Industrial Engineering and Management

Changes in private healthcare supply, demand, and service utilisation during the COVID-19 pandemic

Oskar Niemenoja

Aalto University

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Changes in private healthcare supply, demand, and service utilisation during the COVID-19 pandemic

Oskar Niemenoja

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Abstract

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Abstract

Pandemics have wide-reaching effects on health service utilisation and diagnostic activity. Health service usage declined markedly during the COVID-19 pandemic across most diagnosis classes, especially those unrelated to the pandemic directly. These changes may potentially introduce pressure on the healthcare system in the future. This thesis analyses how the Finnish private healthcare service utilisation, diagnostic activity, and booking patterns were affected between January 2020 and June 2022 during the COVID-19 pandemic.

The study had access to a novel, comprehensive dataset on weekly Finnish private healthcare usage collected from routine electronic medical record data spanning the wide range of health service usage and diagnostic activity. Data from before the COVID-19 pandemic enabled us to create an estimate on the health service utilisation in the hypothetical case without the effect of the pandemic, which was compared to observed time series data. Of the three manuscripts that make up this thesis, one studied nationwide service utilisation, while two focused on the capital region of Uusimaa. The manuscripts covered data from 833 444, 632 466 and 900 572 patients, respectively.

We estimated that service utilisation rates for private healthcare usage decreased by one-fourth across different diagnosis classes during the early pandemic. Only some diagnosis classes recovered to pre-pandemic utilisation levels towards the end of the observation period, while some remained at permanently reduced levels. Upper respiratory system-related diseases displayed a notable increase in diagnostic activity during the initial weeks of the pandemic, as well as late in the observation period. We postulate that the decrease in service utilisation was driven by a decrease in service demand, to which supply reacted. Cancellations were a contributing factor to this decrease only during the first weeks of the pandemic, after which disengagement from within the services was passive. Digital services offered a rapidly scaleable service channel to regulate access to healthcare services. We highlight the importance of healthcare providers and policymakers collecting and utilising high-quality, up-to-date data when managing systemic healthcare utilisation shocks such as pandemics.

Keywords COVID-19, Cov-SARS-2, Health service utilisation, Infection epidemiology, Health policy, Digital health

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Tekijä
Oskar Niemenoja

Väitöskirjan nimi
Muutokset yksityisen terveydenhuollon tarjonnassa, kysynnässä ja palveluiden käytössä COVID-19-pandemian aikana

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Tiivistelmä
Pandemioilla on laaja-alainen vaikutus terveyspalveluiden käyttöön ja kysyntäkäyttäytymiseen. Terveyspalveluiden käyttö laski merkittävästi COVID-19 -pandemian aikana useimmissa diagnoosiluokissa, erityisesti sellaisissa jotka eivät suoraan liity pandemiaan. Tämä terveyspalveluiden käytön lasku voi aiheuttaa pitkäaikaista rasitusta terveydenhuoltojärjestelmälle pandemian aikana ja sen jälkeen. Tämä väitöskirja analyisoi miten yksityisten terveydenhuollon palveluiden käyttö, tautien diagnosointi sekä ajanvarausten dynamiikka käyttäytyivät Suomessa tammikuun 2020 ja kesäkuun 2022 välillä COVID-19 -pandemian aikana.

Tällä tutkimuksella oli pääsy aiemmin julkaisemattomaan ja kattavaan aineistoon suomalaisesta yksityisestä terveydenhuollon käytöstä. Aineisto koostui viikkotasoisesta terveydenhuollon käytön rekisteriaineistosta, joka kattoi laajasti eri diagnoosiluokat sekä terveyspalveluiden käytön. Aineisto ulottui myös pandemiaa edeltävälle ajalle, joka mahdollisti uskottavan ennustemallin luomisen palvelukulutuksesta hypoteettisessa tilanteessa, jossa koronapandemiaa ei olisi tapahtunut. Tätä ennustetta verrattiin palveluiden toteutuneeseen käyttöön. Tämä väitöskirja koostuu kolmesta osatutkimuksesta, joista yksi tutki palvelukäytön muutosta kansallisesti, kun taas kaksi muuta rajautuivat alueellisesti tarkastelemaan Uusimaan aluetta. Tutkimusten otannat olivat 833 444, 632 466 ja 900 572 potilasta.

Arviomme mukaan yksityisten terveyspalveluiden käyttö laski keskimäärin neljänneksellä pandemian alkuvaiheen aikana. Vain osa diagnoosiryhmien palvelukäytöstä palautui tarkastelujakson aikana ennustetulle tasolle, kun taas useat jäivät tarkastelujaksolla pysyvästi oletettua alemmalle tasolle. Ylähengitystietaudeissa tapahtui merkittävää palvelukäytön kasvua välittömästi pandemian alussa sekä tarkastelujakson lopussa. Esitämme, että tämä palvelukäytön lasku oli kysyntävetoista, ja tarjonta reagoi tähän kysynnän laskuun. Peruutuksien vaikutus palvelukäytön laskuun oli merkittävä vain pandemian alussa, jonka jälkeen poistuminen terveyspalveluiden piiristä tapahtui passiivisesti. Digitaaliset palvelut tarjosivat pandemian aikana nopeasti mukautuvan palvelukanavan, joka tasoitti pääsyä terveyspalveluiden piiriin. Korostamme korkealuokkaisen ja ajantasaisen tiedon keräämisen ja hyödyntämisen merkitystä terveydenhuollon tarjoajille sekä päättäjille terveydenhuollon shokkien hallinnassa.

Avainsanat COVID-19, Cov-SARS-2, Terveyspalveluiden käyttö, Infektioepidemologia, Terveyspolitiikka, Digitaalinen terveydenhuolto

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Preface

> Ei minua itse tartunta pelota. Mikä sitten? Epidemian mahdolliset vaikutukset kaikkeen muuhun. Että käy vielä niin, että tuntemani sivilisaation rakennelma romahtaa kuin korttitalo. Olen huolissani siitä, että kaikki nollautuu mutta myös päinvastaisesta seurauksesta: että pelko menee ohitse jättämättä jälkiä, mitään muuttamatta.
> – Paolo Giordano, *Tartunnan aikaan (2020)*

During the writing of this thesis, I have had the privilege to work on research which has simultaneously been challenging yet endlessly inspiring and rewarding. The thesis itself has been a collaborative effort of a great number of incredible individuals, all of whom I wish to thank wholeheartedly. I have had the greatest pleasure of having an incredible team of talented people supporting the creation of this thesis. It is no exaggeration to say that none of this would be possible without your support.

I wish to thank my professor, Paul Lillrank, for his wisdom, vision and guidance during the process. Paul has an incredible skill to turn ideas into concrete visions to be used as a guiding light. I remember our long and often meandering discussions with great warmth. Similarly, I wish to thank Lauri Saarinen, to whom the honour of supervising this work was passed during the summer of 2023. Lauri expressed great intellect and dedication in steering a thesis somewhat outside his comfort zone with clarity and compassion.

I wish to express my deepest gratitude to the pre-examiners of this thesis, Dr. Liisa-Maria Voipio-Pulkki and Professor Kristiina Patja, for their time and expertise in validating this thesis, as well as for their attentive and constructive comments and critique. I am grateful for both improving the quality of this thesis as well as providing a young researcher with invaluable feedback. Similarly, I wish to warmly thank Professor Markku Mäkijärvi for honoring this thesis by acting as the opponent in the public defence.

Words cannot express my gratitude to my thesis advisors, Simo Taimela and Petri Bono. Simo, your brilliance, guidance and uncompromising focus on attention have been a source of never-ending support. They have been the crucible in which diamonds are made. This thesis would look altogether different for the worse without your support. Petri, walking a path through uncharted territory is ever so much more possible when somebody is able to pave a road to walk before you. Your clear-mindedness, experience, and determination have impressed me time and again, and our discussions have turned problems the size of a mountain into mere rubble.

Sari Riihijärvi and Antti-Jussi Ämmälä, your guidance has been truly invaluable at every point of the journey. All of the comments, words of encouragement, and examples you set have been endless sources of motivation. Similarly, I wish to thank Pentti Huovinen and Ara Taalas for collaborating in creating the articles. Mika Salminen and Hanna Nohynek provided expert insight into the issue via interviews and chats. Olli Halminen shared invaluable advice and experiences on the practicalities of writing this thesis. Lotta Walden provided insightful comments and inspiring discussions. Ruth Kaila always had the right words of wisdom and encouragement. I deeply appreciate the encouragement and support from Juha Juosila and Ilari Richardt over the course of writing this thesis. Countless others have also contributed to this thesis via informal discussions, examples and motivation. To all my friends and colleagues, you are simply amazing. Rock on.

To my wife Amanda, I love you beyond words. You are the bedrock on which everything I have done is founded. My son, Elis, you shine brighter than a thousand stars. Sharing our past, present and future adventures together with my family is the largest privilege a person can have, and I treasure it every single day. To my mother, Marjaana, and father, Kari, every single moment of my life, you have been the giants from whose shoulders I have been able to reach for the stars. To my sister Karolina, you have always been there for me whenever I needed it the most. I love you all dearly. I dedicate this thesis to the memory of my grandparents, Pentti and Eeva-Liisa, who were adamant that someday I would be writing the words to the preface of my own dissertation. The confidence instilled in their encouragement has never waned and has come to full bloom in the following pages.

Helsinki, August 1, 2024,

Oskar Niemenoja

Contents

List of Publications

This thesis consists of an overview and of the following publications which are referred to in the text by their Roman numerals.

I Oskar Niemenoja, Ara Taalas, Simo Taimela, Petri Bono, Pentti Huovinen, Sari Riihijärvi. *Time series analysis of the incidence of acute upper respiratory tract infections, COVID-19 and the use of antibiotics in Finland during the COVID-19 epidemic: a cohort study of 833 444 patients*. *BMJ Open*, Volume 12, Issue 1, January 2022.

II Oskar Niemenoja, Antti-Jussi Ämmälä, Sari Riihijärvi, Paul Lillrank, Petri Bono, Simo Taimela. *The Impact of COVID-19 on private healthcare service utilisation: time series analysis in the capital region of Finland during 2020-2022*. Submitted to *BMC Public Health*, 2023, Revised 2024.

III Oskar Niemenoja, Antti-Jussi Ämmälä, Sari Riihijärvi, Paul Lillrank, Petri Bono, Simo Taimela. *The impact of COVID-19 on healthcare booking and cancellation patterns: time series analysis of private healthcare service utilisation in Finland*. *BMC Health Services Research*, Volume 24, Article number 483, 2024.

Author's contributions

Publication I: "*Time series analysis of the incidence of acute upper respiratory tract infections, COVID-19 and the use of antibiotics in Finland during the COVID-19 epidemic: a cohort study of 833 444 patients*"

ON obtained the data for the study. **ON**, SR and ST designed the study. **ON** performed the statistical analysis and visualisations. **ON**, SR and ST drafted the manuscript. **ON**, AT, ST, PB, PH and SR participated actively in interpretation and discussion of the results, critical revision of the manuscript and approval of the final version.

