios recientes y una simulación de las emisiones de carbono evitadas por el programa TelessaúdeRS. **Resultados**: La simulación mostró que 199,492 consultas evitaron más de 14 millones de kilómetros de desplazamiento, ahorrando 1.8 millones de litros de combustible y 6 millones de reales. Esto resultó en una reducción de 1.9 toneladas de CO2e, equivalente al carbono secuestrado por 32,800 plántulas de árboles en 10 años. **Conclusión**: La Telemedicina es una herramienta clave para la descarbonización del sector salud, especialmente en Porto Alegre, al reducir emisiones y promover la sostenibilidad.

Palabras clave: Telemedicina, Huella de Carbono, efecto invernadero, tecnologías de la información, impacto ambiental.

Resumo

Telessaúde e Descarbonização: Uma perspectiva para a região metropolitana de Porto Alegre

O setor de saúde contribui significativamente para as emissões globais, com uma parte expressiva vinda do Brasil. A Telessaúde, ao utilizar tecnologias para oferecer atendimento remoto, ajuda a reduzir as viagens dos pacientes e o impacto ambiental associado. Este estudo investiga o papel da Telessaúde na descarbonização do setor de saúde na região metropolitana de Porto Alegre, focando na redução das emissões de gases de efeito estufa (GEE). **Objetivo**: Avaliar como a Telessaúde pode contribuir para a redução das emissões de GEE no setor de saúde de Porto Alegre. **Metodologia:** Foi realizada uma revisão integrativa de 21 estudos dos últimos cinco anos e uma simulação das emissões de carbono evitadas pelo programa TelessaúdeRS na região. **Resultados**: A simulação mostrou que 199.492 consultas evitaram mais de 14 milhões de quilômetros de deslocamento, economizando 1,8 milhão de litros de combustível e 6 milhões de reais. Isso resultou em uma redução de 1,9 toneladas de CO2e, equivalente ao carbono sequestrado por 32.800 mudas de árvores ao longo de 10 anos. **Conclusão**: A Telessaúde se apresenta como uma ferramenta eficaz para a descarbonização do setor de saúde, especialmente em Porto Alegre, ao reduzir as emissões e promover práticas sustentáveis.

Palavras-chave: Telessaúde, Pegada de Carbono, efeito estufa, tecnologias da informação, impacto ambiental.

INTRODUCTION

Telehealth encompasses various applications such as teleconsultation, tele-diagnosis, and remote consultations, utilizing information and communication technologies (ICT) to provide healthcare services at a distance[1]. In Brazil, its origins date back to the 1980s, evolving through the years with the National Telehealth Program, aimed at integrating education and service within the Unified Health System (SUS)[2]. During the COVID-19 pandemic, telehealth proved crucial in reducing patient travel and virus exposure, while facilitating access to healthcare[3]. Beyond democratizing access to healthcare, especially in regions with poor infrastructure, telehealth reduces the distances travelled by patients and healthcare professionals[1].

Decarbonization in the healthcare sector has become an increasingly urgent concern, particularly in light of the Paris Agreement, which seeks to reduce greenhouse gas (GHG) emissions and mitigate climate change[4]. Brazil, as the seventh-largest global emitter, has committed to reducing emissions by 37% by 2025 and 43% by 2030[4]. Although the healthcare sector represents just 4.4% of global GHG emissions, telehealth emerges as a promising strategy for decarbonization by reducing the need for physical travel, thereby potentially lowering transport-related emissions. In 2022, transport-related emissions in Brazil amounted to 216,877,617 megatonnes of CO_2e[5].

Regarding CO_2 emissions, Rio Grande do Sul recorded 77.6 million tonnes of CO_2 equivalent (CO_2eq) in 2020, surpassing the thresholds established in the Paris Agreement, which sets targets of 43.8 million tonnes by 2025 and 34.8 million tonnes by 2030[6]. To address this challenge, the PROClima 2050 Agenda of the state government aims to reduce carbon emissions by 50% by 2030 and achieve full neutrality by 2050, with actions divided across four pillars: energy transition, GHG emission reduction, environmental education, and climate adaptation[7]. Although specific plans for the healthcare production chain are still lacking, several healthcare institutions are already incorporating sustainable practices into their strategic planning, focusing on energy efficiency and proper waste management.

