Advancing Healthcare Through Technology

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Abstract

Adopting eHealth technologies has great potential to increase access to better quality healthcare services within Singapore. By increasing the efficiency, accessibility, and presence of these crucial services, digital healthcare has great potential to advance national well-being, good health, and promote equity. Since the 2010s, Singapore has taken on national initiatives to spread the adoption of eHealth technologies and modernize its healthcare sector. However, throughout the past decade, certain ethical implications have risen. Contrastingly, while digital healthcare has the potential to reduce inequalities, it may also widen them if implemented without regard to the nation's pre-existing demographic inequalities. This study builds on previous research, which has established the potential and drawbacks of eHealth, now analyzing the effects of its implementation on health inequalities in Singapore. Furthermore, this study controls for specific demographic variables —age, income, and citizenship status— to evaluate if the effects of eHealth on the quality and accessibility of health services in Singapore differs based on such traits. Using a mixed-methods approach, a comprehensive analysis of Singapore's digital healthcare was conducted. Primarily, qualitative data was obtained through interviews with government and eHealth officials along with first-hand accounts from Singaporean citizens. To supplement, quantitative data on health statistics were collected and evaluated in the *Global Development and Design Healthcare Quality Index (GDD HQI)*— a formula created by the Global Development and Design lab to measure the effects of income. age , and citizenship status on the magnitude of healthcare inequality present in Singapore during a given year. Results from the mixed-methods approach signify that Singapore's implementation of eHealth technologies has increased national well-being and reduced inequalities. Furthermore, results show when Singapore's digitization efforts focus on the elderly, lower-income, and non-citizen

populations, the potential of increasing health inequalities for the most marginalized significantly decreases. Thus, this research sheds light on the necessity for Singapore's future digitization efforts to lead with a focus on marginalized communities to guarantee good health and well-being for all of Singapore. Ultimately, this research can help guide the development of healthcare agendas within developing countries with similar political structures and culture.

Keywords: eHealth, technology, health equity, Singapore, health and well-being, health disparity

Background

Health equity has long been a pressing global issue. Due to institutional and legal barriers, many nations fail to provide individuals with a standardized quality of care (National Academies of Sciences, 2017). Even in areas without such structural challenges, barriers such as the distance of services, long wait times, language, and literacy can significantly reduce the accessibility of healthcare (Lyles et al., 2021). As a result of these structural and nonstructural barriers, vulnerable communities, such as the elderly, lower-income populations, and gender and racial minorities, have consistently faced higher levels of health inequality (Richardson et al., 2022).

Ultimately, these disparities can create dire implications for underrepresented communities and the larger national and global population. On the country level, health disparities may exacerbate the costs in propping up such national services. Without sufficient quality care, impacted populations are likely to require more frequent services, increasing the monetary cost of care while overworking the limited numbers of healthcare providers. Consequently, these disparities may erode a nation's healthcare system, due to overwork and high economic costs. On the global level, health inequalities create dire implications on the health and well-being of surrounding nations. With inequitable access to quality healthcare services, marginalized populations are less likely to be resilient to diseases and sicknesses. Given the globalized context of the international community, the unaddressed health issues of underprivileged communities in one nation have the potential to cross regional boundaries and develop into an international concern (Barreto, 2017).

Thus, it is clear that health disparities must be addressed. Amidst discussions on how to resolve this issue, the implementation of digital health technologies has been raised to be a

potential solution. Most notably, digital healthcare may reduce the structural and nonstructural barriers facing underprivileged communities. The digital landscape allows for health services to be conducted remotely, tackling institutional and distance barriers. Furthermore, the adoption of digital technology can increase the efficiency of healthcare, diminishing the issue of waiting time. Finally, utilizing digital technologies to increase education and awareness of health-related issues can proactively mitigate the prevalence of health concerns (Lyles et al., 2021).

However, such technologies may create unintended outcomes if done without precaution, creating implications on the ethicality of such digitized healthcare. Most notably, varying levels of IT infrastructure development, access to technologies, and the lack of digital literacy have posed further accessibility issues to digitized tech itself, also known as the digital divide (Saeed & Masters, 2021). This digital divide has been observed to primarily impact underprivileged communities, such as the elderly, lower-income groups, and gender and racial minorities. Given this, if these health technologies are implemented without taking accessibility into account, such digitization may widen health disparities among the most vulnerable communities, worsening levels of health equity and raising concerns regarding the ethics of digital healthcare.

To study the potential effects and ethics of digital health technologies, this paper analyzes the Southeast Asian region's implementation of such services. More specifically, Singapore serves as a representative case study in analyzing the effects of digital healthcare, as concerns surrounding health inequity have become increasingly salient while digital healthcare has been implemented as a solution to these concerns (S. T. Tan et al., 2019).

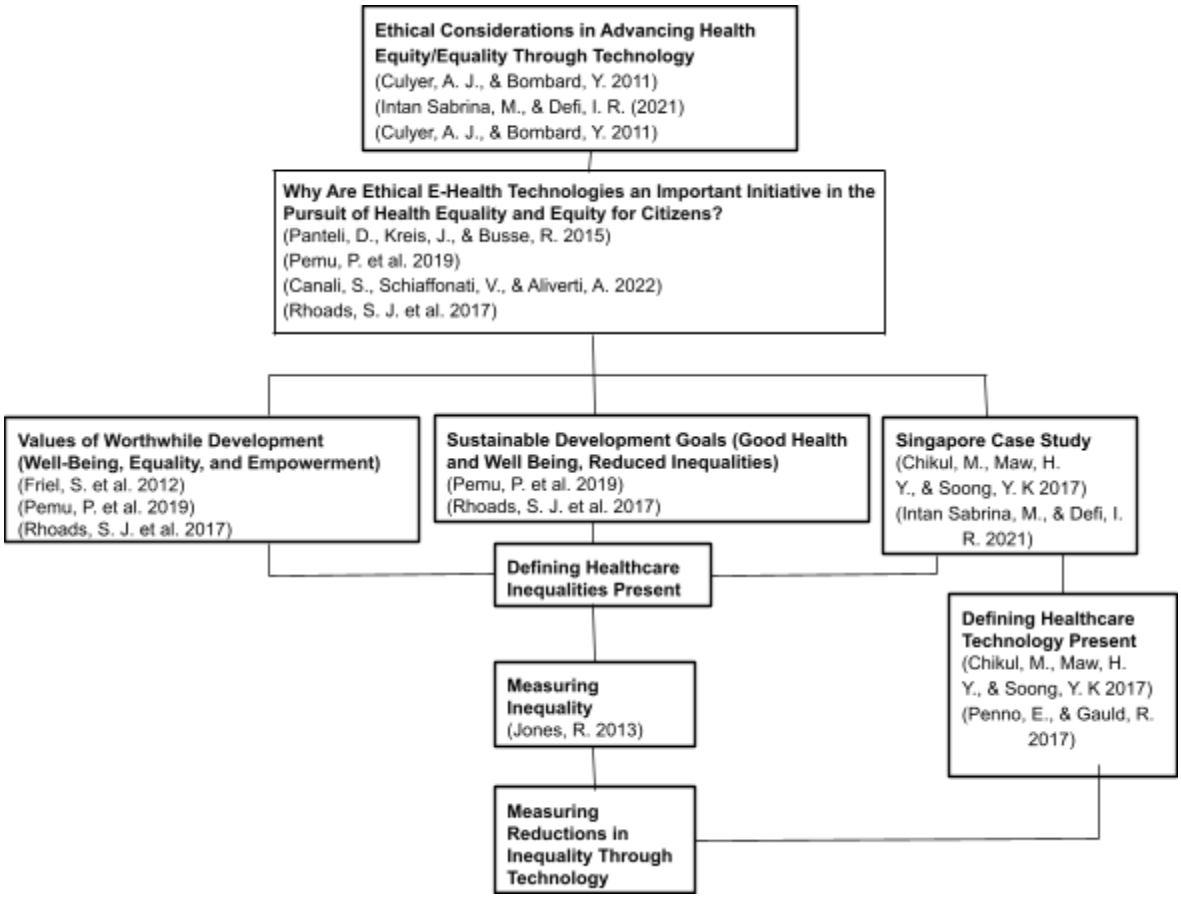
Additionally, Singapore serves as a useful case study in evaluating the effects of digitized healthcare, as over 90% of individuals residing in Singapore are connected to the nation's internet system (Ng et al., 2022). This allows for the research to control for disparities in IT and

internet integration, which would overcomplicate the analytical framework of this research. By controlling for potential disparities in infrastructure development, this paper's research can more reliably isolate the effects of digital technologies on national levels of equity and more specific disparities within demographic groups. Finally, Singapore is one of the smallest nations by area in the Southeast Asian region, allowing the extent of the paper's research on eHealth technology to be generalized across the entire nation.