Publication II: "*The Impact of COVID-19 on private healthcare service utilisation: time series analysis in the capital region of Finland during 2020-2022*"

ON obtained the data for the study. **ON**, SR, and ST designed the study. **ON** performed the statistical analysis and visualisations. **ON**, ST and AÄ drafted the manuscript. **ON**, AÄ, SR, ST, PB and PL participated actively in the interpretation and discussion of the results, critical revision of the manuscript and approval of the final version. **ON** and ST had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Publication III: "*The impact of COVID-19 on healthcare booking and cancellation patterns: time series analysis of private healthcare service utilisation in Finland*"

ON obtained the data for the study. **ON**, SR, and ST designed the study. **ON** performed the statistical analysis and visualisations. **ON** and ST drafted the manuscript. **ON**, AÄ, SR, ST, PB, and PL participated actively in the interpretation and discussion of the results, critical revision of the manuscript and approval of the final version. **ON** and ST had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Abbreviations

ARIMA Autoregressive Integrated Moving Average

CI Confidence Interval

COVID-19 Coronavirus disease 2019, see *Sars-Cov-2*

EHR Electronic Health Record, a collection of EMRs

EMR Electronic Medical Record

EU European Union

GDP Gross Domestic Product

ICD-10 WHO International Statistical Classification of Diseases, version 10

NCD Non-communicable disease

NPI Non-pharmacological intervention

PHEIC Public Health Emergency of International Concern

RF Research Finding

RQ Research Question

Sars-Cov-2 Severe acute respiratory syndrome coronavirus 2, see *COVID-19*

SoE State of Emergency

URTI Upper Respiratory Tract Infection

WHO World Health Organisation

Symbols

General

R_0 The reproduction number

Statistics: ARIMA

ϵ_t residual of the time series at time t

ϕ parameter of the autoregressive model

θ parameter of the moving average model

c constant

d degree of differentiation

L The *backshift* or *lag operator*, equal to $Ly_t = y_{t-1}$

m Number of observations per year for the seasonal model

p order of the autoregressive component

q order of the moving average component

y_t value of the time series at time t

Service utilisation

B Number of bookings

S Number of available supply, i.e. appointments available to be booked

U Service utilisation ratio

1. Introduction

> Tule kanssa, käy keralla
> Tekemähän terveyttä,
> Rauhoa rakentamahan!
> Tee kivut kivuttomaksi,
> Vammat värjymättömäksi,
> Jotta saisi sairas maata,
> Huono huoletta levätä,
> Tuskahinen tunnin olla,
> Vikahinen vieretellä
> – Kalevala, *45th poem*

The effects of pandemics, such as COVID-19, are not limited to communicable diseases. Specifically, pandemics affect the wide range of service utilisation across most diagnosis classes, even if the diseases are not infectious in nature. This dissertation aims to study how the COVID-19 pandemic shifted private healthcare usage and diagnostics in Finland between January 2020 and June 2022 and how healthcare service demand and supply in the whole spectrum of diseases were affected. Based on these, we present several empirical findings and practical implications for the management of healthcare, contributing to the growing body of knowledge for future healthcare professionals and decision-makers preparing for possible future pandemics.

1.1 Context for the study

The pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) introduced an unprecedented systemic shock to the worldwide economy and healthcare sector. The societal restrictions on human movement and behaviour, national education campaigns, mass testing and at-home-diagnostics brought about a systemic change in how we consume and address health as a service and customer. Societies shifted focus to the treatment of a single virus disease almost overnight, employing virtually unrestricted resources and emergency legislation to combat the spread of the disease.

As Mark Twain once allegedly said, *history doesn't repeat itself, but it often rhymes.* Some analyses presented in this paper bear an echo from past epidemics and pandemics, with the setting and potential implications similar to previous epidemics as early as 20 years ago when the effects of SARS were studied (Chang et al., 2004), or again during MERS (Kim et al., 2017), or most recently during the Ebola epidemic (Wilhelm & Helleringer, 2019). These studies showcased a notable decrease in non-epidemic-related healthcare service utilisation, which persisted for the duration of the epidemic. Access to healthcare services was delayed for non-acute care but also for acute services.

An integral focus of many countries' COVID-19 pandemic response was the controlled downsizing of non-acute care to preserve healthcare resources for pandemic management efforts (Sosiaali- ja Terveysministeriö, 2012). Early studies during the pandemic have reported marked reductions in healthcare service utilisation patterns (Moynihan et al., 2020; Sutherland et al., 2020; Williams et al., 2020; Xiao et al., 2021). These decreases do not seem to discriminate between acute and non-acute care. Recent reports note that treatment queues for public healthcare services in Finland have increased during the pandemic, with one contributing factor being the downsizing of non-acute care during the pandemic (HUS, 2023; Terveyden ja hyvinvoinnin laitos, 2023). This accumulation of unmet care was commonly called *care debt* in Finland during the pandemic and was acknowledged as a possible source of stress on the healthcare system in the future (Varanka et al., 2021). During 2020, care debt was estimated to be 170 000 missed care episodes for specialist care and over 1.1 million patient appointments for dental services in Finland (Kestilä et al., 2021).

Individual studies across Europe and the world have reported decreases in care utilisation; for example, mental healthcare service utilisation decreased by 50% in England (Bauer-Staeb et al., 2021), cancer diagnostics by 24% in Finland (Johansson et al., 2022), and emergency department utilisation by 42% in the United States (Hartnett et al., 2020) during early COVID-19. Across England, an estimated 160 900 patients might not have accessed mental healthcare services during the first week after the pandemic lockdown was imposed (Bauer-Staeb et al., 2021). A study conducted in England estimated an increase of 181 additional deaths over the lockdown period due to delays in cancer treatment for every 25% reduction in cancer diagnostic activity (Sud et al., 2020). Literature has dubbed this adverse effect the "collateral damage" of the pandemic (Feral-Pierssens et al., 2020; Masroor, 2020).

Care accessibility has similarly changed at an unprecedented rate during the pandemic. Remote and digital services saw unprecedented growth in usage patterns during the pandemic (Mann et al., 2020; Patel et al., 2020). Self-diagnostics and patient direction via quarantine orders were commonplace during the pandemic (Alexander et al., 2020). Availability of healthcare personnel, protective equipment and laboratory, as well as emergency service capacity, was closely monitored during the pandemic (Varanka et al., 2021; Vindrola-Padros et al., 2020). Cancellations for health service usage saw an abnormal rise in activity, and cancellations by the patient or medical personnel were estimated to be major factors influencing reduced care utilisation (Ihalainen et al., 2022; Macinko et al., 2020). Even where epidemic preparedness plans were available, societies needed to re-imagine healthcare at a rapid pace as the pandemic unfolded (Sosiaali- ja Terveysministeriö, 2012; World Health Organization, 2017b). Societies also experienced the rise of remote work, social distancing and closing down of businesses, international borders and reductions in day-to-day travel (Brauner et al., 2021; de Haas et al., 2020).

1.2 Aim of the thesis

Efficient pandemic response requires a profound understanding of the effects of COVID-19 on health service usage. The aim of this thesis is to answer how private healthcare service usage, supply and demand were affected by the COVID-19 pandemic. Specifically, the study focuses on the effects of COVID-19 on the whole spectrum of healthcare usage in private healthcare services: diagnostics, demand and supply of healthcare services and policy implications for healthcare providers and policymakers. Beyond the obvious effects of the demand for testing, tracing, and treatment of the pandemic, the pandemic introduced a long period of abnormal healthcare service usage, the effects of which are not yet fully understood in the Finnish private healthcare context. Additionally, we explore some behavioural phenomena, such as booking and cancellation patterns during different phases of the pandemic. This contributes to the management of healthcare by elucidating the dynamics by which health service utilisation patterns change and gives context to how these effects could better be managed to mitigate possible adverse effects of the pandemic on healthcare.

We approach this aim in three parts. First, we provide a theoretical background of the pandemic and its management as it was understood at the time of the pandemic. We also provide an overview of relevant concepts related to the management of supply and demand in healthcare. These are conducted via a literature review of the established and emerging research and concepts in the field. Second, we present and discuss the results of the three Manuscripts, which form the empirical part of this thesis. Last, we answer our research questions based on these results, synthesising the results into a number of research findings. The results are specifically considered within the context of healthcare management theory, presenting both practical, medical, and managerial implications for managing healthcare shocks such as pandemics.

1.3 Positioning

Many studies have been conducted on COVID-19, likely more than on any other medical event-related phenomenon in recent history. By November 2023, the WHO database of COVID-related studies lists over 880 000 studies conducted on the topic (World Health Organization, 2023c). Given this multitude, we understand that complete novelty for new research is a tall order. However, much of the attention of the study of the pandemic has been centred on the disease itself. The discussion concerning the direct and indirect effects of the pandemic on health service usage has evolved more slowly. The studies presented herein give a more nuanced overview of the state of Finnish private healthcare service consumption by utilising studies based on high-quality, medium- and long-term time series data and analyses of health service usage.

While the current evidence is emerging across fields, many such studies are limited by their scope, short research period or a relatively narrow selection of services. Comprehensive, nationally representative and concurrent studies of multiple service types have been lacking or targeted only narrow service channels over relatively short periods of time (Inglin et al., 2022; Jäntti, 2024; Johansson et al., 2022; Kuitunen et al., 2020). Recent studies have called out the need for high-quality time series analyses to better understand the effects of COVID-19 on the wider healthcare systems (Tessema et al., 2021), or requested further consideration for the available policy implications for overall healthcare utilisation and equity during past and future pandemics (Roy et al., 2021). This thesis addresses this research gap by employing a large, not previously utilised data set and analyses of Finnish private healthcare usage spanning almost two and a half years of abnormal service usage across a wide spectrum of health service utilisation.

The pandemic has had a profound effect on healthcare systems, modifying the priorities of medical and surgical procedures across a wide variety of diseases and medical practices (Sabetkish & Rahmani, 2021). This study contributes to the understanding of the pandemic's effects on the healthcare system by quantifying and analysing the effects of the pandemic on service utilisation across a wide variety of diagnostic classes. Understanding the magnitude and effect of the changes in service consumption patterns introduced by the pandemic enables policymakers to estimate the potential changes in service volume during COVID-19 within the context of Finnish private healthcare services.

The information landscape around COVID-19 has been continuously emerging, and COVID-19 has presented a uniquely challenging management environment. We acknowledge that the pandemic, along with its policy response and management, has been a source of some debate and conflicting interests. Several opinions on the management of the pandemic existed simultaneously, and the media covered each decision with much scrutiny in real time. This stands to highlight the difficulty of efficient decision-making in a high-stress situation such as a global pandemic.

1.4 Research questions

As has already been established, this thesis aims to broaden understanding of the effects of COVID-19 on how the pandemic affected private healthcare service utilisation and diagnostics beyond its direct effects and how this understanding can be utilised for future pandemic management. This is formulated into the following research problem, which is, in turn, subdivided into several research questions (RQ).

Research problem: *How did the COVID-19 pandemic affect private healthcare service utilisation directly and indirectly? How did the demand and supply of private healthcare services vary during the pandemic? How could this information, if available, be used to manage health service usage during rapid healthcare shocks, such as pandemics?*

This problem is addressed via six distinct research questions. These are thematically structured around the direct and indirect effects of the pandemic on healthcare utilisation and the effect of the pandemic on patient health-seeking behaviour and healthcare supply, access and delivery.

First, we present how healthcare utilisation for different diseases changed during the pandemic.

RQ1.1: *How did the utilisation of services related to communicable diseases change during the early pandemic?*

RQ1.2: *What were the effects of the pandemic on diagnostic activity across different diagnosis classes?*

RQ1.3: *What were the effects of the pandemic on service utilisation across different service production channels?*

Second, we analyse the demand and supply of private healthcare services during the pandemic.

RQ2.1: *How did the way patients interact with health services change* *throughout the pandemic?*

RQ2.2: *How were healthcare supply, demand and access to care affected during the pandemic?*

RQ2.3: *How did the service usage react to changes in supply or demand?*

The questions are each answered in order based on the empirical findings of the Manuscripts I-III, which set the empirical context for the study. The questions are further synthesised into practical implications by considering them within the context of relevant managerial and industrial engineering principles. These are presented in the following chapters and provide the basis for the conclusions of the findings for pandemic management. Finally, several suggestions are drawn from these findings to provide some guidance for future policymakers in pandemic management.

This thesis synthesises novel findings on three separate facets: medical, practical and managerial. First are the medical implications: a descriptive historical account of the effect of COVID-19 on service usage. The second are the practical implications: based on this updated understanding, what steps could be taken to mitigate the adverse effects of pandemics? The third facet is managerial: which tools can organisations employ to manage and achieve changes towards better management of pandemics.

The accompanying Table 1.1 depicts the relation of individual Manuscripts to the respective research questions.

Table 1.1. The research questions and how individual publications relate to each question.

Research question	Manuscript I	Manuscript II	Manuscript III
1.1	X	X	
1.2		X	
1.3			X
2.1	X	X	X
2.2			X
2.3			X

1.5 Structure of the thesis

This thesis, after this introductory chapter, is structured as follows.