The United Nations Sustainable Development Goals (SDGs) align with decarbonization efforts, Emphasizing the importance of ensuring health and well-being (SDG 3) and promoting affordable and clean energy (SDG 7)[8]. Implementing high-impact actions, such as transitioning to clean electricity and adopting sustainable waste management, is essential to achieve net-zero emissions in the healthcare sector[9].

The Metropolitan Region of Porto Alegre, comprising 34 municipalities and approximately 4.4 million inhabitants, serves as an important area for implementing telehealth. The TelessaúdeRS Program, part of the Graduate Program in Epidemiology at the Federal University of Rio Grande do Sul (UFRGS), plays a crucial role in supporting healthcare professionals, receiving funding from the State Health Department of Rio Grande do Sul[10] and the Ministry of Health until August 2024. For instance, the RegulaSUS Program seeks to reduce waiting lists for specialised medical care in the SUS by leveraging technologies that assist primary care physicians in diagnosing and treating patients based on evidence-based protocols. Since its launch in 2015, the RegulaSUS has conducted over 930,000 regulations, resolving 51% of cases without the need for in-person consultations[11].

In this context, this study aims to examine the relationship between telehealth and decarbonization in general and estimate the carbon footprint reduction achieved by the TelessaúdeRS Program in the Metropolitan Region of Porto Alegre.

METHODOLGY

Integrative Literature Review

According to Whittemore and Knafl12, an integrative review is a method that summarises empirical or theoretical literature to provide a comprehensive understanding of a specific health phenomenon or problem. This methodology involves five main steps: 1) Problem identification; 2) Literature search; 3) Data evaluation; 4) Data analysis; and 5) Presentation of results.

Ethical approval was not required.

Following this framework, the methodology of this study was structured as shown in Table 1.

Table 1

Steps for the Integrative Literature Review	**Description**
1) Problem identification, research question	The research question seeks to identify: "What is the relationship between decarbonization and telehealth?"
2) Literature search	Searches were conducted in PubMed, Scopus, and VHL databases. The search terms used were: (telemedicine OR telehealth OR "remote consultation") AND (decarbonization OR "carbon footprint" OR "greenhouse gases" OR "environmental sustainability") and (telemedicina OR telessaúde OR "consulta remota") AND (descarbonização OR "pegada de carbono" OR "gases de efeito estufa" OR "sustentabilidade ambiental").
3) Data evaluation	Filters were applied to display articles published in the past five years (2019–2024) across all databases. Additional filters included: articles only, excluding other types of material such as book chapters or essays, and restricting the selection to open-access articles available in full text for free.
4) Data analysis	The selected articles were evaluated against specific criteria to ensure relevance and validity. Title and abstract Analyzes were conducted for each article to verify alignment with the research question.
5) Presentation of results	Results were presented in table format (Appendix A) and discussed in detail in the Results section.

Emission Simulations for the Metropolitan Region of Porto Alegre

In line with the findings of the literature review, a simulation of emissions avoided through a telehealth Program was conducted. Open data from the TelessaúdeRS Program was used, containing information about the total number of telehealth consultations by municipality and time period.

The data collection period followed the same timeline used in the literature review search, encompassing the last five years (2019 to September 2024). The selection of municipalities was based on the definition provided by the Socioeconomic Atlas of Rio Grande do Sul for the Metropolitan Region of Porto Alegre, which comprises 34 municipalities.

The simulation aimed to estimate the following:

- Travel distances avoided;
- Fuel consumption avoided (in quantity and cost);
- CO2e emissions avoided.

For distance measurements, a specific starting point was established for each municipality in the Metropolitan Region towards the capital, Porto Alegre, using Google Maps. Round-trip distances were calculated for all journeys.

To enable the simulation, certain generalizations were made. Porto Alegre was chosen as the destination for all trips, given its status as the largest city in the region and the main hub for healthcare services. Additionally, it was assumed that each consultation avoided one round-trip journey and that all travel would have been conducted by car, with an average fuel consumption of 11.47 km/liter.

These generalizations exclude the possibility of consultations being conducted in other metropolitan municipalities, patients undertaking multiple consultations, or the use of alternative transport methods (e.g., buses, vans, motorcycles, aeroplanes). Travel from the patient's residence to the Basic Health Unit (BHU) or remote consultation site was also disregarded. This limitation may have influenced the results, either positively or negatively.

The total distance avoided was calculated using the formula:

$$DT = AT \times (d \times 2)$$

Where:

- DT = Total Distance Avoided;
- AT = Total consultations in the municipality;
- d = Distance between the municipality and the destination (one-way).

