

INFRASTRUCTURE The environmental impacts of telemedicine in place of face-to-face patient care: a systematic review

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ABSTRACT

Background

Health services have considerable environmental impacts through the production of greenhouse gases and air pollutants. Changes to service provision are needed to mitigate these impacts. Telemedicine may be one tool to achieve this through reductions in travel.

Methods

A systematic literature review was conducted using four databases. The search was limited to original studies in English. Studies were critically appraised using a cross sectional and economic modelling tool. Results were extracted for environmental impacts of the telemedicine service. The reporting of this review is line with PRISMA guidelines.

Results

Out of 2,916 search results, 14 met full inclusion criteria. All 14 studies found an environmental benefit of telemedicine versus face-to-face consultations through reduced greenhouse gas emissions from travel. Three studies found there to be fewer greenhouse gas emissions through telemedicine consultations after accounting for greenhouse gas emissions from the use of telemedicine equipment.

KEYWORDS: climate change, health services, telemedicine, sustainability

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Background

Health services contribute greatly to energy consumption and waste production. A recent study has shown that healthcare can account for up to 5% of a country's annual carbon footprint.¹ The NHS in England contributes 25% of the carbon emissions of the public sector and 4% of the total emissions for England.² Sources of healthcare emissions include building energy, procurement and travel.³

In a study by Lenzen *et al*, transportation of goods and patients was found to contribute 2.3 Mt of carbon dioxide equivalent (CO₂e) to the total global environmental impact of healthcare.⁴ Travel has been identified by the sustainable development unit (SDU) as a carbon 'hotspot', causing 13% of the NHS in England's carbon footprint.⁵ The SDU recommend that all organisations review the need for staff, patient and visitor travel; and promote care closer to home, the use of telemedicine and working from home where possible.³ The SDU estimate that if teleconferencing was to replace 5% of business miles within the NHS, this could lead to CO₂e reductions of 6,827 tonnes per year.⁶

With the need to reduce face-to-face consultations due to the COVID-19 pandemic, there has been a rapid growth in the use of telemedicine.⁷ Telemedicine is defined by World Health Organization as 'The delivery of health care services ... by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation'.^{8,9} Telecommunication methods include video, telephone, website and mobile application technology.

Research into telemedicine has focused on evaluating clinical outcomes, patient satisfaction and the cost-effectiveness of services.^{10,11} There is less evidence quantifying the environmental impacts of telemedicine. No systematic reviews synthesising this emerging body of evidence have been identified. Potential benefits include a reduction in greenhouse gas emissions and waste production associated with each consultation through reduced patient and staff travel and reduced equipment use, particularly through the reduction in raw materials needed and sanitation required per consultation.¹² Potential negative effects include increased energy use associated with greater digitisation. The environmental impact is likely to vary depending on whether the setting is urban or rural.

The aim of this systematic review is to determine whether telemedicine has environmental benefits and to quantify these benefits. It will also identify whether the environmental benefits of telemedicine vary by the form of telemedicine used or the health service setting.

Methods

This review adheres to the PRISMA guidelines for systematic reviews.¹³ Due to the time-limited nature of this review, it was not registered with a systematic review database.

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Any disagreements between reviewers during the literature search, study selection, data extraction or quality appraisal were resolved by clarifying whether the same criteria (ie search strategy; inclusion and exclusion criteria; data extraction; and quality appraisal tools) were being used and interpreted in the same way. Specific disagreements during application of these criteria were reviewed jointly by the authors. Disagreements were resolved by agreeing on a single interpretation for each criterion and applying these to all studies.

Data sources

Four databases were searched by two independent reviewers: Medline (1946 to 23 June 2020), EMBASE (1947 to 24 June 2020), Web of Science (1970 to 2020) and Greenfile (1969 to 2020) for all articles in the English language that evaluated the impact of telemedicine on the environment.

Search strategy

An initial search strategy was developed for Medline which was adapted for EMBASE, Web of Science and Greenfile. Keywords used were 'carbon' and 'telemedicine'. Keywords were combined with the 'exploded' subject headings 'environment' and 'telemedicine'. See supplementary material S1 for full list of search strategies.