Aside from aggregated trends of health equity, this paper also observes the inequalities faced by specific demographic groups that have historically been marginalized within Singapore and healthcare systems globally— most notably, the elderly, lower-income populations, and non-citizens (Richardson et al., 2022). Within Singapore, older generations may face greater challenges in navigating the digital landscape, lower income groups may struggle to afford such digital resources, and non-citizens may have decreased access to resources relative to Singaporean citizens (Fang et al., 2018). Consequently, this paper defines age, income, and citizenship status as three key determinants of health, or one's ability to tangibly receive quality care.

Ultimately, this paper observes the effects of digitized healthcare on national levels of health equity, while conducting deeper analysis into the specific effects of digitization on demographic groups identified to be influenced by the three key determinants of health. To understand the relationship between the various foundational concepts of this research regarding digitized healthcare, health disparities, ethical development, and these ideas in the context of Singapore, Figure 1 provides a visualization of the linkages between these major themes.

Figure 1: Literature Map



(Source: Authors)

The Literature Map in Figure 1 is a visual representation demonstrating the major themes in scholarship surrounding the major concepts of this paper's research: the potential and ethics of digital healthcare, health disparities, and health in Singapore. Figure 1 serves as a framework for the literature that inspired the research of this paper, demonstrating how specific themes within this arena of scholarship contributed to the lens in which the paper analyzes the issue of health disparities and digitization. Sources falling within the theme of 'Ethical Considerations in Advancing Health Equity/Equality Through Technology' addresses the general topic being

studied while subsequent boxes delve into the research question being addressed: Why Are Ethical eHealth Technologies an Important Initiative in the Pursuit of Health Equality and Equity for Citizens? The sources within subsequent themes — 'Values of Worthwhile Development' and 'Sustainable Development Goals'— highlights the potential positive effects of ethically implemented digitized eHealth tech. In other words, these sources demonstrate how implementing eHealth technologies with the precautions needed to curb the effects of the digital divide have had positive impacts on the Values of Worthwhile Development and related United Nations Sustainable Development Goals. Discussions regarding the specifics of these concepts are presented in the following section. Finally, sources included in the theme 'Singapore case study' provide real examples of eHealth being implemented.

Within existing scholarship surrounding the ethics of digital healthcare and health disparities, this paper's research reinforces pre-existing findings by highlighting how health digitalization can improve equity within the Singaporean context. However, this paper adds to previous scholarship by introducing nuance to the framework of digital health and health disparities. Our paper finds that, while overall levels of health equity may increase, certain demographic groups influenced by the three key determinants of health —age, income, and citizenship status— may feel negative effects at the margins. This creates implications for assessing the ethics of digital healthcare by requiring future research to not only investigate the effects of eHealth on aggregated levels of health equity but rather analyzing the particular impacts of such digitization among specific demographic groups– such as marginalized communities.

The Ethics of Digitized Healthcare: Applications of the Values of Worthwhile Development

This paper utilizes the framework of Jay Drydyk's Values of Worthwhile Development in assessing the ethics of eHealth implementation into national healthcare systems. The Values of Worthwhile Development are a set of objectives which evaluate the ethics of international development projects, programs, and policies based on seven core values: well-being, equity, agency and empowerment, human rights, cultural freedom, sustainability, and government responsibility and anti-corruption (Drydyk & Keleher, 2018). Development initiatives which create tangible, long-lasting progress in these seven values are deemed ethical under this framework of analysis.

This paper's research specifically evaluates how the digitization of healthcare impacts the values of equity and well-being. Well-being is defined as satisfaction of one's living conditions. Historically, the scope of well-being had been confined to economic well-being: possessing a level of income and economic security to allow for one to feel contentment. However, Drydyk's Values of Worthwhile Development introduces the idea of multidimensional well-being. This widens the definition of well-being by incorporating the idea of subjective welfare, such as one's perceived level of happiness, which can be obtained through increasing an individual's freedoms to pursue basic resources and opportunities to enhance their livelihoods. Within this multidimensional approach to well-being, access to crucial services such as healthcare becomes a critical factor in influencing individual well-being (Drydyk & Keleher, 2018). Thus, in the context of digitizing healthcare, such development initiatives have the potential to greatly improve national levels of such multidimensional well-being. With the implementation of eHealth technologies having the potential to bridge structural and nonstructural barriers, increasing numbers of individuals may consistently access quality care, thus increasing their

overall well-being (Reddy et al., 2022). In addition to the value of well-being, this paper assesses the effects of digital healthcare on the value of equity. Through the implementation of digital technology, equitable access to healthcare becomes more tangible, especially among marginalized communities by connecting them to resources they would otherwise struggle to access (Ngwa et al., 2020; Panteli et al., 2015).

Ultimately, when analyzing the ethics of eHealth technologies, it is crucial to observe its effects on well-being and equity to produce a holistic assessment of the impacts of digital healthcare. Thus, the advancement of eHealth technologies into national healthcare systems, when implemented with ethical precautions, can greatly enhance the Values of Worthwhile Development locally and internationally.

Further Ethical Considerations: Applications of the United Nations Sustainable Development Goals

Advancing health equity also addresses the United Nations Sustainable Development Goals. The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity (United Nations Development Programme, 2024). This paper primarily focuses on SDG #3– Good Health and Well-Being along with SDG #10– Reducing Inequalities. Within the context of digitizing healthcare, SDG #3 has the potential of being directly improved, as the implementation of eHealth may increase access to healthcare services to greater individuals (Friel et al., 2012). Increasing the accessibility of health services directly improves the specific indicators of SDG #3, such as indicator 3.8, which defines the establishment of universal health coverage as an international goal. Additionally, indicators 3.3 and 3.4–the eradication of infectious diseases and

noncommunicable diseases–are goals that may be improved by implementing eHealth technologies to bridge health disparities. With equal access to healthcare, individuals have the ability to receive treatment for diseases they might otherwise have been unable to address (Eachus et al., 1999).

In addressing SDG #10 on reducing inequalities, advancing health equity ensures that people who currently cannot afford or easily access healthcare will no longer face discrimination or systemic disadvantages. Certain diseases are more likely to occur among minority populations (Pemu et al., 2019) so it is important to ensure that technology is equitably distributed to those who are more susceptible to disease. Target 10.1, which aims to reduce income inequalities, is a primary focus. By increasing healthcare technology access, those in economic situations lesser than others will receive the same kind of healthcare as everyone else (Chan et al., 2018). Additionally, indicator 10.3–to ensure equal opportunities and end discrimination–is another goal that is being accomplished by providing healthcare equity and expanding accessibility. People will be able to receive the same healthcare opportunities, which makes the world a healthier and better place. It is important to diminish inequalities and try to improve health and well-being to create a better world for all.

Introduction

Health equity has long been a pertinent issue around the world. Some have not always had the same access to healthcare as others, which could lead to greater problems in the long run. When assessing health technology, noneconomic social consequences and ethics in general were considered (Culyar & Bombard, 2011). It has been a topic of consideration for a considerable amount of time. One region of the world that specifically suffers from having bad equity when it comes to healthcare is Southeast Asia, specifically Singapore. In Singapore, the life expectancy

rate is growing, yet the birth rate is in a constant decline. As a result, there are less people in the workforce that are able to keep up the important institutions that are known, especially hospitals and other healthcare systems. People are less able to access the healthcare systems because there is not always someone that is there for what they need. This especially impacts the older population of Singapore, as the older population could suffer more from more specialized problems. Advancing technology is an efficient way to advance healthcare, but it must be done equitably. Therefore, it is important to find a way to advance healthcare technology in order to make it more accessible for everybody by making sure that implementing new technology does not become so costly that some people are unable to afford it.

Problem Statement

Health disparities create towering barriers to accessing crucial healthcare services. Socioeconomic factors such as citizenship status, age, and income level greatly impact the quality and extent of healthcare available to individuals. Most notably, disadvantaged communities —such as non-citizens, the elderly, and lower-income communities— face the largest barriers and are subject to the lowest quality care. Ultimately, these gaps in accessibility pose detrimental impacts, with disadvantaged communities facing diseases of increased severity for longer periods (Eachus, 1999). Thus, in the context of ethical development, this issue has direct implications for fulfilling the 7 Values of Worthwhile Development as well as the United Nations Sustainable Development Goals (SDGs).