The Brazilian GHG Protocol Program tool, provided by the Sustainability Study Center of

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Fundação Getúlio Vargas (FGV), was used to calculate emissions. This tool, commonly employed for corporate and organizational emissions inventories, focuses on mobile combustion, which pertains to emissions from transport modes[13].

- Emissions per liter;
- Total emissions avoided.

For cost savings in fuel, the average resale price over the past five years (2019–September 2024) for Rio Grande do Sul, as disclosed by the National Petroleum Agency (ANP), was used. The multiplier value was set at R$ 5.28 per liter[14].

Equivalent scenarios were provided by entering the results into the Greenhouse Gas Equivalencies Calculator[15].

RESULTS AND DISCUSSION

The results and their discussion are presented below, with an analysis of the data obtained and its interpretation in relation to the study objectives.

The emission factor per liter of fuel saved, defined by the tool, was 3.74 kg of CO_2.

Finally, the total distances were entered into the tool to estimate emissions avoided and determine the following results:

- Liters of fuel saved;

General Overview of Articles

For the database search conducted in Scopus in September 2024, 755 publications were initially identified. After applying filters, 191 articles remained. Of these, following a selection process based on title and abstract analysis, 9 articles were chosen for the review. Similarly, in the PUBMED/BVS search conducted in August 2024, 29 publications were found, reduced to 22 after filtering, and finally narrowed to 12 articles after title and abstract analysis.

Thus, the integrative literature review was composed of a detailed analysis of 21 articles, providing an overview of the research problem and a variety of data and information.

The selected articles are summarized in Table 2:

Table 2

Title	Authors	Study Location	Year
The potential of virtual healthcare technologies to reduce healthcare services' carbon footprint.	Usher, Kim; Williams, Jen; Jackson, Debra	Australia	2024
Exploring the Environmental Impact of Telemedicine: A Life Cycle Assessment.	Savoldelli, Anna; Landi, Daniele; Rizzi, Caterina	Italy	2024
Travel Distance Between Participants in US Telemedicine Sessions With Estimates of Emissions Savings: Observational Study.	Cummins, Mollie R; Shishupal, Sukrut; Wong et al.	USA	2024
Reduction of Environmental Pollutants and Travel Burden Through an Academic Medical Center-based Electronic Consultation Program.	Moore, Susan L; Grim, Stephanie; Kessler, Rodger et al.	USA	2024
A Telemedicine Center Reduces the Comprehensive Carbon Footprint in Primary Care: A Monocenter, Retrospective Study.	Schmitz-Grosz, Krisztina; Sommer-Meyer, Carsten; Berninger, Philipp et al.	Switzerland	2023
The environmental impact of surgical telemedicine: life cycle assessment of virtual vs. in-person preoperative evaluations for benign foregut disease.	Sillcox, Rachel; Gitonga, Baraka; Meiklejohn, Duncan A et al.	USA	2023
Economic and Environmental Impact of Digital Health App Video Consultations in Follow-up Care for Patients in Orthopedic and Trauma Surgery in Germany: Randomized Controlled Trial.	Muschol, Jennifer; Heinrich, Martin; Heiss, Christian et al.	Germany	2022
Assessing the carbon footprint of digital health interventions: a scoping review.	Lokmic-Tomkins, Zerina; Davies, Shauna; Block, Lorraine J et al.	Australia	2022