Chapters two and three explore the background and empirical basis of the thesis. Chapter two explores the current literature on pandemic management, both for past pandemics as well as early lessons from COVID-19. The Finnish healthcare system is also briefly introduced. Chapter three explores the concepts of supply and demand in healthcare, introducing a theoretical framework for understanding the policy implications for pandemic management.

Chapter four explores the data and methodology employed in Manuscripts I-III. We outline the data set, the statistical methods and the analytical and computational tools used in the study. We also address the ethics of the study.

Chapter five offers a brief overview and synthesis of the relevant findings, contexts, domains and conclusions of the individual Manuscripts.

Chapter six explores the research questions within the context of the Manuscripts and builds on the individual studies to answer those questions. We also expand on some of the findings in the Manuscripts to answer some practical and managerial implications. We discuss the strengths and weaknesses of the study. Finally, we propose some further avenues of study for future scholars.

Chapter seven concludes the thesis.

2. An overview of the Finnish healthcare system, COVID-19 and pandemic management principles

> As long as they have the disease, they remain unclean. They must live alone; they must live outside the camp.
> – The Bible, *Leviticus 13:46*

This chapter lays the groundwork for the current understanding of the global impact of the pandemic in general. We explore the theory of pandemic management as it was understood during the early pandemic. We also describe the Finnish healthcare system specifically to provide context for the applicability of the studies in other geographical regions.

2.1 The Finnish healthcare system

To understand the context and applicability of the study, we must briefly explore the Finnish healthcare system. It follows the Nordic healthcare model, mainly comprising universal access to public tax-paid healthcare (Olsen et al., 2016; Tynkkynen et al., 2023). The majority of visits are publicly funded, while private healthcare providers supplement public healthcare services by providing mainly outpatient services. Private services accounted for 21.9% of all healthcare expenditure in 2020 (Matveinen, 2023). A unique feature of the Finnish healthcare system is the comprehensive occupational healthcare system, which makes up about 30% of all general practitioner visits (Terveyden ja hyvinvoinnin laitos, 2024). Employers are required to provide preventive healthcare services to their employees, typically provided through private companies. In addition to preventive care, the offered services typically entail primary healthcare services. Remuneration for the services is covered partially by the employers and partially from payroll deductions. In 2021, 90.1% of all employees of Finland were covered by the program for primary healthcare services (Kela, 2023).

According to the OECD, 10.3% of the Finnish GDP was used on health services in 2021, which is below the European Union average. Annual adjusted per capita expenditure on health was 3 584€, also below the EU average (OECD, 2023). In 2019, the Finnish population used fewer health services than the EU average, at 4.4 doctor consultations per person per year. However, spending on prevention was the highest in EU (OECD, 2021). Approximately 19 600 doctors and 62 100 nurses were registered in Finland in 2021 (Palmgren & Karvonen, 2023). Adjusted for population, Finland has fewer doctors but more nurses than the EU average, at 3.6 doctors and 18.9 nurses per 1 000 population (OECD, 2023). The leading causes of death in Finland in 2022 were cardiovascular diseases, cancer, and Alzheimer's disease and dementia (Tilastokeskus, 2022). The ageing population and chronic diseases will likely continue to increase demand for health services in the future (OECD, 2021). In 2023, a major administrative public healthcare reform reorganised the responsibility for providing health and social care away from individual municipalities to 21 well-being counties, the city of Helsinki, and the Hospital District of Helsinki and Uusimaa (Tynkkynen et al., 2023). While the reform was completed during the COVID-19 pandemic, the effects on private healthcare were limited.

2.2 A brief history of pandemics and pandemic management

The management of pandemics is not a new or novel practice. The word *quarantine* stems from the 15th century Adriatic coastline, from the Italian word *quaranta*, forty. This was the period of days that foreign ships entering medieval Venetia from countries suffering from plague had to wait before entering the harbour. This was to ensure that the plague had time to pass the incubation period and surface. (Emerging Infectious Diseases, 2013).

Pre-industrial pandemics are identifiable only by descriptions of symptoms or saved viral matter. Prior to 1932, when the influenza virus was first isolated and recorded by laboratory analysis, descriptions of rapidly spreading respiratory diseases associated with muscle pain and general weakness were indicative of a viral epidemic or pandemic (Potter, 2001). Written records describing matching symptoms emerge throughout history, with the earliest dating to ancient Greece in 312 BC, but the first epidemics regarded with confidence as influenza-based occurred in 1173 (Ghendon, 1994). First records of widespread epidemics, called pandemics, can likely be associated with either the early 16th century, when a probable pandemic was reported to have spread from Africa to Europe, or the late 16th century when influenza originated from Asia and rapidly infected most of Africa and Europe (Ghendon, 1994; Potter, 2001). Since then, the emergence of pandemics has been fairly regular, with new strains occurring every 10 to 50 years (Potter, 2001).

Certain features historically indicate the emergence of a pandemic. According to Potter, pandemics and epidemics are typically first observed in areas with condensed populations and continuous high humidity and cold temperatures. Proximity of animals, especially poultry and swine, to people further facilitates mutations in viral proteins. In the northern hemisphere, viruses spread during the colder winter months, where crowding of people occurs inside (Potter, 2001). New viral influenza strains occur mainly as the two surface antigens of influenza, haemagglutin (HA) and neuraminidase (NA), undergo mutations and start to spread in the population (Ghendon, 1994). Prediction of the emergence of viral strains is currently not possible (Taubenberger et al., 2007), but they re-occur with relative frequency, and most countries experience an influenza period every year (Potter, 2001).

Historically, the 1918-20 pandemic has been dubbed “one of the most dramatic events in medical history”, as the pandemic is believed to have infected 50% of the human population and killed 20 to 50 million people worldwide (Potter, 2001). The pandemic was especially dangerous in the sense that it also affected relatively young people and not only the sick and elderly (Beveridge, 1991). Interestingly, some records of organised resistance to pandemic management also occurred during the 1918 pandemic, when anti-mask leagues activated in response to government intervention to restrict the spread of the pandemic (Dolan, 2020). National governments already employed or created response measures to control widespread infectious diseases, such as designating quarantine hospitals or mandating doctors to order families and households to self-quarantine (Hellens, 1929).

Since then, two major pandemics have occurred: the 1957-58 influenza and the Hong Kong flu of 1968-69 (Potter, 2001). Additionally, in recent history, the 2002-2004 Severe Acute Respiratory Syndrome (SARS) epidemic, the swine flu epidemic of 2009, the 2012-2021 Middle Eastern Respiratory Syndrome (MERS) epidemic, and the 2013-2016 Ebola epidemic have been especially influential in modifying public response and attitude to infectious disease management (Rahimi et al., 2020). Notably, three of the epidemics of the 21st century have been caused by coronaviruses instead of influenza: SARS, MERS, and COVID-19.

2.3 The Covid-19 pandemic

Covid-19 is an airborne infectious disease caused by the SARS-CoV-2 virus (World Health Organization, 2023d). ICD classification code for the disease is U07.1 for laboratory-verified infection and U07.2 for a suspected infection, both of which were taken into use in February 2020 (Terveyden ja hyvinvoinnin laitos, 2020). Typical symptoms of the disease include cough, fever, and chills, with less common symptoms including loss of taste and smell, muscle pain and diarrhoea (World Health Organization, 2023d).

A majority of the patients exhibit mild symptoms, 14% severe symptoms, with 5% requiring hospitalisation (Wu & McGoogan, 2020). Symptoms manifest within five to six days from exposure (World Health Organization, 2023d). Alongside the acute effects, a range of effects from mental effects to organ failures have been reported on patients, possibly persisting for a long time after the infection (Groff et al., 2021; Michelen et al., 2021; Parotto et al., 2023). This has commonly been named *long covid*. As new mutations such as the omicron variant in 2021 emerged, the symptoms of the COVID-19 infection increasingly resembled typical seasonal influenza, with increased frequency of symptoms such as sore throat and sneezing (Whitaker et al., 2022), making syndromic surveillance less effective in differentiating the virus from other respiratory illnesses (Geismar et al., 2023). Mortality of COVID was initially estimated to be 3%, but the latest estimates place the infection fatality rate at around 0.3% to 0.4% (Bollyky et al., 2022; Levin et al., 2020; Meyerowitz-Katz & Merone, 2020).

The first confirmed cases of COVID-19 (Sars-Cov-2) originated in Wuhan, China, in December 2019 (Li et al., 2020). At the time of writing, the general consensus was that the first reported cases in Europe occurred in France on January 24th, 2020, and the first reported cases in Finland were reported on January 29th. The virus spread quickly through most of the world, with countries placing various restrictions to limit the international spread of the disease (Spiteri et al., 2020; Truong Nguyen et al., 2022). WHO declared COVID-19 a pandemic on the 11th of March, 2020 (World Health Organization, 2020). By the end of 2023, 773 000 000 global cases and 6 990 000 deaths related to COVID-19 had been reported (World Health Organization, 2023b).

As early reports in 2020 confirmed that the virus responded adequately to vaccinations, pandemic containment until national vaccination programs could be rolled out emerged as the main strategy to manage the pandemic. The first vaccinations outside clinical trials started in December 2020, with large national programs underway in most of Europe and the USA during 2021 (Mathieu et al., 2021; McLaughlin et al., 2022). On 5 May 2023, WHO declared that COVID-19 no longer posed a public health emergency of international concern (PHEIC), though it remained a pandemic (World Health Organization, 2023a).

In response to the pandemic, a number of countries employed restrictive measures and non-pharmacological interventions (NPIs) for gatherings, movement of goods, and people and businesses to limit the disease's spread rate (Brauner et al., 2021). With initial reports, especially from Italy, indicating relatively high rates of hospitalisation due to the COVID-19 infection, a common concern for health systems was that the cumulative demand spike for emergency services could cripple health systems for both emergency and non-emergency care. As such, the number of ICU beds and emergency services, as well as limiting the spread of the disease to "flatten the curve" remained key focus areas for the initial pandemic response.

2.4 Economic and societal effects of COVID-19

Alongside the impact on population health, COVID-19 has had a major impact on societies on economic, social and personal levels. Ludvigson *et al.* noted that the COVID-19 pandemic differed from other natural disasters in that it simultaneously disrupted supply, demand and productivity channels in a synchronised manner across large geographic areas. Where typical disasters and exogenous shocks might create short-term fluctuations as preferences, supply chains, demand and supply of goods and services are affected, COVID-19 caused similar effects simultaneously across the globe, creating social, economic and health implications persisting for a long period (Ludvigson et al., 2020).

Economies have been affected by reductions in production, service usage, manufacturing and logistics (Delardas et al., 2022). Restrictive measures affected the transport of people and goods. Among the sectors most affected by the pandemic has been the service sector, with tourism, hospitality, sports, and leisure sectors especially impacted (Naseer et al., 2023). The 2020 Tokyo Olympic games were postponed by a year, cities such as Paris, Amsterdam and Rome were deserted from tourists, trade fairs, music tours and cultural events were postponed or cancelled, and supply chain shocks closed down manufacturing plants around the world (Fernandes, 2020). Companies and employees were encouraged to implement work-at-home policies either completely or partially (Valonen, 2020). According to the estimates of the Finnish Ministry of Finance conducted during the pandemic, for each increase of 10 persons per million requiring hospital care per month, the general economic confidence indicator was reduced by 0.21 points (Palmén, 2021).

Broader societal impacts of the pandemic included changes in access and utilisation of education, increased stress on the criminal justice system, changes in the consumption of housing and commodities, as well as increased air quality and decreased greenhouse gas emissions during the early pandemic (Schnitzler et al., 2021). The economic, cultural and societal impacts of the pandemic are so pervasive that the pandemic is as much a cultural phenomenon as it is a health-related one.