To address these inequalities, technology is a potential solution. Advances in technology can help correct these disparities by decreasing healthcare costs and proliferating crucial services to regions and communities without the existing infrastructure (Chikul et al., 2017). For example, telemedicine has been proposed as a solution to bridging the gap in access to crucial

health services, especially allowing disadvantaged communities to receive proper consultation without having to physically be at a high-quality hospital (Perwitasari & Susanti, 2019). Already, there have been major developments in implementing technology within the healthcare sector. In Singapore, Radio Frequency Identification Technology (RFIDs) and Automatic Guided Vehicles (AGVs) yielded promising results in bridging this gap in healthcare accessibility (Chikul et al., 2017). Thus, it is evident that incorporating technology in the form of telemedicine and automation has a hopeful future. However, there are rising concerns surrounding the ethical implications of eHealth technology.

The world of technology is constantly evolving and adapting to suit the needs of its users. While this has the potential to yield innovations and progress, it may also lead to ethical oversights. In the context of healthcare, technology has the potential to drive positive change in bridging the healthcare gap between advantaged and disadvantaged communities. For example, many disadvantaged communities may lack the necessary technological infrastructure to develop telemedicine services. Additionally, some technologies (phones, laptops, tablets) may be prohibitively expensive for low-income populations, thus disincentivizing the development of eHealth. Furthermore, digital and health literacy pose serious barriers to the efficient use of online health services, as patients may lack the education to interpret and implement the needed care (Reddy et al., 2022). If placed in the hands of private enterprises, digital divides may also be widened, as corporations may only fund tech development projects in areas where they see high profits (Penno & Gauld, 2017). Thus, digitizing healthcare comes with a slew of negative implications that must be addressed to harness the benefits of such developments.

Purpose Statement

Advances in health tech can facilitate more equitable access to healthcare services. By increasing the use of telemedicine and implementing more ICT applications, one can increase accessibility to higher-quality healthcare (Intan Sabrina & Defi, 2021). Especially when considering the gaps in accessibility present between rural and urban populations or lower-income and higher-income populations, as well as disparities across gender, race, and age, the need for developing and implementing such technologies is apparent to help address these inequalities (Hanibuchi et al., 2012). These potential outcomes of utilizing telemedicine and Information and Communications Technology (ICT) applications point to developments in both the Values of Worthwhile Development and the SDGs. Policies that facilitate the expanding use of eHealth target multiple Values of Worthwhile Development: well-being, equality, and empowerment. Furthermore, these initiatives have the potential to help reach SDG #3: Good Health as well as SDG #10: Reducing Equality.

While much literature has emphasized these positive benefits, there are high risks involved as well. Due to the lack of pre-existing policies and precedents for regulating such new technologies, ethics surrounding the proliferation of eHealth has become a significant area of concern (Intan Sabrina & Defi, 2021). Thus, to facilitate ethical growth and promote the Values of Worthwhile Development and the SDGs, a great focus must be placed on the negative externalities that may be born from improper implementation and regulation of technology. By analyzing the current barriers that prevent ethical development in Singapore, the work being done to help fully harness the potential benefits of technology in healthcare is being advanced. Furthermore, by researching the groups most vulnerable to these divides, specialized solutions can be developed that can prevent disadvantaged communities from being neglected or isolated.

Thus, by narrowing the focus on an under-researched, yet integral topic in aiding the equitable development of digital healthcare, significant findings can be applied to this area of Singaporean development.

Main Research Question

In order to address the concept of health equality and equity for Singaporeans from a personal care and policy level, it is crucial to examine the current state of technology in the healthcare field. This led to the development of the main research question: Why are eHealth technologies an important initiative in the pursuit of health equality and equity for citizens? This paper aims to use quantitative data sets and qualitative interviews, narrative analysis, and scholarly articles in order to examine the impact of eHealth-centered technologies on citizens.

Objectives

The primary goal of the research is to investigate the significance of eHealth technologies on target populations, and how these contributions lead to health equity for citizens. This study aims to achieve multiple objectives, such as: (1) examining the role of technology in healthcare, (2) identifying and assessing the specific eHealth technologies developed, (3) identifying and assessing the outcomes of patient care, and (4) reducing health disparities using these means. Through this research, the main aim is to provide insights into the significance of eHealth technologies on citizens in the pursuit of providing health equity.

To support the primary objectives of the research being done, the development of the sub-research questions has been formulated. In the context of eHealth technologies, how can one promote health equity using eHealth technologies while focusing on ethical implementation, how can one ensure that the eHealth technologies being developed create more good than harm in terms of ethics and regulation, and how can one target health disparities while preventing bias?

This paper will dive into critical areas such as ethics, marginalized populations, and technological advances. It is crucial to break down the objectives to clarify the target goals of this research. Examining the role of eHealth technologies in reducing health disparities, increasing access to care, improving patient outcomes, and fostering a stronger sense of equality and equity for citizens can be achieved by analyzing how these specific technologies aid certain target populations.

Methodology

Overview

To understand why these health technologies assist in health equity and equality for citizens, this paper analyzes the implementation of eHealth initiatives from 2013 to 2023. More specifically, this research adopts a mixed methods approach, utilizing interviews and case study analysis along with quantitative approaches using the *Global Development and Design Healthcare Quality Index (GDD HQI)*— an index created by the research group evaluating the overall accessibility of quality healthcare within Singapore. Interviews were conducted with key informants covering perspectives in the government, tech industry, and the public within Singapore. More specifically, for the case studies, this paper analyzes the effects of two national healthcare programs which implemented digital health technologies: Smart Elderly Monitoring and Alert System (SEMAS) and Smart Health Video Consultation program (SHVC). Finally, the GDD HQI metric will be used to assess the equity of Singapore's healthcare system, while supplementary data analysis will help uncover the effect of Singapore's eHealth on this equity score. Singapore healthcare data was acquired from datasets created by the Singapore Department of Statistics (2023) and the Singapore Ministry of Manpower (2024).

Regarding the qualitative approach, case study and narrative analysis was utilized from the review of previous studies conducted in Singapore and the larger Southeast Asian region. This was coupled with the interviews of three Singaporean professionals: Shaun Oon, the Singaporean Deputy Director at Ministry of Culture, Community and Youth; Raphael Ng, a Business to Business (B2B) Enterprise Consultant currently working in Germany; and Shi Jie Samuel Tan, a Singaporean student currently working towards his PhD at the University of Maryland, College Park. These three interviewees were asked questions on their personal experiences with the Singaporean healthcare system and the aspects that either hinder or help the progression of a more equitable healthcare system in the city-state. These questions were then input into the developed quantitative equation that could then be implemented to determine the level of equity in Singapore in any given year. After these values were calculated, percent differences between years could then be used to determine if healthcare equity in Singapore is increasing or decreasing.

Both the quantitative and qualitative components of this research interrelate to allow for a critical understanding of the impact of eHealth on health equity in Singapore. The qualitative case study and interview analyses provide context for the GDD HQI values. For example, the narrative analysis reveals older individuals' struggles with eHealth as well as barriers for non-citizens, which are corroborated by the age and citizenship variables in the equation. In comparison, the quantitative data supports qualitative findings on inequity. For instance, the GDD HQI demonstrates numerical disparities linked to income status, which are reflected in interviewee observations about the stratification of public versus private healthcare costs. The qualitative framework's focus on ethical dimensions is backed by measurable evidence. Quantitative disparities outlined by the GDD HQI scores highlight ethical concerns raised

qualitatively, such as the exclusion of marginalized populations like the elderly, low-income, and non-citizen populations.

Indicators for Evaluation

Singapore is less restrictive on where and how telemedicine activities can be carried out (Intan Sabrina & Defi, 2021). As a result, Singapore has tried to implement Radio Frequency Identification Technology (RFIDs) and Automatic Guided Vehicles (AGVs) to reduce the costs of healthcare and labor as a whole. RFID technology is proving to be an essential tool in tracking valuable and strategic mobile assets in medical facilities (Chikul et al., 2017). RFID technology has been shown to improve the efficiency of retrieving data, and organizing systems so that it is easier to find what is needed. RFID and AGV technology have been proven to drastically improve efficiency and productivity, which as a whole improves healthcare equity, and the systems make it so that healthcare would not be as costly as it is now. It is important to find a way to keep up with the institutions that are so vital while also making sure that it is not too expensive, and new technologies that Singapore has looked into could be the first stepping stone. Along with that, there are technologies like wearables that people now wear daily for medical reasons. Health equity is about making sure that different users are equally provided with services and care as part of their interactions with the health system (Canali et al., 2022) in order to reduce inequalities.