Title	Authors	Study Location	Year
Telehealth: Reducing Patients' Greenhouse Gas Emissions at One Academic Psychiatry Department.	Penaskovic, Kenan M; Zeng, Xiaoming; Burgin, Stacey et al.	USA	2022
A Transparency Checklist for Carbon Footprint Calculations Applied within a Systematic Review of Virtual Care Interventions.	Lange, Oliver; Plath, Julian; Dziggel, Timo F et al.	Germany	2022
Positive environmental impact of remote teleconsultation in urology during the COVID-19 pandemic in a highly populated area.	Filfilan, A; Anract, J; Chartier-Kastler, E et al.	França	2021
Every cloud has a silver lining: the environmental benefit of teledermatology during the COVID-19 pandemic.	O'Connell, G; O'Connor, C; Murphy, M	USA	2021
Analyzing telehealth emissions and variations in primary care settings - A scoping review	Rachel de Sain, Amanda Irwin	Australia	2024
Carbon emissions and air pollution savings among telehealth visits for cardiology appointments	Gunn, Alexander H.; Murray, Evan M.; Patel, Manesh R et al.	USA	2024
Does telemedicine reduce the carbon footprint of healthcare? A systematic review	Purohit, Amy; Smith, James; Hibble, Arthur	United Kingdom	2021
Environmental impact of telerehabilitation visits in an urban setting	Iaccarino, Mary Alexis; Paganoni, Sabrina; Tenforde, Adam et al.	USA	2022
Health care in rural areas: proposal of a new telemedicine program assisted from the reference health centers, for a sustainable digitization and its contribution to the carbon footprint reduction	Moncho-Santonja, Maria; Aparisi-Navarro, Silvia; Defez Garcia, Beatriz et al.	Spain	2022
High acceptability, convenience and reduced carbon emissions of tele-neurology outpatient services at a regional referral centre in Kenya	Yakub, Fazal Abdulaziz; Shah, Jasmit; Sokhi, Dilraj Singh	Quênia	2023
Impact of Remote Cardiac Monitoring on Greenhouse Gas Emissions	Bawa, Danish; Ahmed, Adnan; Darden, Douglas et al.	USA	2023
The environmental impacts of telemedicine in place of face-to-face patient care: a systematic review	Ravindrane, Ramyadevi; Patel, Jay	United Kingdom	2022
Pediatric telemedicine visits reduce greenhouse gas emissions	Grabski, David F.; Meyer, Matthew J.; Gander, Jeffrey W.	USA	2024

Among the study locations, the United States was the most represented with nine articles, followed by Australia (three articles), Germany (two articles), and the United Kingdom (two articles). Individual articles were found from France, Italy, Kenya, and Switzerland. No articles from Brazil or Latin America were identified.

The temporal scope of this review encompasses the COVID-19 pandemic period, which significantly transformed healthcare services and accelerated the adoption of telehealth. During the pandemic, measures such as social distancing and travel restrictions made telemedicine indispensable. A Medicare report[16] revealed that, in the United States alone, telemedcine consultations increased 63-fold, from 840,000 in 2019 to 52.7 million in 2020.

The impact of the pandemic also influenced scientific production. As shown in the chart below, a progressive increase in publications was observed between 2019 and 2024, although no articles related to the topic of this review were found in 2019 and 2020. This suggests that the subject gained prominence after the pandemic's critical period as researchers began to evaluate the changes introduced by telehealth practices. The sharp increase in 2024 publications reflects the

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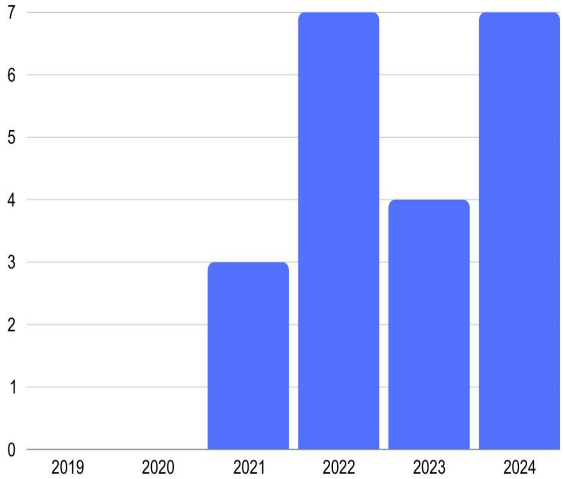
consolidation of telehealth in the scientific agenda, especially after the WHO declared the end of the global health emergency in 2023. Figure 1 below illustrates this scenario:

Figure 1



The reviewed articles provided evidence of a relationship between telehealth and decarbonization. All selected studies indicated that telehealth practices significantly reduced greenhouse gas emissions.

Main Causes of Reduction

The primary factor contributing to the reduction in CO2 emissions is the decreased travel of patients and healthcare professionals. This aspect was the central focus of 18 out of 21 studies.

For instance, Penaskovic et al.[17] evaluated 7,582 appointments at 26 psychiatry clinics between March and December 2020, with 85% conducted via telemedicine. Analysing avoided travel distances and CO2 emissions per mile travelled, the study calculated a net saving of 867,011 kg of CO2, equivalent to the emissions of 189 cars in one year.