The social and economic effects did not affect the world equally but placed disproportionate stress on minorities and poorer socioeconomic classes. The effect was already noticed during the 1918 pandemic, where "the lower the economic level, the higher was the attack rate" (Sydenstricker, 1931). Similarly, the effect of COVID-19 has been felt more strongly by the more vulnerable. In Africa, the COVID-19 pandemic exacerbated the challenges in attaining routine care (Tessema et al., 2021). Minorities were disproportionally affected globally. Blue-collar jobs required increased physical contact with others or experienced factory closures, while white-collar jobs could be transferred to remote work (Shah et al., 2020). Schools transferring to remote teaching widened education inequalities, as families from poor backgrounds might have had fewer resources for learning materials and internet access as well as capabilities to support learning at home (Haelermans et al., 2022). In America, African Americans were disproportionally more likely to die from the pandemic than the general population (Abedi et al., 2021). In Finland, the most socially vulnerable families reported difficulties in attaining necessary social services, partly due to a lack of information and limited access to computers and tools to contact social services remotely (Kestilä et al., 2021). The effects may also be intergenerational and arise long after the pandemic, as childhood poverty and parents' mental health problems have been linked to increased risk for mental health disorders later in life (Paananen et al., 2013).

While the pandemic shared similar cultural elements globally, it is important to understand that the effects, reactions and policy responses differed noticeably between different countries. The world was not uniform in its response to the pandemic, nor was it equally affected. The policy responses employed by governments were likewise not strictly correlated with the pandemic situation but mirrored local political and information landscape and public sentiment.

2.5 Preparedness for global pandemics prior to COVID-19

An excerpt from the Finnish legislation from 1927 contains several familiar measures to protect the population from risks associated with infectious diseases. These include regulation on the obligation to notify officials of potentially dangerous contagious diseases of symptomatic patients, tracing, voluntary and involuntary quarantine, disinfection and hygiene measures, protection of the at-risk population, training and guidance of the population, restrictions on movement, and potential closure of schools and workplaces (Hellens, 1929). Patients would be vaccinated against communicable diseases where vaccinations were available, and personal liberties could be restricted to protect the populations by placing restrictions on working while sick. The main focus of the strategy was to treat the infected, prevent the spread of the disease and increase the immunisation of the sick.

Many of these elements were applicable in much the same form in later revisions of pandemic preparedness guidance and legislation. During the 21st century, Finland updated its pandemic influenza preparedness twice: first in 2006 and later in 2012 based on the experiences of the 2009 swine flu pandemic. The plan contained elements on coordination between officials, communications and stockpiling of goods, plans for acquiring vaccinations and medicine, as well as measures to restrict the spread of the epidemic or pandemic at varying phases of development. These measures contained elements on public communications and guidance, reducing the spread of the infection in the infected population, reducing the spread of the infection in the exposed population, reducing social interaction in the general population, hygiene and disinfection measures, restrictions and guidance on national travel, and restrictions and guidance on international travel (Sosiaali- ja Terveysministeriö, 2006, 2012). The documents also consider cases where certain actions would not be appropriate or effective, such as restricting travel between parts of the nation or mass measurements of fever in public areas. Prior to the pandemic in 2017, a WHO joint external evaluation concluded that the capabilities of Finland in place to detect, assess, notify and respond to major public health events were extensive and effective (World Health Organization, 2017a).

The responsibility for preparedness for controlling a communicable disease outbreak was split between several agencies in Finland. Public healthcare actors are required to maintain regional preparedness plans, and these are regularly practised. Ministry of Social Affairs and Health and the Finnish Institute for Health and Welfare were responsible for national preparedness, coordination of epidemic surveillance, and vaccination programmes, while regional and local municipalities, regional administrative agencies and hospital districts were responsible for most of the operative responsibilities and preparedness (Karreinen et al., 2023).

Compared to earlier pandemics, the role of the private sector for national preparedness was increased during COVID-19. In addition to the routine healthcare capacity, public healthcare actors involved the private sector by, for example, outsourcing COVID-19 testing or utilising staffing services (HUS, 2020). In addition to the public sector, private companies also introduced healthcare demand by buying mass testing for workplaces or events. As such, some healthcare service demand during the pandemic was not purely consumer-driven but at least partly structured.

The assumption on which the focus of the Finnish influenza management plan was built was a relatively short, controlled influenza pandemic during which essential care was secured by regulating access to non-acute care. The total duration of the main phase of the pandemic was estimated to be at most six months, during which the population gains sufficient immunisation to the virus via natural herd immunity. The plans assumed that 35% of the population would contract the virus over the course of the first wave (Sosiaali- ja Terveysministeriö, 2012).

The plans were based on the WHO pandemic preparedness guidance, which categorised pandemics into six distinct levels (World Health Organization, 2009). During levels 1-2, the zoonotic virus does not yet infect humans. During levels 3-5, transmissions between animals and humans as well as between humans are possible. Level 6 is categorised as the pandemic phase, where the spread of the infection can not be restricted. According to the recommendations, during levels 1-3, the focus should be placed on planning for a possible pandemic; during level 4, the focus should be on restricting the spread of the virus, whereas during levels 5 and 6, the focus should be solely on managing the effects of the pandemic. These levels were loosely rephrased into four distinct phases in a revision of the categorisation: the inter-pandemic period, the alert period, the pandemic period and the transition phase after the pandemic (World Health Organization, 2017b). While these take into account both the inter-pandemic phases between pandemics as well as the transition period from a pandemic phase to inter-pandemic phases, Halmberg & Lunden identified that national and international preparedness plans are typically vague in managing the long-term effects of the pandemic (Holmberg & Lundgren, 2018).

Pandemics are by their nature international and require worldwide coordination efforts to contain. The International Conference for the Control of Influenza in Courchevel, 1992, attempted to codify a number of recommendations on pandemic planning. These included enhanced surveillance of viral strains, improvements in vaccine development, development of global, national and regional plans and inclusion of public and mass media to control the spread of the virus at all stages (Ghendon, 1994). Before COVID-19, many European countries employed individual preparedness plans similar to Finland, with the European Centre for Disease Prevention and Control listing 21 national plans supplementing the international planning (ECDC, 2017). In addition to the preparedness plans, many countries employed clinical guidelines on treating influenza and pandemic patients (Rigby et al., 2022). Virtually all plans list the protection of the functioning of the health care system as a vital interest. According to the French "Plan national de prévention et de lutte 'Pandémie grippale'" (2011): "In addition to its health impact, an influenza pandemic can cause disorganisation of the health system, and also disturbances in social and economic life. The response to it involves not simply a health care approach, but also an inter-sector approach." (Le secrétariat général de la défense et de la sécurité nationale, 2011).

2.6 The pandemic response: Flattening the curve and raising the line

Traditionally, a difficulty related to pandemic management was that viral matter from the virus can only be collected after the onset of the pandemic, and the real causative strain of the virus can be deduced only well after the first phases of the pandemic (Ghendon, 1994). Thus, pandemic management is always playing catch-up with the virus, which likely also evolves and develops resistance to immunity over the pandemic. However, in the case of COVID-19, the RNA structure was known even before WHO declared the disease a pandemic (Wang et al., 2020). As the pandemic progressed, vaccine production was unprecedently rapid. Four main types of vaccines were developed for the pandemic: *message-* or *mRNA-based* vaccines such as Spikevax and Comirnaty; *adenovirus-based vector vaccines* such as Vaxzevria, Sputnik V; *subunit* or *particle vaccines* such as Nuvaxovid; and *inactivated virus vaccines* such as Sinovac, BBIBP-CorV or Covaxin (Ndwandwe & Wiysonge, 2021). Typically, the time-to-market for vaccines is several years as multiple human trial phases have to be passed (Krammer, 2020). In the case of COVID-19, the first vaccines were accepted for use in late 2020, less than a year after the virus was isolated.

At its core, pandemic restrictions aim to slow or stop the spread of a contagious disease by ensuring that the rate at which infected individuals can spread the virus to new hosts remains low (Flaxman et al., 2020). This is done to both protect healthcare peak capacity and gain time to develop effective vaccinations or viral medicine. The speed at which a certain virus spreads is often represented using the reproduction number, or R_0. This represents the number of new patients to whom each infected spreads the disease. If $R_0 = 1$, each infected spreads the disease to exactly one other individual, and the number of infected persons in the population remains stable. If R_0 exceeds one, the number of infected in a society increases. If R_0 is less than 1, the number decreases. The dynamic is exponential, and as such, the virus can spread relatively quickly, even if the initial infected population is small.

The initial fear related to COVID-19 was that this exponential spread would result in a large number of patients requiring intensive care across a relatively short period, thus possibly overloading the healthcare system and disrupting care for infected and other patients equally. "Flattening the curve" referred to managing the R_0 number through a number of non-pharmacological interventions, thus slowing down the spread of the virus and reducing its impact on the wider healthcare system. "Raising the line" referred to increasing healthcare capacity. Together, these aimed to maintain a manageable level of stress on the healthcare system, preventing a systemic collapse of healthcare services and disrupting access to care altogether. Figure 2.1 presents a graphical representation of this.

The aim of this policy was to protect peak healthcare capacity. However, reducing R_0 prolongs the pandemic and necessitates a longer duration for protective measures (Douglas et al., 2020). Paradoxically, completely stopping the virus might not be optimal, as removing protective measures might introduce the virus uncontrollably back to the public. Simultaneously, the ongoing protective measures can create a continuously compounding economic, social and healthcare cost for the public. Instead of

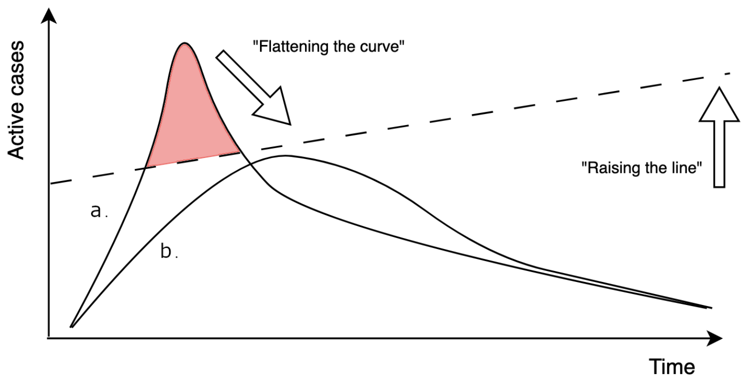

Figure 2.1. A popular simplification of the pandemic response plan communicated to the public was the dual effect of "Flattening the curve" and "Raising the line". The overarching goal is transitioning from line a to line b, thus allowing time to build up the healthcare capacity. This would avoid overloading the healthcare system capacity, represented here with the red hue. The dotted line represents healthcare peak capacity at any given point in time. Adapted from (Pearce, 2020)

a full closure, an effective pandemic strategy is often a balancing act between healthcare capacity management and increased herd immunity via vaccinations or contracting the disease.

2.7 Effects of pandemics on healthcare systems

A naive consideration of the effects of the pandemic refers only to the direct impacts of the pandemic, i.e. infections and deaths. However, a more nuanced view is presented by Roy et al., 2021, of which a modified version is presented in Figure 2.2. The pandemic affects population health directly via infections and other directly related conditions, such as *long covid*. Alongside these direct effects, healthcare supply and delivery are also affected indirectly. Priorities for different medical and surgical procedures are changed, many routine functions of the healthcare system may be disrupted or their resources reserved for the use pandemic management, and the effects encapsulate a wide range of clinical practices (Sabetkish & Rahmani, 2021). Care service capacity and medical clinics are reserved for pandemic treatment, testing and tracing, and healthcare personnel absenteeism may increase due to infections. Health-seeking patterns of patients are changed by public information campaigns and public sentiment. Service delivery is affected, and care may be prioritised, for example, by downsizing non-acute care. These combine with the direct effects to influence the total public health effects of the pandemic via both direct and indirect channels. Population morbidity and health, in turn, affect the demand and delivery of care services, creating a feedback loop which amplifies the indirect effects of the pandemic.