The indicators that are being used to define whether the proposed solutions in Singapore are working are income level, age, and citizenship status. The variables of patient care outcomes, health disparities, and available health services are all important for showing the indicators of success because there can be so much disparity in all of them. When developing new technologies, one must consider evaluating wider social impacts (Penno & Gauld, 2017). With

regard to patient care outcomes and health disparities, one can see how people of different backgrounds may have worse overall healthcare due to several factors. People may not receive equal healthcare solely because of their citizenship status. Along with that, people of different backgrounds, socioeconomic status, and living arrangements may not have the same accessibility to healthcare as other people do. For example, people who are richer in Singapore and live in a central district may be able to receive healthcare more openly and easily than someone who is not considered wealthy and lives in the outskirts of the city. It is also important to pay close attention to age differences to see how that affects healthcare disparities. Healthcare quality for older populations may be influenced by the need for more extensive care from trusted caregivers—care that may not be necessary for younger patients. Therefore, it is important to examine different variables to identify indicators of success in achieving healthcare equity in Singapore, as this approach offers the most effective path toward ensuring equal access for all.

Qualitative Analysis

The first aspect of the study's mixed-method design constitutes a qualitative approach, based on case study and narrative analysis. Case studies were derived from previous literature reviews on digital healthcare in Singapore and eHealth integration in the larger Southeast Asia region. When analyzing these case studies, a new lens of international development was adopted: one based on the Values of Worthwhile Development and the SDGs. As a result, when reviewing case studies, the impacts of digital healthcare on ethical development were assessed by centering the focus around eHealth's effects on well-being, equity, and good health. Through introducing this new lens when analyzing these case studies, the ethical implications of digital healthcare were revealed, thus aiding in answering the central research question of how ethical eHealth development can make Singapore's healthcare system more equitable. To further the qualitative

aspect of the research design, narrative analysis was employed, through the interviewing of Singaporean healthcare professionals, policy experts, and technology developers about the Singaporean healthcare system and eHealth. Interview questions were created based on background information pertinent to the research question and were specifically tailored to the interviewees.

These questions were centered around inquiries into the current state of healthcare in Singapore, the health disparities present in Singapore, and the potential of digital healthcare to either improve the current infrastructure and remediate inequalities or exacerbate and introduce new issues into Singapore's healthcare system. These interviews were then used to determine which forms of inequality would most likely be affected by the introduction of eHealthcare technology under the lens of the SDGs standards and of the 7 Values of Worthwhile Development outlined in the Routledge Handbook of Development Ethics.

Quantitative Analysis

The quantitative side of the mixed methods approach will be centered around the application of the *Global Development and Design Healthcare Quality Index (GDD HQI)*, which will uncover the magnitude of Singapore's healthcare inequalities based on three demographic determinants: age, income, and citizenship status. The statistics that were entered into the GDD HQI were acquired from Singaporean healthcare datasets from the Singapore Department of Statistics (2023) and the Singapore Ministry of Manpower (2024). These variables were chosen to be the most important when determining factors that affect healthcare equity after interviewing the Singaporean key informants: Shaun Oon, Raphael Ng, and Shi Jie Samuel Tan . Income was determined to be an important variable as higher income individuals are able to afford healthcare from private hospitals, a luxury to those less wealthy as less affluent Singaporeans tend to enter

government hospitals for care as they are more likely to accept government subsidies (S. Oon, personal communication, November 6, 2024; S. Tan, personal communication, October 23, 2024; R. Ng, personal communication, October 14, 2024). Age was determined as an important variable because of the association of older generations being less digitally literate which is important in an increasingly digital healthcare system. Citizenship status is the largest indicator of healthcare equity as citizens are guaranteed government subsidies for healthcare which mitigates the negative effects of a lower income on healthcare equity. In addition citizens are also guaranteed government caretakers once they get older, mitigating the negative effect of age on healthcare equity. The effect of citizenship status on mitigating the effects of age and income is why it was decided to be a multiplier as opposed to another added variable. Differences in GDD HQI between different age groups, income levels, and years of citizenship will be used to identify which form of healthcare inequality is most prevalent in the city-state. The GDD HQI equation formulated is listed here:

$$\left[\left(\frac{Gross\ Monthly\ Income\ (\$)\ (2019\ Prices)}{1000}\right) + \left(10 - \frac{Age}{10}\right)\right] 0.5(if\ noncitizen) = GDD\ HQI \quad (1)$$

These three socioeconomic variables have been included in the model as they are the major determinants of health inequity in Singapore. First, previous research conducted on Singapore's health disparities has consistently established income as one of the largest determinants of healthcare inequality. Often, patients of low-income levels do not have the monetary means to pay the increasing costs of outpatient care (Chan et al., 2018). Although Singapore's universal healthcare covers inpatient care —healthcare requiring hospitalization and extended institutionalization— outpatient care —such as regular checkups and minor hospital visits— are not covered under Singapore's healthcare system. While Singaporean government

subsidies assist low-income citizens in accessing basic health services, the quality of care offered at the lowest level is drastically different from the highest, and even average healthcare programs available. This effectively leaves the lowest income levels without the means to pay for quality healthcare, let alone any basic health services (C. Tan et al., 2021). Singapore is also a hub for global health tourism, a phenomenon where richer individuals from neighboring countries with less adequate healthcare systems come to Singapore for health benefits – a phenomenon that can drive up costs for local citizens. In the GDD HQI formula, this income value is expressed as the gross monthly income of a Singaporean citizen divided by 1000 to standardize the income value and ensure numerical consistency across all variables in the index. For example, since the median gross monthly income for Singaporeans in June 2023 was $5,197 per month, the amount entered into the equation for the income category would be 5.197. It is important to note that all income values inserted into the GDD HQI formula are adjusted for inflation based on 2019 prices to maintain a consistent dollar value unaffected by inflation over time. 2019 is the year the Singapore Ministry of Manpower (2024) uses for its income data collection which is why that specific year is replicated in the GDD HQI Income Value calculation.

The second demographic determinant within the GDD HQI is age. Previous studies conducted in Singapore assessing the integration of digital healthcare have established age as a determining factor (Luk, 2018). With the increasing integration of eHealth in Singapore's healthcare infrastructure, many services are being transferred to digital platforms. For example during the COVID-19 pandemic, Singapore's Ministry of Health instituted the TraceTogether Programme which was accompanied by the TraceTogether App as a means of the Singapore government to standardize healthcare tracing digitally (Lee et al., 2021) . Although these initiatives have been adopted to broaden the accessibility of quality healthcare by bridging

geographic barriers and reducing the cost of services, this has also created an alienating effect on older generations. On average, the elderly have lower digital literacy and are less connected to central internet services. As a result, the digitalization of Singapore's healthcare services has created divides among different age groups, because of this generational gap in technological knowledge. Fears about digital scamming have also alienated elderly populations from adopting these new means of technology, a fear that is passed on through word of mouth via anecdotal stories of victims (R. Ng, personal communication, October 14, 2024). This means that elderly populations largely rely on younger family members or caretakers to assist with their healthcare needs as Singapore's healthcare system has largely abandoned the traditional form of non-telehealth technology. The GDD HQI formula has accounted for this demographic determinant in health inequity, where lower ages receive an increased score on the metric as a Singaporean's age is divided by 10 and then that number is subtracted from 10. It is important to note that the GDD HQI Age Value only accounts for the adult population, as technological literacy is difficult to calculate in younger populations. To give an example, the median age in Singapore in June 2023 is 43.0 years. Dividing this number by 10 gives a value of 4.30 years. 10 - 4.3 = 5.70, which is accounted for as the GDD HQI Age Value.

The final demographic determinant included in the GDD HQI is citizenship status. In comparison to income level and age group, this metric is seen to be the most significant. In regards to citizenship status, non-citizens may not see the same healthcare benefits of naturalized Singaporean citizens. Further, in regards to culture, Singapore's law requiring all male citizens to serve in the military for two years creates a stark distinction between citizens and non-citizens as time spent serving creates a sense of a sense of brotherhood among the men who serve and their families. This is a phenomenon not seen in non-citizen populations. Government practices like

this mandatory military service create a culture that places its citizens first regarding benefits and subsidies greatly benefiting lower-income citizen communities. This distinction can even be seen based on where the two populations live.

As of June 2023, Singaporean demographics encompassed 3,072,310 ethnically Chinese residents, 561,330 ethnically Malay residents, 374,860 ethnically Indian residents, and 140,750 residents that belonged to other minority ethnicities (Department of Statistics, 2023). Due to race riots during the period immediately following Singapore's independence in the 1960s, the Singaporean government arranged public housing in a manner that ensured that ethnic populations were evenly spread out and that communities were not homogeneous to promote multiculturalism. However, this careful planning is not the case for Singapore non-citizens. Singapore non-citizens, especially migrant workers are often cramped into smaller spaces which has proved to be detrimental during the COVID-19 pandemic as those regions received a higher frequency of cases due to the high population density (Ngiam et al., 2021).