Similarly, Filfilan et al. (2021) studied 80 patients from two urology departments. They estimated that in-person consultations would have resulted in 6,699 km of travel (83.7 km per patient). Teleconsultations avoided 1.1 tonnes of total CO2e emissions due to reduced travel. However, emissions from teleconsultation infrastructure amounted to 1.1 kg of CO2e per session compared to 0.5 kg for in-person visits.

Studies by Savoldelli et al., Sillcox et al., and Tomkins et al.[18-20] reinforced this conclusion through Life Cycle Analyzes (LCA) that considered all inputs involved. For example, Savoldelli et al.[18] evaluated the environmental sustainability of virtual versus in-person consultations for patients with heart failure in an Italyn hospital.

Their analysis revealed that telemedicine generated 0.41 kgCO2e per consultation, with internet use accounting for 74% of total emissions. Conversely, in-person consultations generated 9.77 kgCO2e, with 98% of emissions attributed to patient transportation.

These findings demonstrate that while telemedicine infrastructure may generate emissions comparable to in-person consultations in some cases (e.g., Filfilan et al.[21]), the overall environmental benefit is evident when transportation emissions are considered.

Results of the Emissions Simulation

The simulation of emissions avoided by the TelessaúdeRS Program, based on data from 2019 to September 2024, revealed significant public health and environmental impacts, underscoring telehealth's potential as a sustainable solution.

During this period, 199,492 remote consultations were recorded in the Metropolitan Region of Porto Alegre. These consultations avoided 14,821,144.60 kilometres of travel, reducing urban congestion and transport demand while improving citizens' quality of life.

This reduction also led to a saving of 1,178,992.18 liters of fuel, amounting to financial savings of R$6,225,078.71, demonstrating the financial feasibility of a more efficient and sustainable healthcare delivery model.

Environmentally, the Program prevented the emission of 1,983.67 tonnes of CO2 equivalent (CO2e). This reduction is comparable to:

- The annual emissions of 472 petrol-powered passenger vehicles;
- The electricity consumption of 391 homes for one year;
- Charging 130,955,316 smartphones.

These results confirm telehealth’s potential not only for improving healthcare accessibility but also for promoting decarbonization in the healthcare sector and combating climate change.

Final Considerations

This study investigated the potential of telehealth as a decarbonization tool, with a focus on the Metropolitan Region of Porto Alegre. By reducing the need for patient and healthcare professional travel, telehealth has demonstrated its capacity to significantly lower greenhouse gas

(GHG) emissions while enhancing access to healthcare services.

The findings, supported by a literature review of 21 studies and a simulation of the TelessaúdeRS Program's impact, highlight telehealth's environmental benefits. From 2019 to September 2024, the program conducted 199,492 remote consultations, avoiding over 1.1 million liters of fuel consumption and 1,983.67 tonnes of CO2e emissions—equivalent to the annual emissions of 472 vehicles. These results affirm telehealth's potential to address climate challenges while delivering financial savings.

Nonetheless, certain limitations warrant attention. The analysis focused predominantly on travel reduction as the primary driver of emission decreases, overlooking broader environmental impacts such as energy consumption and user behavior in virtual environments. Additionally, variability in methodologies across the reviewed studies and the scarcity of regional data—particularly in Latin America—limit the generalizability of findings. The lack of detailed data on telehealth operations and reliance on generalized assumptions further constrain the accuracy of emission estimates.

Despite these constraints, telehealth emerges as a critical tool for aligning healthcare with global sustainability goals, including the Paris Agreement and the United Nations Sustainable Development Goals. By leveraging technology, telehealth not only enhances the efficiency and accessibility of healthcare services but also contributes to mitigating climate change. To fully realize its potential, future research should incorporate context-specific data, refine methodologies, and explore broader environmental variables to provide a more comprehensive understanding of telehealth's impact.

In conclusion, telehealth represents a transformative approach for decarbonizing the healthcare sector, offering substantial environmental, financial, and societal benefits. Its integration into healthcare systems is essential for building a more sustainable and resilient future.

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Leonardo Viapiana da Costa: Research project design, literature review, methodology selection, data processing, calculations and simulations, compilation of results, and conclusions.
Cláudia de Souza Libânio: General guidance (content, text structure, etc.), review, editing, adjustments to the methodology, refinement of results, and conclusions.
Alessandra Dahmer: General guidance (content, text structure, etc.), review, editing, technical guidance, suggestions for improvement, and conclusion.

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