Study selection

Two review authors independently screened the titles and abstracts of all studies identified by the search (Fig 1). Inclusion and exclusion criteria were based on the population, intervention, comparison and outcome (PICO) framework. Studies needed to meet all inclusion criteria and no exclusion criteria to be included for full text review. Only studies in English were included due to time and resource constraints.

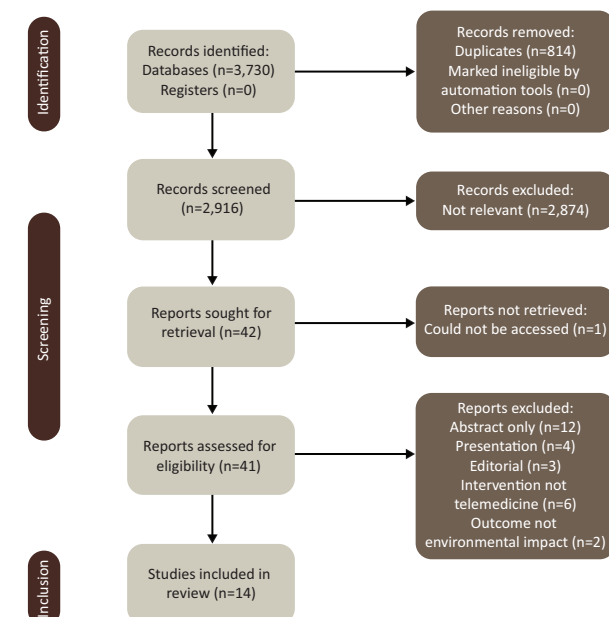


Fig 1. Search strategy for inclusion of studies.

Inclusion and exclusion criteria

The inclusion criteria were patients and healthcare practitioners from any geographical location or time period (population); telemedicine (intervention); face-to-face healthcare consultations (comparison); the environmental benefits of telemedicine (outcome); and any quantitative study design or quantitative elements of mixed method studies.

Exclusion criteria were any population under evaluation that did not include patients and healthcare practitioners; interventions not involving telemedicine; no comparison with face-to-face consultations; no evaluation of the environmental benefits of telemedicine; and study designs that did not have a quantitative element (reviews, editorials, abstracts and presentations).

Quality assessment

Two independent reviewers carried out quality assessment. The included studies were critically appraised to determine their quality and risk of bias. The studies identified were a composite of cross sectional and modelling designs. The National Institutes of Health's (NIH) quality assessment tool for observational cohort and cross-sectional studies was used to critically appraise cross sectional elements of a study.¹⁴ The modelling of environmental costs and benefits was similar to economic cost and benefit modelling. Therefore, a modified version of the Philips *et al*'s checklist was used to appraise the modelling aspects of the included studies.¹⁵

Data extraction

Data extraction was carried out by the two independent review authors.

Analysis

Due to the heterogeneity of study outcome measures and methodology, it was not possible to undertake a quantitative synthesis. A narrative synthesis of study findings was carried out in accordance with Cochrane Consumers and Communication Review Group.¹⁶ Study findings were reported for two main outcomes: environmental impacts of reduced travel and environmental impacts of utilising telemedicine units. Variables such as type of telemedicine, type of environmental impact and context of the service were considered when investigating the heterogeneity of findings across studies. This approach has been recommended by the Synthesis Without Meta-analysis (SWiM) in systematic reviews reporting guideline.¹⁷

To facilitate comparison between heterogeneous outcome measures, unit conversions were undertaken to provide common metrics and calculations were undertaken to summarise data. This was also in accordance with the SWiM in systematic reviews reporting guideline.¹⁷

Results

Search results

The search yielded 3,730 results. After duplicates were removed, there remained 2,916 results for title and abstract screening, of which 2,874 were excluded as irrelevant. A total of 42 were included for full text review, out of which, 14 were included in the study. Out of the papers excluded after full text review, 12

were excluded as they were abstracts only, six did not evaluate telemedicine, four were presentations, three were editorial or opinion pieces, two did not evaluate the environmental impacts of telemedicine and one could not be accessed. A total of 44 references from the 14 included studies were reviewed (title and abstract) but no further studies for inclusion were identified.