Singapore's place as an Asian Tiger economy (which refers to the economies of Singapore, Hong Kong, Taiwan, and South Korea that saw a surge in growth at the end of the 20th century), has caused the island nation to be an attractive destination for healthcare tourism amongst wealthy individuals across Asia due to its quality (Han, 2023). Thus, the Singapore government places measures extending healthcare subsidies to citizens only, ensuring that foreigners do not overpopulate Singapore's hospitals and polyclinics. To account for these factors, a multiplier has been included in the GDD HQI. This is done by multiplying the total GDD HQI value by 0.5 if the person residing in Singapore is a noncitizen. For example, the 2 examples from the age and income values mean that a 43-year-old Singaporean who makes $5,197 a month and has been a citizen for 5 years would yield a value of 10.897 in the GDD HQI

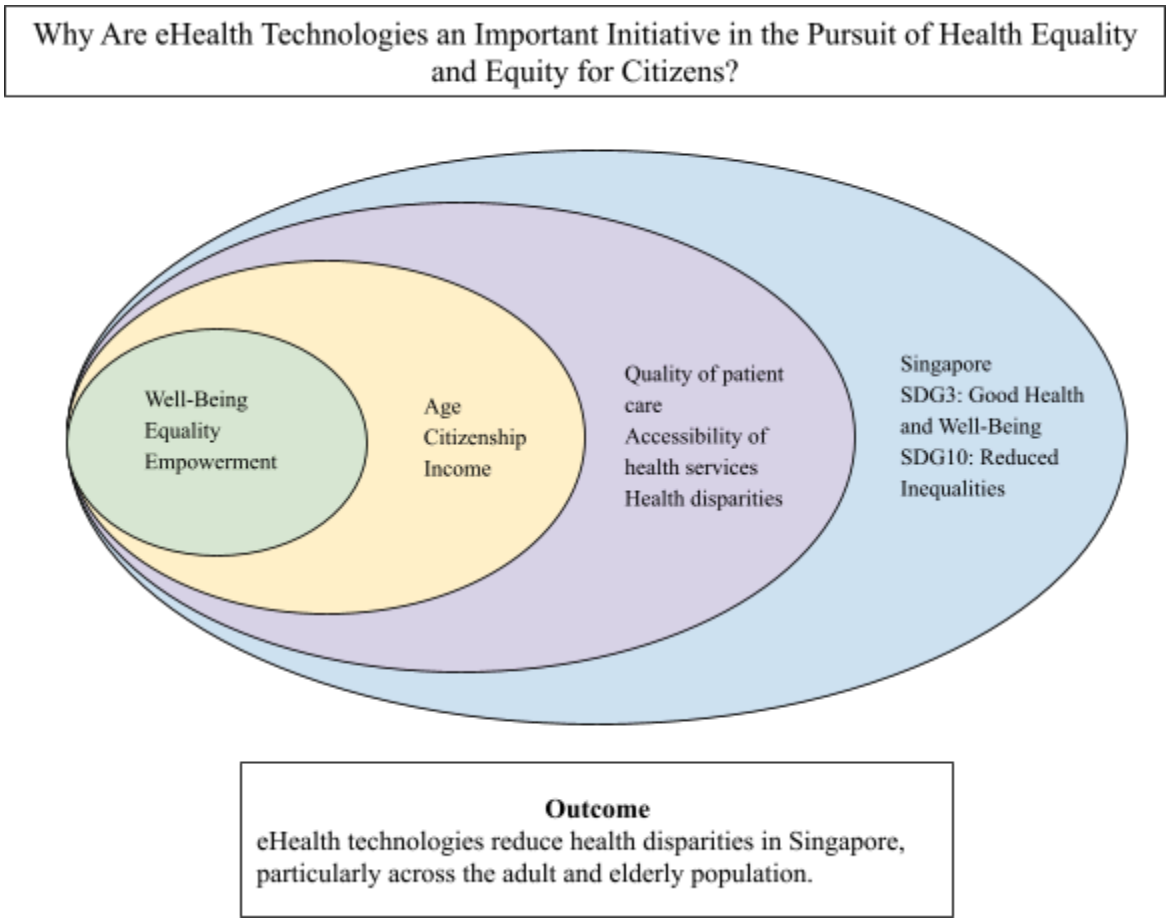
if they were a citizen but only 5.4485 in the GDD HQI if they were a noncitizen. This sharp reduction in values showcases how noncitizens, especially migrant workers, struggle to receive adequate healthcare quality (Ang et al., 2020). However, this disparity can be mitigated with the right amount of wealth as that 0.5 multiplier is offset by a high GDD HQI Income Value. For example, if you were an extremely wealthy 43-year-old individual with a monthly income of $100,000, your GDD HQI as a noncitizen would be 52.85, well above the average even as a noncitizen, showcasing how enough money can mitigate the drawbacks that a lack of a citizenship may cause.

For data collection purposes, a collection of tables was created (see Appendix B) which showcases the calculations of the median GDD HQI Age Value and the median GDD HQI Income Values from 2013 -2023 (Table B1 and Table B2). These values were then used to calculate the median GDD HQI for both citizens and non-citizens (Table B3) for that same period. The final table takes into account the change in GDD HQI to determine the extent healthcare equity is changing over time (Table B4). Since an increased GDD HQI is designed to be associated with higher healthcare equity, an increase or decrease in the GDD HQI annually can describe the extent to which healthcare equity in Singapore is improving or regressing by calculating the percent change from one year to the next. Since the values used to calculate the GDD HQI values are the median age and income statistics over ten years, the data showcases how healthcare equity is changing for the average Singaporean. [1]

The Conceptual Framework defines the scope of the research and the variables that will be measured during its duration to demonstrate the proposed outcome. It outlines the methodology of the research.

[1] Table B1, Table B2, Table B3, and Table B4 can be found in Appendix B

Figure 2: Conceptual Framework



(Source: Authors)

The conceptual framework in Figure 2 is designed to outline the group's methodology by emphasizing the key variables that will help evaluate how ethical eHealth technologies can promote health equity and equality. The dependent variables, also referred to as the Values of Worthwhile Development, are heavily influenced by the scope of these technologies and determine whether health initiatives can improve human well-being, equity, and empowerment in Singapore. The control variables include the characteristics of age, ethnicity, and residence of the target population, the adult and elderly population in Singapore. Defining these variables streamlines the methodology, allowing for an extensive analysis of the impact of equitable

eHealth technologies in this specific region and population. These variables remain constant throughout the application of eHealth technology initiatives. The independent variables are datasets that are tracked within the target population. These variables directly impact the dependent variables, offering a measure to reference the effectiveness of ethical eHealth initiatives in improving well-being, equity, and empowerment. While these variables only shift in statistical value, their impact on the dependent variables based on the scale of measurement is vital for analyzing the efficacy of ethical eHealth initiatives. Lastly, the environmental variables align with the United Nations' Sustainable Development Goals (SDGs) particularly SDG #3 (Good Health and Well-Being) and SDG #10 (Reduced Inequality). These goals represent the broader, positive societal and environmental impacts that the methodology aims to address through the implementation of ethical eHealth technologies. These variables also remain unchanging, but serve as an overarching reminder for what this research seeks to achieve.

Results

Overview

Quantitatively, Singapore's implementation of eHealth has led to an increased accessibility of quality healthcare services. The GDD HQI saw a percent increase every year except in 2019-2020 which can largely be attributed to the COVID-19 pandemic, which strained global healthcare resources. This period was a heavy outlier as Singapore's healthcare equity has continued to increase into the mid-2020s. Singapore's greater accessibility to healthcare services can be observed through the positive relationship between the independent and dependent variables of the study. The independent variables are defined as the different eHealth initiatives adopted by Singapore. Further, the dependent variables are defined as the well-being, level of equality, and empowerment of Singaporean citizens. In the context of healthcare, these concepts

can be measured with the following indicators: the widespread availability of health services, the quality of such services, and the resulting patient care outcomes. These values can be measured using metrics such as healthcare infrastructure, patient-centered evaluations, and population health data. After reviewing a variety of case studies dealing with the digitization of Singapore's healthcare, there have been observed improvements in these indicators, demonstrating that eHealth technologies have the potential to create positive outcomes by enriching the well-being, equity, and empowerment within the context of the nation's healthcare.