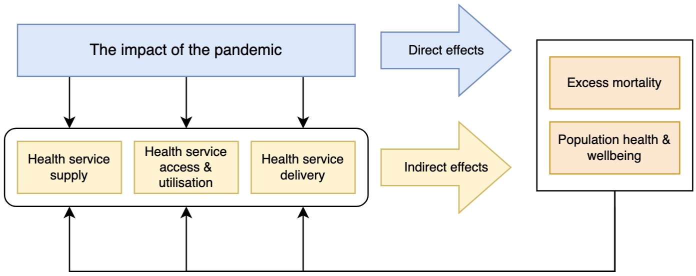

Figure 2.2. The total effects of the pandemic are dependent on both the direct effects of the virus and the indirect effects, which are manifested through the population health seeking and utilisation patterns as well as healthcare supply and delivery. These result in short-, medium and long-term changes in population morbidity and health. Adapted from (Roy et al., 2021)

There is an emerging body of evidence that the effects of epidemics and pandemics are not limited to the treatment of infectious diseases alone. Healthcare service usage decreased by 24% in Taiwan during the 2003 SARS epidemic and by 18% in areas affected by Ebola in Africa between 2013 and 2016 (Chang et al., 2004; Lim et al., 2004; Wilhelm & Helleringer, 2019). Similar decreases have been observed with COVID-19, with a reported one-third decrease in healthcare service usage (Arsenault et al., 2022; Moynihan et al., 2020; Tessema et al., 2021). Recent reports have reported consistent and systematic decreases in both acute and non-acute healthcare utilisation across multiple regions during COVID-19 (Mansfield et al., 2021; Williams et al., 2020). Decrease in mental health service utilisation (Taxiarchi et al., 2023), diabetes (Inglin et al., 2022), emergency department visits (Lange et al., 2020), and oncology (Johansson et al., 2022) have been reported.

Wang *et al.* estimated that while worldwide the COVID-19 related deaths totalled 5.94 million between January 2020 and December 2021, the overall all-cause excess mortality was as high as 18.2 million persons during the same period (Wang et al., 2022). In other words, only one in three of the deaths associated with the COVID-19 pandemic were directly caused by the pandemic, whereas the other two were caused by indirect effects. While a direct death resulting from COVID-19 is relatively straightforward to report, these indirect causes of mortality encompass the whole spectrum of human health. Undoubtedly, these factors also include a net effect on population health in general beyond deaths alone. These changes are harder to quantify, but we can refer to missed acute care as a benchmark for conditions which were left untreated. Bauer-Staeb *et al.* estimated that in England alone, as many as 160 000 patients forwent planned mental health appointments during the first weeks of the pandemic (Bauer-Staeb et al., 2021). Lee *et al.* reported that between March 2020 and January 2022, mortality in the United States from chronic conditions such as diabetes, Alzheimer's, and heart conditions increased by 25 000, 25 000 and 50 000 excess deaths, respectively (Lee et al., 2023). Banerjee *et al.* estimated that reductions in cardiovascular disease service activity due to the pandemic resulted in 50 000 to 100 000 excess deaths in England (Banerjee et al., 2021). In France, out-of-clinic cardiac arrests increased two-fold during the initial phases of COVID-19, with a reduction in the rate of survival (Marijon et al., 2020). Lai *et al.* estimated 17 000 excess deaths during the first year of COVID-19 in England due to decreases in cancer treatment (Lai et al., 2020). Alongside excess mortality, these changes in health service utilisation patterns can cause long-term population health issues, which may only emerge after a relatively long time after the pandemic itself has passed. Taken together, these factors - both the all-cause excess mortality as well as population health - constitute the direct and indirect effects of the pandemic.

One factor contributing to the discrepancy between the popular focus on the direct effects instead of the indirect effects is undoubtedly the availability of information. During the early pandemic, most nations quickly utilised existing registers or created new infectious disease registers (Dron et al., 2022). Alongside infections, COVID-19-related deaths and hospitalisations were reported daily on all levels of human society, from regional to global. However, comprehensive information systems that elucidate the situation concerning availability and access to care, non-COVID-19 related diseases, and patient behavioural patterns were mostly absent. It is easier to report on and manage phenomena that one can easily measure, so the availability of high-quality long-term data on health service usage, in general, could be an important factor for future pandemic management. While some studies collected and reported such data during or shortly after the pandemic (Mansfield et al., 2021), the focus was placed on studying the direct effects of the pandemic. This study is an extension to this ongoing effort to provide increased understanding and information for policy management in preparation for future pandemic shocks.

3. Some factors affecting healthcare utilisation: healthcare supply, demand, access and need in healthcare

> The purpose of healthcare is to help people with problems that, for whatever reasons and justifications, are perceived to be medical conditions. Help is what healthcare delivers; health is a consequence that may or may not happen.
> – Lillrank, *Logics of Healthcare*

3.1 On measuring health

According to the World Health Organisation, health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." WHO constitution envisages "...the highest attainable standard of health as a fundamental right of every human being." Health is not limited to just healthcare but encompasses the entirety of factors related to health (World Health Organization, 1946). In an abstract sense, it can be expressed as a type of human capital, in which all individuals receive a certain amount of health "stock" at birth that deteriorates over time (Grossman, 2017; Santana et al., 2023). Individuals may choose to invest in their health to improve their health, which in turn can be utilised to enable higher levels of well-being and function. Specifically, the human capital theory expands traditional economic models by identifying that health is both a capital asset, in that it enables one to work, and a consumption commodity, as being healthy is preferable to being unhealthy. All of the inputs for an individual's health, such as housing, healthy nutrition, sleep, exercise, social needs, and healthcare, form the inputs of a *health production function*, which dictates the total level of health for a person (Wagstaff, 1986). A person or a society may choose different levels of investments in these inputs, resulting in a decrease or increase in the total health of a person or a population.

There are multiple ways to measure health intervention outcomes, both directly observable and via predictive measures. To obtain empirical data, one can conduct measurements and directly assess variables related to the health status of the population. These include morbidity and work ability as well as service utilisation and diagnostic activity. However, while directly observable variables are relatively easy to calculate, they provide little context for policymaking.

Direct diagnostic activity is a straightforward but simple proxy for measuring health service activity. If one person is diagnosed with influenza and care is provided, one unit of healthcare is administered. If a village used 100 units of healthcare last week and 96 the next, a decrease of 4% in health service usage was experienced. However, such a model only considers direct diagnostic activity as value-adding. Imagine instead that these four units of healthcare were used for preventive measures, such as educating the villagers on the practices of good hand hygiene. Even if the absolute number of service utilisation was decreased, the community is probably now more prepared to address viral infections in the future.

More accurate metrics take into account the opportunity cost of administering care for the patient. According to Weinstein *et al.*, each measure of health assumes a certain outcome or optimisation problem for maximising health and health improvement subject to limited resources. As an example, we may take quality-adjusted life years or QALYs, where each year of life of an individual is ranked between 0 and 1. A value of 0 denotes death, 1 denotes perfect health, and these are summed over the course of the person's life. Health at a certain level of QALY has a certain level of value, and given limited resources, organisations can design initiatives to maximise said value. In choosing to measure QALYs, we choose to optimise both individual lifespan and quality. However, decision-makers may want to prioritise other outcome features such as access to care, equity of healthcare or specific political goals, among others. (Weinstein et al., 2009)

During a pandemic, what data are measured and how affects the resulting calculated measures. Therefore, the selection of the data is important beyond considerations of quality and accuracy: by selecting a measurable phenomenon and collecting data on it, we are implicitly defining the problem to be solved. Thus, the selection of the health value schema affects policymaking. If a community wishes to maintain or improve the level of health subject to desired policies given a set of constraints, it should select a matching schema and allocate resources such that the outcome is best fulfilled. A key difficulty in health policy management is successfully identifying the impact and contribution of a given policy action on any given metric. Calculating the empirical data is only possible *ex-post* and is therefore not available when planning any given policies. Predictive models which try to forecast the possibility of a given outcome variable are inherently sensitive to assumptions in the models. As pandemics or severe epidemics are relatively rare, validating these models is difficult.

A central element of pandemic management is managing this difference in the information landscape effectively. Predictive models are necessary for strategic planning of the pandemic, such as vaccination strategies or pandemic preparedness schemes. Direct observations of the status of the pandemic enable real-time decision-making based on the status of the pandemic.

3.2 Health care supply, demand and need

A comprehensive explanation of healthcare supply-demand dynamics is often debated and out of the scope of this dissertation, but for the sake of empirical background, we give a brief overview of the topic. For a more detailed introduction, see, e.g. Mankiw, 2021, Santana et al., 2023, and Lillrank, 2018.

According to Culyer and Wagstaff, “entities such as ‘good health’ are necessary for an individual to ‘flourish’ as a human being”, a reference to moral philosophy literature (Culyer & Wagstaff, 1993). The demand for healthcare is driven by both *utility* and *need*. The utility of healthcare includes the ability to work, move and express oneself. Before post-industrial social security schemes, lengthy incapability to work as the breadwinner of the family could be catastrophic. Healthcare is also a basic need. We pursue good health simply because we want to be healthy. The uncomfortableness of disease is in itself reason enough to seek good health. As such, healthcare is a special case of service demand, one which usually is prioritised above most other needs when the need is the strongest.

Healthcare supply, on the other hand, consists of the healthcare workforce, medication, diagnostic ability and supplies available to the economy (Santana et al., 2023). Medicine and health care are scarce resources, creating an allocation problem for the economy. The range of resources is usually more limited than the range of potentially treatable conditions. Health care is usually free or heavily discounted for the recipient at the point of service, so the true cost of the supply can remain invisible (Mankiw, 2021). Healthcare can also suffer from the agent-principal problem, where the principal, being the public authority, tasks agents in the form of healthcare providers to deliver healthcare services to patients. Due to information asymmetry, the agents may choose not to provide care purely in the best interest of the principal, but for example maximise personal economic gain (Nguyen, 2011).

According to Santana *et al.*, *need* is the capability to benefit from health care (Santana et al., 2023). It contains measures that are effective in improving, maintaining, or slowing the decline of one’s health status. The need is the catalyst that converts the population’s health status into demand for access to care. Bradshaw categorised social need as *normative* or expert-given, *felt* or subjective, *expressed* and *comparative* or in relation to another (Bradshaw, 1972). The need is both internal and external. It is subjective (*felt*) but also regulated (*normative* and *comparative*). For example, a person might feel they need health services during a certain pandemic phase, but societal movement restrictions dictate that non-urgent needs are not prioritised due to fears of the pandemic spreading. Similarly, a person might not feel they require a vaccine, but normative guidelines recommend immunisation by vaccination.

In contemporary marketing theory, this distinction is made more clear by denoting subjective needs as *wants*, (Kotler, 2001). Needs turn to wants, wants turn to demand, and demand activates the supply side (Lillrank, 2018). Needs and wants differ in that needs are, at least partially, subject to objective or third-party assessment, whereas wants are subjective declarations of preference. With respect to health policy planning, wants and needs behave differently. Demand forecasting and supply planning are possible by understanding the needs of a population, whereas subjective wants create demand. As long as the subjective and objective needs are met, this resource planning is effective. However, patients might not need what they want or want what they need (Lillrank et al., 2010). Matching normative needs to subjective wants is a key function of effective healthcare management, especially during demand shocks.

3.3 Demand shocks

According to Lillrank, services are immaterial tradable goods that, through customer-provider interactions and co-creation of value, result in state changes that have positive value. Services as sellable entities cannot be stored, while physical service components, such as pharmaceuticals and facilities, can. Therefore, service management requires both the management of inventories and capacity, which in the case of a pandemic means controlling the number of hospital beds, consumables such as medicine, disposables such as masks, gloves and protective equipment, as well as manpower of different types. When demand is stable, these can be managed with reasonable accuracy. However, when demand abruptly changes, service providers need to rapidly adjust production to meet the new status quo. (Lillrank, 2018)

For the theory of capacity planning, services present a number of considerations compared to physical goods. Namely, services are local, cannot be stored and have a high degree of volatility for demand (Stevenson, 2007). Service production needs to be synchronised with demand with regard to time and, typically, space, in contrast with physical goods, where value creation and consumption can happen in an asynchronous fashion. Different measures can be taken to control this volatility, and healthcare services specifically aim to standardise operations to the degree permitted by the variability in the service demand (Lillrank, 2018). Generally, relatively accurate resource planning can be conducted as healthcare utilisation rates follow somewhat regular seasonal patterns. The population morbidity for most conditions is generally relatively stable, with seasonal variations associated with influenza, holiday periods and daily, weekly and annual variations. These can be deducted if population demographics are known. The exception, however, is related to conditions where the health statuses of large portions of the population change rapidly. These may occur, for example, during major accidents, natural disasters, armed conflicts and specifically during infectious epidemics.