Characteristics of the included studies

The 14 studies included in the review ranged in date from 2009 to 2020 (supplementary material S2). Study lengths ranged from 4 months to 17.5 years. Study locations were all in high-income countries: Australia, Canada, Portugal, Spain, Sweden, UK and USA. Seven studies made reference to serving rural or remote communities.^{18–24} Two studies served only urban communities.^{25,26} The remainder did not state whether patient populations were rural or urban.

Nine telemedicine services used videoconferencing technology, four used telephone consultations, one did not specify.^{18–31} Eight studies evaluated telemedicine services in which patients travelled to a designated telemedicine site, either in a primary or secondary care centre for a telemedicine consultation.^{18,19,21–25,28} Five studies evaluated a telemedicine service in which patients remained at home for the consultation.^{26,27,29–31} In one study, both options were present.²⁰ Healthcare specialties included renal medicine, head and neck cancer, vascular surgery, urology, more than one specialty, and not specified.^{18–31}

Eleven studies looked only at the environmental impact of travel, such as greenhouse gas emissions, air pollution and number of trees needed to plant to mitigate carbon dioxide equivalent emissions (CO₂e).^{18,19,22,23,25–31} Three studies evaluated a broader scope of impacts, estimating the environmental impacts of travel and of using the telemedicine unit.^{20,21,24}

Study design

Of the 14 papers included, 12 were cross sectional in design with elements of modelling to estimate environmental impacts (supplementary material S2).^{18–26,28–30} Two studies were mixed-method designs with qualitative aspects using interviews and direct observations, quantitative aspects using cross sectional data collection and environmental modelling.^{27,31}

Results of quality assessment

All studies were of low quality. The key items introducing bias to the cross-sectional elements of studies were definition of study population, recruitment of participants, sample size justification and outcome measures. Two studies did not clearly describe the modelling methodology being used.^{20,31} Only three studies accounted for an element of uncertainty in their models with a sensitivity analysis.^{19,20,28} All studies measured the environmental impacts of reduced travel, but only three studies also measured the environmental impacts of conducting a telemedicine consultation ie the net environmental impact of telemedicine consultations.^{20,21,24} This was a strength as it provided a more robust evaluation of the overall impacts of telemedicine, rather than impacts of travel alone.

Net environmental impact of the telemedicine service

Three studies looked at the environmental impact of travel and use of the telemedicine unit (Table 1).^{20,21,24} The impact of using

Table 1. Net environmental impacts of telemedicine services^{20,21,24}

Author	Consultations / patient numbers	Net CO ₂ e emissions saving
Holmner <i>et al</i> , 2014	719 consultations	Total: 58.31 tonnes CO ₂ e Average per consultation: 0.08114 tonnes CO ₂ e
Masino <i>et al</i> , 2010	840 consultations	Total: 185.12 tonnes CO ₂ e Average per consultation: 0.2195 tonnes CO ₂ e
Whetten <i>et al</i> , 2019	2,020 teleconsultations	Total: 618.74 tonnes CO ₂ e Average per consultation: 0.31 tonnes CO ₂ e

the telemedicine unit was estimated using a life cycle analysis to calculate carbon emissions from the production of telemedicine equipment as well as the energy consumption and carbon emissions associated with their use. Different assumptions were made in the type of telemedicine equipment used, duration of consultations, vehicle mix and emissions per distance travelled. Studies had services of varying patient size, study length and distances travelled.

The telemedicine services provided between 719 to 2,020 consultations.^{20,24} This resulted in total distance savings of 237,152 to 769,157 km.^{20,24} Total emissions savings calculated as the difference between total travel-related emissions and emissions generated through use of the telemedicine unit ranged between 119,033 to 618,738 tonnes CO₂e. This led to an average emission saving per consultation of 66.54 to 305.97 kg CO₂e. The differences in net emissions savings can be explained by the heterogeneity of the telemedicine services and patient populations.

Net environmental benefit is reliant on both travel reduction and ensuring the telemedicine system is the most energy efficient. The study reporting the highest net emissions saving per consultation was one that used a telemedicine operating system with the lowest energy use per consultation rather than greatest travel avoided. One study undertook a sensitivity analysis that showed bandwidth and duration of consultation had the greatest effect in increasing CO₂ emissions.²⁰ All three studies used videoconferencing, therefore it cannot be determined if greater emissions savings would have been made had telephone consultations been used.