However, when controlling for variables in this study (income, age, and citizenship status), instances of negative outcomes from Singapore's integration of eHealth are observed. More specifically, the digitization of healthcare services is seen to create new inequities based on the digital divide. The digital divide is defined as the disparity between communities that have access to internet technologies and those that do not (van Dijk, 2020). This divide can be interpreted in the literal sense —the access to IT infrastructure and services— however, it may also be interpreted as the divide in digital literacy. Both have been seen to impact the equity of Singapore's new era of eHealth. This problem is only exacerbated by Singapore's aging population which leads to a greater percentage of the population being technologically illiterate. The disparity between citizens and noncitizens is also apparent as the GDD HQI showcases how health equity for a Singaporean noncitizen in 2023 is still worse than for a Singaporean citizen in 2013 when plugging Singapore health data (income, age, citizenship status) from 2023 and 2013 into the equation (Table B3). For a Singaporean noncitizen in 2023, the calculated GDD HQI value when entering values for income, age, and citizenship was 5.4485, significantly worse than the value for a Singaporean citizen in 2013 which was 9.705, indicating that health equity above all factors favors Singaporean citizens. This supports the idea that Singapore's emphasis on

improving healthcare for the masses is generally relegated to its citizen population, regardless of income and age.

The integration of quantitative and qualitative research methods facilitates a comprehensive understanding of eHealth's impact on health equity in Singapore. Insights from qualitative case studies, narrative analysis, and interviews expand on the interpretation of GDD HQI values. For instance, narrative analysis sheds light on challenges faced by older Singaporean adults in using eHealth technologies and equity-based barriers encountered by non-citizens, findings that align with the age and citizenship variables included in the GDD HQI equation. Meanwhile, the quantitative data reinforces qualitative observations on the extent of healthcare inequities. The GDD HQI, for example, quantifies income-based disparities, reflecting interviewee accounts of the divide between public and private healthcare affordability. Further, the qualitative framework's emphasis on ethical considerations is supported by quantifiable evidence that comes from Singapore health data that is plugged into the GDD HQI. The disparities highlighted by GDD HQI scores emphasize ethical issues raised in the qualitative analysis, such as the marginalization of the elderly, low-income individuals, and non-citizen populations.

The Positive Effects of Digital Healthcare in Singapore

The implementation of digital healthcare has brought Singapore into a new age of healthcare which has changed the way development practitioners, companies, and the government see the healthcare industry. For example, in 2014, the Smart Elderly Monitoring and Alert System (SEMAS) was launched in Singapore. SEMAS was a telehealth program that provided at-home consultations and live monitoring of the health of elderly populations. Through a motion-sensitive sensor, the activity level and amount of sleep were monitored and, if such data

was of concern, the sensors would notify the elderly about these trends, prompting more movement or sleep. By the end of the initial pilot period, the program saw such great success in monitoring the health of elderly populations that it underwent widespread integration into elderly care (Luk, 2018). Through this adoption of digital healthcare, services once limited to in-person visits are now accessible remotely. As a result, the accessibility of such care increased with Singapore's implementation of SEMAS, creating great positive implications for the potential for eHealth to increase health equity. Especially in the current age of Singapore's demographic transition where the growth rate of the elderly outweighs the stagnant growth of the working-age population, such remote monitoring and consultation of the elderly can significantly alleviate administrative burdens on hospitals and allow healthcare facilities to provide better quality care to more patients.

Aside from programs directly targeting the elderly, Singapore has also implemented telehealth programs for the general population. For example, in 2017, the Singaporean government launched the Smart Health Video Consultation program (SHVC), which provided online consultations for patients post-discharge. Online consultations were accessed through live video meetings on computers and smartphones. Further, the SHVC was padded with a two-factor authentication along with two-sided encryption for maximum data security during and after calls. The SHVC saw overall success in bringing quality post-discharge consultations to patients at home (Raghavan et al., 2021). By transforming the nature of such outpatient care to an online platform, not only did the SHVC cut healthcare costs but also allowed for a greater number of patients to access such affordable post-discharge as a result. Although Singapore subsidizes universal healthcare for its citizens, the insurance coverage of such care is generally limited to in-patient care. Consequently, for patients seeking outpatient care, which constitutes the majority

of post-discharge consultation, many times they are forced to pay high upfront costs due to this lack of coverage. This poses huge implications for the equity of Singapore's healthcare, as low-income patients will not be able to afford these crucial outpatient or post-discharge healthcare services. Thus, the prospect of digital healthcare in promoting the widespread accessibility of high-quality services is significant, as can be seen through the SHVC's services.

As can be seen through the case study analysis, the introduction of new technologies to the medical system has allowed humanitarians to increase healthcare equity amongst its citizens. These benefits are also seen directly in the industry itself as Singapore B2B enterprise consulting employees showcase that the increase of digital use in healthcare has had a direct impact on their lives through the Central Provident Fund (S. Oon, personal communication, November 6, 2024). The GDD HQI index showcased that the citizenship category was most effective in increasing equity after the introduction of technology highlighting how healthcare practitioners have succeeded in providing adequate care and resources to those with a higher socioeconomic status.

Similarly, from the personal testimonies of Singaporean citizens, the efficiency of the Singaporean healthcare system under its digitized infrastructure is clear. S. Tan (personal communication, October 23, 2024), a PhD student at the University of Maryland, College Park, who lived in Singapore for around 20 years, spoke of the benefits of the nation's centralized eHealth system. He spoke of his experience using such technology, which substantially decreased his waiting time between scheduling and waiting for appointments. He also cited how Singapore's centralized application system allows for easier transfer of documents and subsidies, with an easier referral process for different services that include the most holistic coverage. This creates better regulation for personal data and information, benefitting the privacy concerns of civilians within digital healthcare. The Singaporean government ensures that the elderly are

included in the digitization of health services, with anti-scam features to increase digital literacy and digital integration by encouraging older citizens to acquire personal devices. S. Tan (personal communication, October 23, 2024) also spoke on digital technology and tracking data that allows governments to track national health by providing policy points that can increase the chances of better health and services.

The Negative Effects of Digital Healthcare in Singapore

While technology has undoubtedly had positive effects on increasing healthcare equity in Singapore, the widespread adoption of digital healthcare has not come without its consequences. The most prevalent concerns identified by the qualitative research on the integration of a digitized healthcare system in Singapore include privacy concerns over healthcare data, technological barriers for older generations, worries about over-centralization and over-surveillance by the government, and cultural resistance to moving away from traditional holistic healthcare treatments. A representative of the Singaporean Ministry of Culture, Community and Youth warned about the implications of eHealth technologies that can potentially decrease healthcare equity by ensuring that all civilians regardless of income level or status receive adequate care in the forms of subsidies, insurance, and other means. In the private sector, a common grievance amongst those at Singapore B2B enterprise consulting is income level when it comes to the trend of digitizing as they perceive that it may decrease equity if not handled correctly (S. Oon, personal communication, November 6, 2024). From a mathematical perspective, the GDD HQI showcases an increased disparity in citizenship status, showing how eHealth technologies have increased inequality in non-Singaporean citizens and migrant workers.

The integration of both quantitative and qualitative findings presents a comprehensive understanding of how eHealth technologies influence healthcare equity in Singapore. The GDD HQI data revealed a consistent increase in national healthcare equity over time, supporting the claim that digital healthcare improves access and quality. However, when divided by income, age, and citizenship status, the data showed significant disparities, particularly for noncitizens and the elderly. These quantitative insights are supported by qualitative findings, including personal interviews and case studies, which highlighted challenges such as digital illiteracy among older adults and restricted healthcare access for noncitizens. The data demonstrate that while eHealth technologies have enhanced overall healthcare outcomes, they risk reinforcing existing inequalities if not implemented with inclusive and equitable strategies in mind. This underscores the need for targeted digital health initiatives that specifically support marginalized populations.

Discussion

Key Findings

Through analysis of a mixed-methods approach to defining the question: Why are eHealth technologies considered a necessary initiative in the pursuit of health equality and equity for citizens, initial qualitative findings indicated that Singaporean citizens, particularly the elderly and low-income groups, faced the greatest challenges in accessing healthcare technologies. However, as further research was conducted, it was found that citizenship status posted the greatest barrier to healthcare accessibility. Additionally, aligning with SDG #3 (Good Health and Wellbeing) and SDG #10 (Reduced Inequalities) was supporting case and narrative study research that outlined the creation of equitable eHealth technology frameworks to ensure healthcare accessibility and improve wellbeing.