There are a number of typical strategies employed to control and manage variability in service utilisation. In general, managers can try to match time-perishable capacity to demand by applying demand management, therefore smoothing demand, adjusting capacity, or allowing customers to wait (Fitzsimmons & Fitzsimmons, 2004). Table 3.1 presents some of these strategies, as well as examples associated with these. For example, during the fall of 2021, vaccinations were prioritised for at-risk populations. However, if supply was at risk of perishing due to no-shows, it was generally handed out to passers-by or via wait lists. This smoothed demand by inducing off-peak demand. Most actions associated with COVID-19 testing, tracing and vaccinations were automated relatively quickly, thus engaging the patient in the service creation process. This had the side effect of creating excess service, as patients took on some of the work typically attributed to nurses during the booking process. *Service-dominant logic* states that customers are always co-creators in service value processes, and efficient managerial response entails including the customer in the value process (Fitzsimmons & Fitzsimmons, 2004).

Two strategies are especially important within the context of this thesis: demand management and queuing. Customer demand was decreased to protect supply multiple times during the pandemic, and patients were de-incentivised to seek healthcare for non-acute cases or regular checkups. Simultaneously, the scarcity of resources was handled via queuing, where follow-up care was postponed. On average, recent reports from COVID-19 suggest that pandemic shocks decrease service usage between a fifth and a third, a notable decrease (Arsenault et al., 2022; Moynihan et al., 2020; Tessema et al., 2021). These phenomena may not be common across other types of systemic shocks in healthcare. Similar effects were not identified during the economic depression of the 90s in Finland, during which service demand stayed stable, even though public expenditure decreased (Blomster & Simpura, 2001; Konttinen et al., 2000). This suggests that pandemics may be unique in incentivising societies to self-regulate service usage.

Table 3.1. Different strategies to manage time-perishable capacity. Adapted from (Fitzsimmons & Fitzsimmons, 2004; Johnston & Clark, 2005; Lillrank, 2018).

Strategy	*Option*	*Example during COVID-19*
Smooth demand	Employ reservations and limit walk-ins	Most hospitals operated on a strict per-reservation -basis
	Increase off-peak demand	Excess vaccinations were distributed via waitlists
	Demarket peak demand	National guidelines recommended delaying non-acute care
	Price incentives	Public COVID-19 testing was limited to tracing, with testing for travel and leisure operated via private companies
Adjust service capacity	Seasonal workers	COVID-19 tracing and vaccinations employed large numbers of temporary workers
	Resource flexibility	Healthcare personnel were reallocated and transferred to tracing and treatment
	Increase self-service rates	Patients were involved in the self-registration for COVID-19 testing
	Increase capacity	The number of ICU beds and laboratory testing was increased throughout the pandemic
	Increase productivity	COVID-19 related laboratory testing was highly standardised and optimised for efficiency
Allow customers to wait	Allow accumulation of customer queues	Non-acute care was regularly postponed during the pandemic

If service production systems operate at peak or near-peak capacity for prolonged periods of time, managers and front-line operators may enter a 'coping zone' (Johnston & Clark, 2005). The high resource utilisation rates stress the workers and customers alike, decreasing quality and limiting managers' options for managing the service system. Managerial or operational options for solving emerging problems might become limited due to the general stress level of the system. Moreover, systems at peak capacity are more sensitive to disturbances and have more limited capability to react to variations in demand. At worst, the inability to react to change under such conditions can paralyse the system. Therefore, capacity management strategies should be prepared and employed beforehand, as during the hectic periods of the pandemic, little attention can be placed on process improvement or planning.

According to Culyer and Wagstaff, 1993, policymakers can regulate access to care for different populations in the hopes of altering the way they consume health care. Demand management is typically done via pricing incentives or public address and media correspondence. The role of media is particularly widely studied in the context of demand management. According to Wahl-Jorgenssen, "Media coverage sets the agenda for public debate. While the news doesn't necessarily tell us what to think, it tells us what to think about." (Wahl-Jorgensen, 2020). Public attention also creates a shared feeling of importance. Vasterman noted that during the 2009 swine flu pandemic, a majority of Dutch media coverage was alarming in its nature (Vasterman & Ruigrok, 2013). Wallis examined how the 2003 SARS epidemic in the UK was framed as the "killer" virus (Wallis & Nerlich, 2005). Such coverage shapes public opinion on the overall safety and health of the population, as well as willingness to seek help for themselves or relatives for healthcare-related matters.

3.4 What constitutes health service usage

So far, we have explored demand, need and supply. Economics dictates that demand met by supply facilitates service transactions, such as a patient seeking an appointment with a doctor. However, demand and need are abstract concepts that are observable only via indirect channels such as customer interviews. Supply is more directly observable but still entails dozens of individual factors to be tracked separately. The easiest measure for observing service usage is the number of appointments or service encounters for any given period in a single geographic location. While easy to measure, this metric alone is not particularly actionable. If we observe a change in service usage, what drives it? Was unmet demand met by an increase in available supply, or did the population at large suddenly get sicker? Did increased awareness of the symptoms of some diseases make patients more likely to seek care for it? From a managerial standpoint, these all represent different approaches to managing health service utilisation.

A simplified model for the components of total service usage is presented in Figure 3.1. We argue that healthcare service usage consists broadly of three components: population morbidity, patient health-seeking behaviour and healthcare supply. Population morbidity contains the prevalence of diseases in a population, regardless of healthcare activity. For influenza and transmissible diseases, this value can fluctuate rapidly. However, for other disease groups, such as cardiovascular diseases, it may remain relatively stable in a given population. It is improbable that a given population experiences a large, simultaneous change in the rates of coronary diseases, cancers or non-communicable infections.

Health-seeking behaviour consists of the ways in which patients interact with healthcare services. It entails ease of access, perceived quality and trust towards healthcare institutions and service utilisation channels, such as preference for digital or brick-and-mortar appointments. This behaviour is not strictly egoistical, as individuals might, for example, limit their healthcare consumption willingly to spare resources for other at-risk populations near peak capacity. Early reports from England, for example, reported that 20% of patients felt uncomfortable visiting their GP and 47% felt uncomfortable visiting their hospital (Ipsos MORI, 2020).

Finally, service provider activity denotes the available healthcare resources, diagnostic ability, medicine and supplies. During crises, supply chains are especially vulnerable to various shocks and disruptions. For example, medication or protective gear supply can bottleneck service availability. Providers may also choose to limit their supply to protect peak capacity or to free up capacity for tracing and testing (McConkey & Wyatt, 2023).

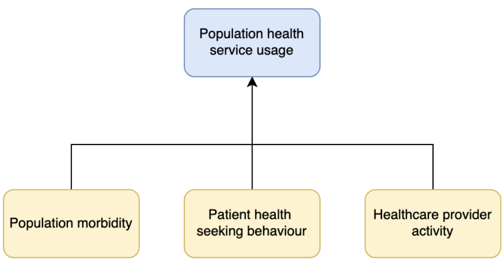

Figure 3.1. A simplified model for healthcare utilisation. Here, healthcare service usage consists of three components: population morbidity, population health service behaviour and provider activity. Similar reasoning has been suggested elsewhere as well (McConkey & Wyatt, 2023).

A single managerial action may affect several of these components simultaneously. A public awareness campaign can affect patient behaviour and morbidity at the same time: fear or aversion to attending public gatherings or places might both limit the spread of communicable diseases and lower willingness to visit hospitals. A hospital restricting access to care directly lowers total healthcare capacity, but patients might, as a consequence, forgo visits to a hospital for non-acute conditions if they consider the waiting times unreasonable. Rather than causal phenomena, one should consider these as topological mechanisms via which healthcare utilisation is realised.

These three values denote the overall consumption of health services, each providing a unique constraint. During pandemics, all three are affected and have different dynamics with respect to the overall pandemic situation. During the early pandemic, many healthcare professionals in Finland were directed to transmission tracing, there was a shortage of protective gear, and people were recommended to delay non-urgent care to preserve the peak capacity of healthcare services. Simultaneously, people were directed to be very self-conscious about their and their relatives' health. This created a multilateral shock to healthcare services and an overall reduction in healthcare service utilisation. Rather than managing the health service usage alone, understanding the factors behind the observed service usage enables managerial activity. However, several components likely need to be managed simultaneously during a pandemic. Healthcare policy and its management is a complex dynamic, where the effects of individual policies might be difficult to identify from the overall service utilisation.

4. Data and methods

> Sillä ihmettelemme vain sitä, joka meistä näyttää harvinaiselta ja erinomaiselta, eikä mikään muu voi näyttää siltä kuin se, mikä meille tähän asti on ollut tuntematonta tai mikä eroaa tavallisesta. Tämän eroamisen vuoksi sitä näet kutsutaan erinomaiseksi. Kun joku meille ennen tuntematon seikka uudestaan ilmestyy käsityspiiriimme tai aistimuksiimme, jää se ainoastaan sentähden muistiimme, että sen herättämä käsite on aivoissamme vahvistunut jonkun mielenliikutuksen vaikutuksesta tai käsityskyvyn huomaavaisuudesta, jota kykyä tahdomme taivuttaa erityiseen tarkkaavaisuuteen ja punnitsemiseen.
> – Descartes, *Metodin esitys*

The following chapter explores the ethics of the study as well as the data sources, methodology, and statistical models used to analyse the data for the individual Manuscripts.

4.1 Ethics of the study

All studies adhered to the highest standards of data privacy and protection of personally identifiable information, and the researchers had no access to personally identifiable data. All data were de-identified and aggregated to levels where individual patients could not be identified. Furthermore, Manuscripts II-III were subject to additional de-identification procedures of the Finnish Social and Health Data Permit Authority Findata, further increasing the safeguarding of privacy and confidentiality of the individuals. Informed consent was not required, as the studies were noninterventional, registry-based, and solely entailed the analysis of de-identified data sourced from pre-existing records.

4.2 Data sources

We used a novel, previously unexplored data set from Finland's largest private health service provider. The data was sourced from routine EMR data collected during normal operations, which had been pseudonymised and aggregated for analysis. The data set contained booking, appointment, diagnosis, diagnostics and utilisation data for outpatient and hospital healthcare services between 2017 and 2022. The data set was comprehensive in the sense that every service event generated both an electronic record and an associated ICD-10 code in the registry. In contrast with environments where the classification of diseases is not mandated, the data set represented a complete overview of all of the services administered within the study period.

Because the pandemic affected different geographical areas separately, Manuscripts II-III limited the data set to the capital region of Uusimaa. In contrast, Manuscript I explored the phenomena in the scope of the whole country. As the data set was sourced from a predominantly occupational healthcare provider, data was limited to the working-age population between the ages of 18 and 65.

Feature engineering on the data included imputing missing values or removing incomplete or faulty records. These were done by checking missing or `'nan'` values within the data and either removing them or replacing them with 0, depending on if the missing data represented `NULL` or zero results, respectively. The data set was not stable across time, and over the course of the pandemic, independent variables within the data set possibly changed over time. As an example, the ICD-10 codes for COVID-19, 'U07.1' and 'U07.2', replaced previous codes associated with suspected upper respiratory diseases in early 2020. Furthermore, we excluded some major non-typical or sporadic health events from the data, such as the local norovirus epidemic in Finland in 2017, which was excluded from training data for Manuscript II.

4.3 Methodology

Our exposure event was the introduction of the virus in Finland in March 2020. As outcome variables, we considered the following: for Manuscript I, these were public interest, upper respiratory system-related diseases, COVID-19 testing, antibiotics usage and urinary tract infections as a control variable; for Manuscript II, outcome variables were the observed numbers of appointments across the different diagnosis groups; and for Manuscript III, these were the numbers of bookings, available appointments and cancellations across different service production channels. For each of the outcome variables, we fitted a predictive model on weekly data from the time period between 2017 and 2020 to create an estimate of the service utilisation during the pandemic in a hypothetical situation without the effect of COVID-19. Observed outcome variables were compared to the predicted baseline activity. For categories where pre-2020 data was not available or where it was deemed to represent changes in reporting structure rather than in service usage, an estimate was not calculated, and instead, only the observed numbers were presented. Examples of these include COVID-19-related testing and temporary diagnosis codes.