Only one study reported air pollutant emission savings. This found total savings of 0.36 tonnes of particular matter, sulphur oxides, and nitrogen oxide.²¹

Environmental impact of avoided travel

Eleven studies evaluated only the environmental impacts of reduced travel (Table 2).^{18,19,22,23,25–29,30,31} Total distance saved ranged from 7,338.61 to 8,602,912.51 km.^{19,25} Total CO₂e emissions savings ranged from 0.35 to 1,969 tonnes.^{19,30} The largest distance and, therefore, emissions savings were made by services with the highest number of consultations.

Average distance saving per consultation ranged from 14.97 to 772.6 km.^{26,27} Average CO₂e emissions savings ranged from 0.69

Table 2. Environmental impacts of avoided travel^{18,19,22,23,25–29,30,31}

Author	Consultations	Distance savings, km	Travel-related emissions savings, tonnes CO ₂ e
Andrew <i>et al</i> , 2020	263	Total: 203,202 Average per consultation: 772.6	Total: 51 Average per consultation: 0.19
Connor <i>et al</i> , 2011	350	Total: 14,899.83 Average per consultation: 42.57	Total: 3.05 Average per consultation: 0.0087
Connor <i>et al</i> , 2019	1,008	Total: 15,085 Average: 14.97	Total: 0.70–2.93 Average per consultation: 0.00069–0.0029
Dorrian <i>et al</i> , 2009	42	Total: 29,316 Average: 698	Total: 5.17 Average per consultation: 0.12
Dullet <i>et al</i> , 2017	19,246	Total: 8,602,891.12 Average: 447.0	Total: 1,969 Average: 0.102
Miah <i>et al</i> , 2019	409	Total: 7,439.98 Average: 18.2	Total: 0.35–1.45 Average: 0.00087–0.0036
Oliveira <i>et al</i> , 2013	20,824	Total: 2,313,819 Average: 111.11	Total: 448–472 Average: 0.02–0.02
Paquette <i>et al</i> , 2019	146	Total: 7,338.61 Average: 50.26	Total: 1.63 Average: 0.01
Thota <i>et al</i> , 2013	1,025	Total: 547,124.10 Average: 522.95	Total: 158.67 Average: 0.16
Udayaraj <i>et al</i> , 2019	202	Total: 5,676.16 Average: 28.10	Total: 1.04 Average: 0.01
Vidal-Alaball <i>et al</i> , 2019	9,034	Total: 192,682 Average: 21.3	Total: 29.35 Average: 0.0032

to 190 kg per consultation.^{26,27} The variation in emissions per consultation was not correlated with service size.

The mean distance and emission savings per consultation were 334.912 km and 0.09555 tonnes CO₂e for telemedicine services serving rural populations compared with 167.79 km and 0.0377 tonnes CO₂e for telemedicine services serving urban populations (or where not otherwise stated). This suggests there may be greater emissions savings for telemedicine services in rural communities due to greater reductions in travel.

One study applied a deterministic sensitivity analysis to evaluate the impact of varying ratios of face-to-face versus telemedicine consultations.¹⁹ At 50% replacement of face-to-face with telemedicine consultations, there were emissions savings of 985 tonnes CO₂, 25 tonnes carbon monoxide, 1.9 tonnes nitrogen oxide and 2.8 tonnes volatile organic compounds. This suggests that even low levels of replacement of face-to-face consultations can result in emissions savings.

Only two studies calculated vehicle emissions associated with physician travel or indirect emissions of fuel.^{28,29} Therefore, the remaining studies likely underestimate travel-related emissions savings.

Two studies looked at non-CO₂ emissions associated with travel.^{19,23} Carbon monoxide, nitrogen oxide and volatile organic compound savings ranged from 4.05 to 25.97 g, 0.19 to 4.86 g and 0.29 to 3.2 g, respectively.