Income and Healthcare Access

When focusing the findings down through the variables of measure, the qualitative research yielded findings on the impact of income that allowed for a better understanding that basic healthcare necessities are available as needed but may not be of the highest quality. The income-dependent structure of healthcare access in Singapore underscores the economic divide in service quality despite universal healthcare provisions. While the Central Provident Fund (CPF) and government subsidies help mitigate costs for lower-income citizens, those who simply have the money to pay for first-rate treatment benefit from access to private healthcare options, which are often faster and tailored to individual needs. This dual-tier system is further strained by the reliance on digital health tools, as lower-income groups face challenges affording compatible devices or the level of specialized healthcare needed to treat chronic or serious illnesses. Ultimately, Singapore's universal healthcare culture and system benefits all citizens with fundamental healthcare access but the factor of income largely impacts the quality of care received.

Age and Digital Literacy

When analyzing the outcomes of the research through the lens of the control variables, the most significant finding was that age presents a significant barrier to digital healthcare adoption, particularly among older adults who lack the digital literacy required to navigate eHealth platforms effectively. While government initiatives like support programs and grocery subsidies encourage technology adoption, senior individuals remain more susceptible to scams and are concerned about health data privacy issues, deterring a full digital integration of the Singaporean population. The findings suggest that digital healthcare strategies must incorporate

user-centric designs and tailored support systems to support the elderly, who face the most disproportionate rates of healthcare equity compared to Singaporean individuals of all other ages.

Citizenship Status

The last variable of citizenship status emerged as a critical determinant of healthcare access and equity in the final research results. Non-citizens, including migrant workers and immigrants, face significant barriers, such as not qualifying for subsidies leading to higher out-of-pocket expenses for healthcare services. This disparity reflects a broader policy tension between Singapore's commitment to its citizen-centric healthcare system. The largest disparity in healthcare equity is based on citizenship status since Singapore's universal healthcare culture and coverage are strictly limited to citizens. Among all three variables measured, citizenship status was found to have the greatest impact on an individual's experience with the Singaporean healthcare system. This was surprising since some initial findings emphasized the impact of ethnicity as a major impactful variable, which was promptly replaced by citizenship status after further research was conducted.

GDD HQI Formula

When plugged into the GDD HQI formula as data points, the value for income level is the average monthly income for the healthcare quality being measured, with the outlying factor being that having an abnormally high monthly income will result in a higher GDD HQI formula value which in turn indicates higher healthcare quality and access (Table 1). This is to account for the research found that supported evidence on being able to afford specialized healthcare services leading to better access and quality of care. When taking into account the data points for age as a variable, the higher the age, the lower the substantial numerical value for healthcare quality becomes, because in older Singaporean populations, the level of technological literacy is

significantly lower than that of other age groups in Singapore (Table B2). Lastly, when measuring the impact of citizenship status, the numerical value indicating healthcare quality gets reduced by 50% for a non-Singaporean citizen compared to a Singaporean citizen to emphasize the critical impact that being a citizen has on healthcare quality and access. This is reflected in the GDD HQI equation through a multiplier of 0.5 applied to noncitizens, effectively reducing their overall health equity score by half.

Broader Factors Supporting eHealth

Aside from focusing on the three impact variables for measuring healthcare equality, additional findings were discovered that are both relevant and supportive of the conclusions met with this research. In Singapore, their high levels of public trust in government initiatives have facilitated the widespread adoption of digital health technologies, which enables seamless service delivery and efficient resource allocation. This level of trust in the central government stems from a history of effective leadership that sought to benefit the Singaporeans as well as how young of a country Singapore is. In comparison, Singapore is only 59 years old, is about the same size as New York City land-wise, and is a developing population that values centralized and efficient healthcare over stringent data privacy concerns. This means that government digitization initiatives are well-accepted, as Singaporeans rely on government oversight to manage healthcare technology and maintain ethical standards to benefit their lives. Aside from strong public trust in the government, the high rate of internet penetration across the country also allows for users to be centrally connected and increases accessibility. Additionally, the high percentage of Singaporeans who own smartphones allows for smoother integration of digital healthcare systems due to the large amount of technology ownership in Singapore.

Ethical Policy Considerations

Ultimately, the research findings suggest that Singapore's eHealth framework has significantly improved healthcare efficiency and service accessibility through digitization. As Singapore develops and continues to expand its digital healthcare system, it will be interesting to observe how technology and eHealth systems will continue to bridge the gap between privilege and necessity. The biggest inequalities that were identified were enhancing support for low-income groups, addressing barriers faced by the elderly, and ensuring access for non-citizens. Looking forward, there are heightened expectations for continuous improvement in healthcare quality and accessibility, especially as Singapore's government explores AI and other advanced eHealth technologies in an ever-evolving age of technological development. While this research backs the beneficial impact of technology on Singapore's healthcare system, there will continue to be emerging concerns about the ethical use of eHealth technologies and the handling of health data.

Research Objectives Overview

These results supported the primary research objectives and met the standards that the findings were sorted into. The objective of examining the role of technology in healthcare found key findings on its impact on healthcare accessibility. By examining the role of technology in healthcare through the lens of Singapore's digital healthcare system, this research was able to conclude that eHealth technology is a catalyst for positive changes in healthcare accessibility and equity.

Another objective successfully addressed was identifying the specific eHealth technologies developed. When evaluating healthcare technologies, the broad range of systems

from wearables to centralized apps to electronic medical record databases provided a sense of how rapidly eHealth technology was being developed in Singapore.

The objective of evaluating the outcomes of healthcare technology on patient care yielded results that emphasized the relevance of demographic factors. When analyzing patient care outcomes, the research approach utilized three major variables: income, age, and citizenship status to determine the positive and negative patient healthcare outcomes.

The final objective was to reduce health disparities using healthcare technologies and prior knowledge on healthcare accessibility. Identifying inequalities caused by factors pertinent to income level, age, and citizenship status made it simple to identify potential methods to mitigate these health disparities in Singapore. Overall, seeking to create more specialized support programs for marginalized populations to ensure equitable healthcare access for not just Singaporeans but also for the global community is a major takeaway from this research.

Conclusion

When looking back at the initial research question: Why are eHealth technologies considered a necessary initiative in the pursuit of health equality and equity for citizens?, the overarching conclusion is that eHealth technologies must offer substantial benefits that outweigh potential harms for the populations most reliant on them. The ability of eHealth technologies to help address inequalities in healthcare access and quality by expanding support systems that target marginalized populations like those with lower income, those who are older, and non-Singaporean citizens make them valuable assets. eHealth technologies as a catalyst for health equality and equity help expand the scope of healthcare quality and accessibility to marginalized groups.

Within Singapore itself, this research identified that eHealth systems have been an instrumental part of the rapid improvements in their highly digitized healthcare system. Although the focus was on the nation of Singapore, the research findings have proven that fundamentally, the expansion of digital healthcare systems across the world can be a mechanism for positive change by providing a modern approach to mitigating health disparity and inequality. The academic contribution of this research lies in its potential to guide the development of evidence-based recommendations and frameworks that can guide practitioners around the world in making informed policy decisions. By focusing this research through the lens of the Values of Worthwhile Development and the United Nations Sustainable Development Goals, this research is filling a gap in development ethics research. The specific focus on eHealth systems in Singapore as a mechanism to decrease health disparities through both a qualitative and quantitative approach provides a unique research perspective.

The final findings of this research point to approaches for future inquiry, particularly within telemedicine and health equity. Further research into telemedicine should explore how it can be tailored to serve populations with limited digital access. This could inform the creation of health programs that are not only technologically advanced but also socially inclusive within Singapore's evolving digital healthcare system. Further research into methods to address health inequity could provide recommendations to limit the scale of health disparity among marginalized populations not only in Singapore but in other regions around the world. By identifying the mechanisms through which marginalized populations are excluded from healthcare, future research can yield insights that contribute to global frameworks for equitable healthcare delivery.