Common descriptive and statistical methods were used to calculate descriptive statistics on the data. These usually contained mean and median values as well as 80th or 95th quartile measures on the values. Some data privacy considerations directed the usage of data, such as representing age as age categories instead of numeric values. For these, modes of the data were presented. Other statistical analyses for the data included descriptive or visual analysis of the individual datum. Visual analysis replaced statistical testing for time series data where the behaviour of the time series was of reported interest. This was done when comparing different time periods, grouping the data or describing the temporal trends in the data. For some of these phenomena, such as in Manuscript II, the articles presented exact measurements for different periods and their differences as supplementary material.

The articles employed predictive forecasts on the service utilisation rates given the absence of COVID-19. Our goal was to build a credible baseline that could accurately account for seasonal variations in and forecast trends in the data. Most existing research on service utilisation rates were pre-post designs, which compared service utilisation rates during COVID-19 with pre-pandemic rates, with only a few studies accounting for seasonality or growth trends in health service utilisation. The pre-post design approach has a number of shortcomings. Firstly, health service usage has been increasing over time, with an annual increase of a few percentage points. Pre-post analyses miss this organic increase in service consumption if not accounted for. Secondly, healthcare services exhibit high seasonality in line with the time of the year, holiday seasons and flu and respiratory system infection seasons. A naive approach comparing different periods may confuse seasonal changes as resulting from COVID-19. Based on these, we selected a seasonal forecast model trained on pre-COVID time series data.

We modelled the baseline health service usage using the autoregressive moving average (ARIMA) forecast on weekly time series data. ARIMA decomposes a time series into seasonal, linear and stochastic components, which can be modelled independently. As such, it creates a credible baseline for health service usage, which accounts for both the seasonality and organic growth of the service usage. The estimates were compared numerically and visually against observed weekly values, and absolute and cumulative differences between the values were recorded. Major deviations from estimates were estimated by noting where observed values were close to or outside the 95% confidence intervals (CI) of the predicted values. As predictive models lose accuracy as the predicted period is extended, a specific maximum time horizon for predictions was manually chosen for each individual study. These were June 2020, June 2022 and July 2021 for Manuscripts I through III, respectively.

The empirical articles explored service usage rates directly. These were used to build theory by drawing on contemporary works in demand-supply dynamics in healthcare and general management principles, explained in depth in this thesis. Medical, practical and managerial implications were synthesised from these analyses within the context of the research questions presented in this thesis.

Some analyses referenced general time periods during the pandemic. The three general time periods referenced in this thesis were *the early pandemic*, *the active phase of the pandemic* and *the late pandemic*. The periods are as follows: the early pandemic covers the initial onset of the pandemic in Finland and the first state of emergency between March 18th, 2020, and June 15th, 2020. The late pandemic references the time period when regulatory measures were generally lifted in Finland, which coincided with increased vaccination coverage from October 2021 onwards until the end of the observation period in June 2022. The active phase of the pandemic refers to the time period between the early and late pandemic.

4.4 Statistical methods: Autoregressive Integrated Moving Average

The Autoregressive Integrated Moving Average or ARIMA model was the method for assessing the baseline utilisation. The model consists of three components: the autoregressive `AR` component, the integrated `I` component, and the moving average `MA` component. It is a generalisation of the ARMA model, with a preceding differentiation step to ensure stationarity. Thus, the model does not rely on the assumption of non-stationary with regard to the mean. Mathematically, the model $ARIMA(p, d, q)$ is expressed by the Formula 4.1.

$$(1 - \phi_1 L - ... - \phi_p L^p)(1 - L)^d y_t = c + (1 + \theta_1 L + ... + \theta_q L^q)\epsilon_t \tag{4.1}$$

The parameters ϕ and θ are parameters of the model, y_t and ϵ_t refer to the value and error residual of the time series at time t and c is constant (Hyndman & Athanasopoulos, 2018; Petropoulos et al., 2022). Here, p refers to the order of the autoregressive component, q to the order of the first moving average component and d to the degree of the differentiation.

The *backshift* or *lag* operator L refers to the time series itself shifted back L times.

$$Ly_t = y_{t-1} \tag{4.2}$$

Higher powers denote additional operations so that two applications of the operation shift the data back two periods.

$$L(Ly_t) = L^2 y_t = y_{t-2} \tag{4.3}$$

The model can also be expressed in a sequential form without the lag operation as

$$y'_t = c + \phi_1 y'_{t-1} + ... + \phi_p y'_{t-p} + \theta_1 \epsilon_{t-1} + ... + \theta_q \epsilon_{t-q} + \epsilon_t \tag{4.4}$$

, where y'_t refers to the time series, differenced one or more times (Hyndman & Athanasopoulos, 2018). The autoregressive component $(1 - \phi_1 L - ... - \phi_p L^p)$ simply predicts the value of y_t as a linear combination of the past values of itself. The name "autoregression" refers to this principle of calculating regression against the variable itself. The moving average component $(1+\theta_1 L+...+\theta_q L^q)\epsilon_t$ estimates the error parameters as a linear combination of past regression error terms. Together, this ARMA model can capture information on time series under the assumption of stationarity. The integrated component $(1 - L)^d y_t$ refers to the process of introducing stationarity to non-stationary time series by replacing each value with the difference between itself and the previous value. This operation can be repeated multiple times, denoted by d.

If the data contains seasonalities, such as annual trends, we can further represent the model as $ARIMA(p, d, q)(P, D, Q)_m$, where P, D, Q refer to the seasonal component of the model with m number of observations per year. The components are simply multiplied by the non-seasonal terms. For example, $ARIMA(1, 1, 1)(1, 1, 1)_4$ is represented with the Formula 4.5, where the parameters $(1 - \Phi_1 L^4)$, $(1 - L^4)$ and $(1 + \Theta_1 L^4)$ are the seasonal terms (Hyndman & Khandakar, 2008).

$$(1 - \phi_1 L)(1 - \Phi_1 L^4)(1 - L)(1 - L^4)y_t = (1 + \theta_1 L)(1 + \Theta_1 L^4)\epsilon_t \tag{4.5}$$

The parameters ϕ and θ are calculated using the maximum likelihood algorithm, and the goodness-of-fit can be analysed using the Ljung-Box portmanteau test on the residuals (Box et al., 2016; Ljung & Box, 1978). In our analyses, the quality of fit was assessed at $p > 0.05$. In practice, the model parameters were estimated programmatically by using the Box-Jenkins method, the R statistical language, and the $forecast$ package (Box et al., 2016; Hyndman et al., 2023; R Core Team, 2018).

5. Findings

> Koska nykyisin tiedämme, että *tärkein tartunnanlähde useimmissa tapauksissa ovat tartunnan saaneet tai tarttuvaa tautia sairastavat ihmiset*, niin kohdistetaan toimenpiteet ennen kaikkea näihin henkilöihin ja heidän lähimpään ympäristöönsä. Päätehtäväksi muodostuu *sairastuneiden huolto, tartunnan leviämisen estäminen* ja *sairaan vastustuskyvyn vahvistaminen*. [...] Maassamme voimassa olevat asetukset, 1. p:nä heinäkuuta 1927 vahvistettu Terveydenhoitolaki ja 2. p:nä joulukuuta 1927 annettu Terveydenhoitosääntö antavatkin viranomaisille ja muille asiaan kuuluville valtaa ja keinoja yhteiskunnan ja sen jäsenien tehokkaaseen suojeluun kulkutautien aiheuttamilta vaaroilta.
>
> – O. v. Hellens, *Tarttuvien tautien vastustamista koskeva lainsäädäntö, 1929*

This thesis consists of three Manuscripts, denoted by the Roman numerals I through III. This section briefly discusses the main findings of the studies. An overview of the main characteristics of the studies and their findings is presented in Table 5.1

Table 5.1. Characteristics of the individual sub-studies.

	Manuscript		
	I	II	III
General research focus	The dynamic of acute upper respiratory tract infections (URTIs), public interest, COVID-19, and use of antibiotics during the pandemic	Long-term effects of COVID-19 on diagnostic activity across different diagnosis classes	Long-term effects of COVID-19 on healthcare booking and cancellation patters across different service production channels
Population	833 444 patients	632 466 patients	900 572 patients
Region	Finland	Uusimaa, Finland	Uusimaa, Finland
Number of events	3 314 425 appointments	6 521 394 appointments	7.3 million bookings, 11.0 million available appointments and 405.1 thousand cancellations
Observation period	January 2020 - June 2020	January 2020 - June 2022	January 2020 - July 2021
Phenomena of interest	COVID, public interest, URTIs, usage of antibiotics	Diagnostic activity, ICD-10 classes	Service production channels: digital remote appointments, primary care physician and specialist appointments, laboratory testing, imaging and hospital services
Main outcome variables	Numbers of weekly patients for URTIs, COVID-19 and prescribed antibiotics in Finland, and Google search trend frequencies	Numbers of appointments for the different diagnosis groups	Bookings, available appointments and cancellations
Analysis type and methodology	Population-based time series	Population-based time series	Population-based time series
Descriptive statistics	sum, mean, median, mode	sum, mean, mode	sum
Statistical baseline	ARIMA, point estimate and 95% CI	ARIMA, point estimate and 95% CI	ARIMA, point estimate and 95% CI
Results	A rapid increase in COVID-related internet searched preceded a rise in URTIs and COVID-19 infections. Prescriptions for URTI-related antibiotics declined by 71% during the first 4 weeks of the pandemic	The overall quantity of diagnoses declined by one-fourth immediately following the onset of the pandemic with a slightly smaller overall reduction thereafter. After the pandemic-related restrictions were lifted, the total diagnostic activity started to recover to pre-pandemic projection levels. However, this recovery has been mainly driven by upper respiratory system-related activity.	Utilisation of physical service channels decreased by up to 50% during the first 18 months of the pandemic. At the same time, remote channels experienced a marked increase in utilisation rates. Laboratory and imaging decreased by up to 50% when compared with pre-pandemic projections. Cancellation rates were elevated only for the first weeks of the pandemic
Interpretation	At the beginning of the epidemic, many people contacted health care professionals with relatively mild symptoms, as indicated by the reduced rate of URTI-antibiotics prescriptions	The pandemic resulted in an overall reduction in outpatient healthcare utilisation which persisted for 30 months. While the overall diagnostic activity has eventually recovered to predicted levels, many classes of diagnoses display reduced levels of activity in the study population over the follow-up period.	The reduction in in-person appointments and the increase in the utilisation of digital services was likely a contributing factor in the decrease of the utilisation of diagnostic and imaging services throughout the study period. Remote services can act as a rapidly scalable buffer to facilitate access to health services.

5.1 *Article 1:* Time series analysis of the incidence of acute upper respiratory tract infections, COVID-19 and the use of antibiotics in Finland during the COVID-19 epidemic: a cohort study of 833 444 patients

The article evaluated the trajectories of upper respiratory tract infections (URTIs), COVID-19 cases, and the usage of URTI-related antibiotics during the early COVID-19 pandemic. The data set consisted of 3 314 425 healthcare visits by 833 444 individual patients across Finland. The number of expected visits from March 2020 onwards was estimated using the autoregressive integrated moving average model, which was fitted with data between 2017 and 2020. Additionally, we assessed public interest in the COVID-19 pandemic by collecting Google search trend frequencies for pandemic-related search terms.

There was a rapid increase in COVID-related internet searches in Finland in early 2020 between weeks 10 and 12. At the same time, diagnoses for acute upper respiratory tract infections increased by 106%. Prescriptions for URTI-related antibiotics declined by 71% in the early pandemic, while no relevant change took place in prescriptions of antibiotics for non-communicable infections, namely urinary tract infections.

The evidence of the study suggests that patients approached health services with relatively mild symptoms during the early pandemic. The concurrent effect of the increased number of visits and decrease in antibiotics points to a change in patient behaviour. Health service providers should prepare for relatively rapid variations in service demand for upper respiratory-related diseases during the early pandemic.