Discussion

Key findings

This systematic review demonstrates the potential for telemedicine to reduce greenhouse gas emissions and other air pollutants through reduced travel. The total quantity of potential

CO₂e savings is equal to the annual energy expenditure of 2,295 households or 0.018% of the total CO₂e emissions of NHS in England.^{32,33} Many studies did not specify if the setting was rural or urban, clinical specialty or type of telecommunication being used. Out of the studies that did, benefits were seen in both rural and urban settings, across a range of clinical specialties, and using telephone and videoconferencing. The magnitude of this benefit was dependent on the energy consumption of the telemedicine systems, number of patients, mode of transport used and distance of travel avoided. Variables affecting telemedicine energy consumption include bandwidth of the telemedicine unit, duration of consultations, rate of use, and hardware and software type.

Most telemedicine services included in this review used videoconferencing rather than telephone consultations. All studies evaluating the emissions produced through using telemedicine units utilised videoconferencing, so it is not possible to determine whether services using videoconferencing have greater environmental impact than those using telephone consultations.

The choice between video and telephone consultations may have an impact on quality of patient care. Video consultations may provide higher quality consultations by being more similar to face-to-face consultations. Specifically, as video allows for non-verbal communication and some aspects of physical examination. A systematic review by Rush *et al* comparing telephone and videoconferencing consultations found that videoconferencing was comparable or better than telephone consultations at reducing the number of unnecessary healthcare consultations.³⁴ It resulted in increased accuracy of diagnosis, treatment decisions and fewer physician-related medication errors. However, consultation duration was longer than for telephone consultations.

Telemedicine can improve access to care, especially in rural and remote settings where there may also be the greatest environmental benefits due to significant reductions in travel.⁹ This would require patients to be willing to have a remote consultation in place of face-to-face, having the access and skills to use the technology, and to be satisfied that their care is as good or better than in-person care.³⁵

Certain settings may be more conducive to the use of telemedicine; for example, routine outpatient or general practice rather than acute hospital settings where there is more likely to be the need for immediate investigations or interventions. Telemedicine may be valuable in providing specialty expertise that would not otherwise be available in that setting; for example, in acute stroke care to enable thrombolysis.

This systematic review identifies that more comprehensive research is needed to quantify accurately the extent to which telemedicine can be environmentally beneficial and scenarios in which this is likely to occur. Future studies should aim to have longer timeframes, provide a real counterfactual reasoning, reduce bias and confounding, and use more robust modelling methodology. Modelling can be improved by inclusion of a sensitivity analysis and clarification on the assumptions within the models. A wider scope of environmental impacts should be evaluated, such as waste production, equipment or building energy use.

Limitations

Due to the mixed design of the included studies, a single critical appraisal tool could not be identified. As a result, an adapted tool was used. Synthesising the results of critical appraisal to stratify studies according to their overall quality was challenging. This was because it was difficult to determine whether certain criteria in the critical appraisal tool had a greater bearing on the overall quality of a study than others. Ultimately it was decided that each criterion would be given equal weighting. Due to the heterogeneity of the studies, it was not possible to undertake a quantitative synthesis, so a qualitative synthesis was carried out.

Conclusion

The COVID-19 pandemic has dramatically increased the use of telemedicine in place of face-to-face consultations. Used in response to COVID-19, teleconsultations have removed the need for physical contact between healthcare provider and patients that is crucial in preventing viral transmission. In response to public health emergencies, telemedicine is beneficial for triage and providing large numbers of healthcare professionals to areas where local health services are overwhelmed.³⁶ Outside of an emergency response, telemedicine has been shown to have similar outcomes to face-to-face consultations for mental health and physical health conditions such as diabetes and heart failure.^{10,36}

While there will always be a need for face-to-face healthcare, there are scenarios in which telemedicine may be more appropriate. This review demonstrates that, alongside the benefits during the pandemic, there are important environmental benefits that support the continued use of telemedicine beyond the COVID-19 pandemic.

The studies included in this review were overall of poor quality. To support the use of expanding telemedicine use, higher quality research to strengthen the evidence base is required. ■

Supplementary material

Additional supplementary material may be found in the online version of this article at www.rcpjournals.org/fhj:

S1 – Full list of search strategies.

S2 – Study design and characteristics.

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