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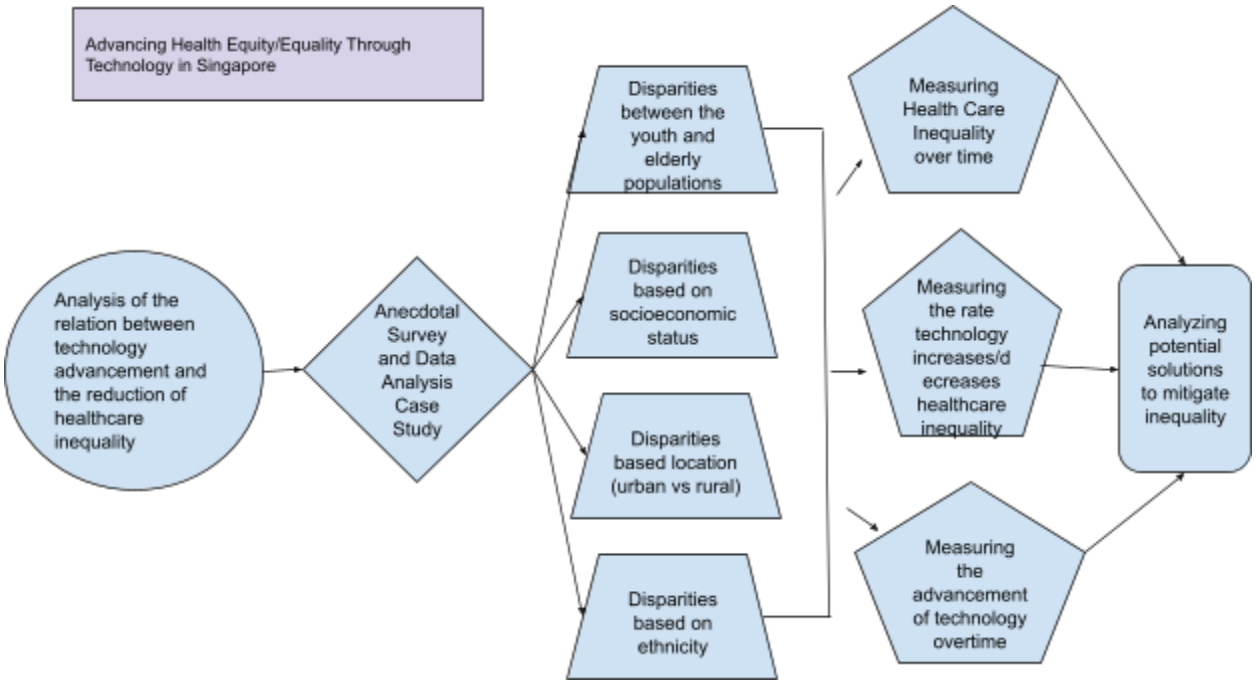
Appendix A

Figure 1A: Analytical Framework



(Source: Authors)

The framework in Figure 1A outlines the analyses that will be done as a result of research conducted on the impact of technology on health equity in Singapore.

Appendix B

Table B1: Median Mid-Year Gross Monthly Income from Employment (2013-2023) GDD HQI Income Value Calculation for Singapore Citizens and Permanent Residents

Year	Median Monthly Gross Income (US Dollars at 2019 Prices)	GDD HQI Income Value (Gross Monthly Income/1000)
2013	3,705	3.705
2014	3,770	3.770
2015	3,949	3.949
2016	4,056	4.056
2017	4,232	4.232
2018	4,437	4.437
2019	4,563	4.563
2020	4,534	4.534
2021	4,680	4.680
2022	5,070	5.070
2023	5,197	5.197

(Source: Authors)

Table B1 takes the median mid-year gross income data from the Singapore Ministry of Manpower (2024), Manpower Research and Statistics Department and translates it into its corresponding income value in the Global Development and Design Healthcare Quality Index. “It is important to note that Gross monthly income includes all earnings from employment, such as wages, overtime, commissions, tips, allowances, and a portion of annual bonuses. For employees, this is calculated before deductions like CPF contributions and income tax, while for

self-employed individuals, it is based on average monthly profits before taxes. Due to the nature of survey-based data, short-term year-on-year income changes may fluctuate, so it's more reliable to assess income growth over longer periods (e.g., 5-10 years). The income figures are adjusted using the Consumer Price Index (CPI) based on 2019 prices for consistency," (Ministry of Manpower, 2024).

Table B2: Median Mid-Year Age (2013-2023) GDD HQI Age Value Calculation for Singapore Citizens

Year	Median Age	GDD HQI Age Value (10 - Age/10)
2013	40.0	6.00
2014	40.4	5.96
2015	40.7	5.93
2016	41.0	5.90
2017	41.3	5.87
2018	41.7	5.83
2019	42.0	5.80
2020	42.2	5.78
2021	42.5	5.75
2022	42.8	5.72
2023	43.0	5.70

(Source: Authors)

This table takes the median mid-year gross income data from the Singapore's Department of Statistics (2023) and translates it into its corresponding income value in the Global Development and Design Healthcare Quality Index.

Table B3: Median GDD HQI for Singaporean Citizens vs Non-Citizens (2013-2023)

Year	GDD HQI Income Value (Gross Monthly Income/1000)	GDD HQI Age Value (10 - Age/10)	GDD HQI Value (Citizen)	GDD HQI Value (Non-Citizen) x 0.5
2013	3.705	6.000	9.705	4.8525
2014	3.770	5.960	9.730	4.8650
2015	3.949	5.930	9.879	4.9395
2016	4.056	5.900	9.956	4.9780
2017	4.232	5.870	10.102	5.0510
2018	4.437	5.830	10.267	5.1335
2019	4.563	5.800	10.363	5.1815
2020	4.534	5.780	10.314	5.1570
2021	4.680	5.750	10.430	5.2150
2022	5.070	5.720	10.790	5.3950
2023	5.197	5.700	10.897	5.4485

(Source: Authors)

Table B3 shows the GDD HQI value from 2013-2023. The GDD HQI is calculated by adding together the GDD HQI Income Value (Table B1) and the GDD HQI Age Value Income (Table B2). To calculate the GDD HQI value for non-citizens the GDD HQI values for citizens are cut in half.

Table B4: Median Change in GDD HQI for Singaporean Citizens vs Non-Citizens (2013-2023)

Year	Change in GDD HQI (Citizens)	Percent Change in GDD HQI (Citizens)	Change in GDD HQI (Non-Citizens)	Percent Change in GDD HQI (Citizens)
2013-2014	0.025	0.2576	0.0125	0.2576
2014-2015	0.149	1.531	0.0745	1.531
2015-2016	0.077	0.779	0.0385	0.779
2016-2017	0.146	1.466	0.0730	1.466
2017-2018	0.165	1.633	0.0825	1.633
2018-2019	0.096	0.935	0.0480	0.935
2019-2020	-0.049	-0.473	-0.0245	-0.473
2020-2021	0.116	1.125	0.0580	1.125
2021-2022	0.360	3.451	0.1800	3.451
2022-2023	0.107	0.992	0.0535	0.992

(Source: Authors)

Table B4 shows the median change in GDD HQI value from 2013 - 2023 for Singaporean Citizens and Non-Citizens using the values from Table B3.

About the Authors

Khadija Wane is a junior Information Science major at the University of Maryland, College Park. She is an undergraduate researcher and Peer Research Mentor for the Global Development and Design stream at the university, focusing on leading research with her team members that dives into how eHealth technologies can increase equity for Singaporean citizens, as well as addressing health disparities, patient outcomes, and accessibility of healthcare services. Additionally, she has a role in developing the toolkit website for the stream, which guides project managers, development practitioners, and policymakers on making ethical and accessible choices within their projects.

Aryaan Ahmed is a sophomore Public Policy major on a pre-law track at the University of Maryland, College Park. He is an undergraduate researcher in the Global Development and Design stream within the First Year Research and Innovation Experience (FIRE) Program. He and his team are researching the effects of digital healthcare in Singapore and how equitable the healthcare system in Singapore is as a whole. Along with that, he has a role in contributing case studies about public policies related to the sustainable development goals in order to make the AI for the Global Development and Design Toolkit behave like an ethicist and a proper decision maker.

Eugene Choi is a sophomore Public Health Science major on a pre-medical track at the University of Maryland, College Park. He is an undergraduate researcher in the Global Development and Design stream within the First Year Research and Innovation Experience (FIRE) Program. Along with his research team, he is working on research that evaluates the extent to which digital healthcare technologies in Singapore increase or decrease equity for users

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Jiun Park is a sophomore Economics and Political Science double major with an International Relations minor at the University of Maryland, College Park. She is an undergraduate researcher through the First Year Research and Innovation Experience (FIRE) Program and is a part of the Global Development and Design research stream. Her research team focuses on assessing the role of eHealth technology in Singapore and how those systems can increase health equity for Singaporean healthcare users. She brings a valuable academic background in economics and international affairs to the team and has a key role in integrating qualitative research findings into the final manuscript.

Rishit Roy is a sophomore Bioengineering major at the A. James Clark School of Engineering at the University of Maryland, College Park. He is an undergraduate researcher through the First Year Research and Innovation Experience (FIRE) Program and his research team is focusing on the extent eHealth technologies contribute to increasing or decreasing health equity amongst users of the Singaporean healthcare system. He is passionate about combining his technical knowledge of healthcare through an engineering perspective with the social science knowledge from a development ethics perspective. Additionally, he has a role in outlining the AI algorithm decision tree for the Global Development and Design Development Ethics Toolkit.