5.2 *Article 2:* The Impact of COVID-19 on private healthcare service utilisation: time series analysis in the capital region of Finland during 2020-2022

This article assessed the medium-term effects of the COVID-19 pandemic on health service utilisation. Specifically, the main outcome variables were the number of visits to healthcare personnel by their disease type. The disease types were categorised mainly by the ICD-10 main-level code. F00-F99, for example, contained mental-behavioural and neurodevelopmental disorders, and M00-M99, the diseases of the musculoskeletal system and connective tissue. The data set was comprised of 632 466 individual patients and 6 521 394 healthcare appointments in the Finnish capital region of Uusimaa.

To assess a baseline for the data, the autoregressive integrated moving average model (ARIMA) was fitted using data between 2017 and 2020. The observation period was between January 2020 and June 2022. Some diagnosis groups did not exist prior to 2020, such as COVID-19 cases themselves. These were presented as-were, without the predicted baseline.

The study examined both the trajectories of the service utilisation rates as well as the cumulative compounding difference between the predicted and observed values. This cumulative sum represented an approximation of the decrease or increase in the number of visits for the disease groups. Moreover, the study noted how the reopening of society during the winter and spring of 2021 and 2022 coincided with the increased vaccination coverage for the first and second doses of the vaccine. These preceded a notable increase in COVID-19 cases, deaths and hospitalisations during the late pandemic, as demonstrated by Figure 1 of the study.

The overall quantity of diagnoses declined by one-fourth immediately following the onset of the pandemic, with a slightly smaller overall reduction thereafter. However, there were considerable variations between the different diagnosis classes. After the pandemic restrictions were lifted following the increased population vaccination coverage, the overall diagnostic activity started to recover to pre-pandemic projections, with variations between the individual diagnosis classes. The total cumulative number of diagnoses, however, remained below the predicted levels for the remainder of the observation period.

Some notable features emerged from this data. The recovery of service usage during the spring of 2022 was driven in large part by an increase in COVID-19 and other URTI-related appointments when the pandemic swept through the then-vaccinated population. The study identified three distinct recovery patterns. One is for diseases tightly correlated with COVID-19 and increasing in usage; one is for diseases that exhibited a recovery in service usage towards the end of the study period; and the rest of the disease groups displayed reduced levels of diagnostic activity until the end of the observation period. These may cause potentially long-lasting effects if left untreated or underdiagnosed in the general population, potentially increasing pressure on the healthcare system after the pandemic.

5.3 *Article 3:* The impact of COVID-19 on healthcare booking and cancellation patterns: time series analysis of private healthcare service utilisation in Finland

This study analysed the effect of the pandemic on healthcare booking and cancellation patterns across different service production channels. Where the previous manuscripts focused on various illnesses and their time trends, the outcome variables of this study were the numbers of bookings, cancellations and healthcare appointment supply as represented by the number of available appointments. These were examined across different service production channels: physical, digital, primary care practitioner, specialist, laboratory and imaging and hospital services.

The data set included 7.3 million bookings, 11.0 million available appointments and 405.1 thousand cancellations by 900.6 thousand individual patients in the Uusimaa region of Finland. Data from the years between 2017 and 2020 was used to create a baseline for service usage without the effect of COVID-19, which was compared with the data for the observation period between January 2020 and July 2021. Autoregressive integrated moving averages (ARIMA) analysis with 95% confidence intervals were used to model the baseline prediction.

The results showcased considerable changes in service usage patterns. The utilisation of physical, in-person primary care practitioner appointments decreased by up to 50% during the first 18 months of the pandemic compared to pre-pandemic projections. Digital channels experienced a rapid, multi-fold increase in service usage by more than 350% during the early pandemic, which persisted for most of the pandemic. The numbers for laboratory and imaging service usage decreased up to 50% below the pre-pandemic projections. Specialist services and hospital services were not affected in this fashion but remained at the predicted levels for the duration of the study period. Cancellations for most services increased sharply by up to three times the pre-COVID levels during the first weeks of the pandemic but returned quickly to pre-pandemic values and were unaffected for the rest of the observation period.

A number of findings can be drawn from this study. The dynamic between the increase in digital services and the decrease in utilisation of physical service channels and diagnostics services suggests a shift in service usage patterns. Digital services can act as a rapidly scaleable buffer for healthcare supply. The shift to digital service channels can affect whole production chains, including diagnostics, to a wide extent. Patients chose to disengage from within the services actively by cancelling planned care only during the early pandemic, after which the disengagement patterns were passive. Thus, the decrease in service usage resulted from forgoing care altogether and not by cancelling planned care.

Beyond the main findings presented in the study, one key insight can be drawn from the study's main figures. Figure 1 of the study explores how bookings, available appointments, and their ratio were affected at each point during the pandemic. Notably, all physical service production channels, save for COVID-19 laboratory testing, experienced a decrease in the service utilisation ratio, or the ratio between bookings and available appointments, immediately after the onset of the pandemic. As both the number of bookings and the number of available appointments decreased during the early pandemic, this suggests that the number of bookings decreased more rapidly than the observed change in supply.

6. Discussion

> On aivan heti selvää, että tiedonkeruuta on ehdottomasti automatisoitava niin paljon kuin mahdollista. Tarvitaan sähköinen valtakunnallinen seurantajärjestelmä, joka arvioi terveydenhuollon järjestelmän kuormitusta. On kerättävä tietoja koronavirukseen sairastuneista potilaista, muista potilaista, käytettävissä olevista hoitopaikoista ja tehohoidon paikoista.
> – Mäkijärvi, *Koronapeli*

6.1 Findings in the context of the research questions

Chapter 1 introduced six research questions related to the research problem. This chapter explores these within the context of the Manuscripts I - III. Major discoveries are synthesised into *Research Findings (RF)*, which we will number within the scope of our research questions. These are presented in Table 6.1.

The chapter is organised as follows. Each of the research questions is explored in order, and respective findings are presented based on the Manuscripts. The findings are numbered relative to the research question they refer to.

6.1.1 Utilisation of healthcare services

The research questions *RQ 1.1* through *RQ 1.3* were set within the topic of healthcare service utilisation. Specifically, the questions explored how the pandemic affected healthcare service utilisation during the pandemic.

RQ 1.1: *How did the utilisation of services related to communicable diseases change during the early pandemic?*

We formulate two research findings:

Finding 1.1a: *The utilisation of URTI-related services increased markedly during the first weeks of the pandemic but decreased thereafter during the active phase of the pandemic. During the data collection period, seasonal fluctuations associated with influenza seasons could not be observed.*

Finding 1.1b: *The increased vaccination rates in the late pandemic preceded a notable increase in COVID-19-related service utilisation. Service utilisation during early 2022 consisted in large part of URTI-related diseases.*

Two major conditions were directly associated with the pandemic: the suspected or confirmed COVID-19 cases specifically and upper respiratory system related diseases in general. Especially during the early pandemic, based on clinical symptoms, URTIs were virtually indistinguishable from COVID-19. The utilisation of these services followed a specific pattern. The services exhibited a notable increase in traffic during the early days of the pandemic, after which utilisation was reduced to below-expected seasonal rates. In Manuscript I, we deduced that this increase-decrease cycle of interest coincided with a reduction in URTI-related antibiotics, generally prescribed for post-infection diseases. This dynamic suggests that the patient mix changed during the early to mid-pandemic, during which patients approached service providers with relatively mild COVID-like symptoms.

The subsequent reduction in utilisation persisted for most of the pandemic. Changes in utilisation rates of URTIs likely reflect real changes in population morbidity in general due to increased hygiene measures and general awareness of the spread of infectious diseases. Seasonal influenza virtually disappeared during the pandemic, which generally provides a major source of routine healthcare traffic.

Manuscript III demonstrated that the utilisation rates of URTI-related diseases, specifically COVID-19, dominated healthcare utilisation rates towards the end of the observation period. Increased vaccination levels and fewer mobility restrictions preceded increased URTI-related diagnostic activity, which provided a major source of healthcare activity during the period. However, the data utilised in this study does not allow us to draw conclusions on the drivers of this traffic, and a number of factors not present in the data likely contributed to this effect. Service providers should be prepared to answer high fluctuations in service demand associated with respiratory system-related diseases and the virus itself during different phases of the pandemic.

Decision-makers should also plan for and actively prepare for reacting to changes in the number of patients related to communicable diseases, especially if these coincide with otherwise limited resources.

RQ 1.2: *What were the effects of the pandemic on diagnostic activity across different diagnosis classes?*

Finding 1.2: *Diagnostic activity of services decreased on average by one-fourth during the early pandemic. Only some diagnostic groups exhibited recovery of utilisation rates towards the later parts of the pandemic.*

Manuscript II studied the effects of the pandemic on different diagnosis classes. We identified three distinct patterns for utilisation rates. With *RF1.1a* and *RF1.1b*, we identified some effects associated with URTIs and COVID-19 itself. Besides these, almost all disease groups exhibited a marked reduction in utilisation rates when compared to pre-pandemic projections. Service utilisation for different diagnosis classes was reduced by one-fourth on average during the early pandemic, with a slightly smaller overall reduction towards the end of the pandemic. These changes likely cannot be attributed to changes in population morbidity alone. A reduced supply of healthcare personnel is a plausible explanation, but the change is sufficiently uniform across all disease groups that there is reasonable reason to expect changes in patient behaviour as well.

Another interesting finding was that the time trends in service utilisation varied for different diagnostic groups. Towards the latter half of the pandemic, we identified some disease groups that saw a recovery in diagnostic activity, while others exhibited permanently reduced utilisation patterns. We categorised any diagnosis class which recovered to within 10% of pre-pandemic utilisation prediction into a separate subgroup, which we named *"partial recovery"*.

Reduced care utilisation alone does not directly translate to health risks in the population. While the severity of the diagnoses could not be observed in the studies, it is reasonable to assume that these reductions in service utilisation likely affect non-acute care the most. Forgoing regular checkups for generally healthy individuals or mild injuries probably does not introduce major long-term risks into the population, and minor conditions can be recovered from without medical intervention. However, the decrease in utilisation of some diagnosis groups, such as mental health, cancer and circulatory system-related diseases, may represent latent conditions if left undiagnosed and untreated over longer periods. Questionnaires conducted during the pandemic pointed to a greatly reduced willingness to seek hospital care even if necessary (Ipsos MORI, 2020; McConkey & Wyatt, 2023). If untreated, such conditions may pose long-term risks to the population long after the pandemic. The scale and severity of this discrepancy should be closely monitored, both for managing the long-term effects of COVID-19 and for any future pandemics.

RQ 1.3: *What were the effects of the pandemic on service utilisation across different service production channels?*

Finding 1.3a: *The shift from physical to digital service production channels coincided with decreases in the utilisation of laboratory and diagnostic services.*

Finding 1.3b: *The pandemic may have affected patient overall care paths, including imaging and laboratory service usage.*

Finding 1.3c: *Digital services can act as a rapidly scalable buffer to regulate access to healthcare services during shocks.*

Manuscript III analysed different healthcare service production channels. Our focus was not limited to service utilisation alone but to customer engagement patterns in general. Service utilisation is created when supply meets demand and patient needs and wants are converted to care provided via appropriate healthcare resources. Therefore, we also included appointment availability, booking and cancellation data in our study.

Both physical primary care physician visits, as well as laboratory and imaging diagnostics, displayed marked reductions in utilisation rates during the pandemic. At the same time, digital services experienced a notable increase in utilisation. Concurrently, as some healthcare consumption shifted from physical to digital channels, traditional diagnostics exhibited markedly reduced utilisation. These suggest that the pandemic affects patient pathway trajectories beyond the decrease in service utilisation alone.

Manuscript III elucidated several points pertaining to service utilisation patterns. One possible proxy for service utilisation elasticity is the service utilisation ratio, i.e. how much of the available supply is converted to bookings. Some supply is almost always wasted due to no-shows, cancellations or mismatches in service planning, but for a generally in-demand service such as healthcare, these ratios are relatively high and stable. We demonstrated that this ratio declined markedly during the initial weeks of the pandemic but returned to the predicted equilibrium relatively quickly. This effect was consistent for both physical general practitioner and specialist appointments as well as hospital services, but diagnostic services displayed a permanently reduced utilisation ratio that was below the pre-pandemic projections. Digital channels were remarkably resistant to fluctuations in demand, with the utilisation ratio remaining stable throughout the study period.

6.1.2 Patient behaviour, supply and demand of healthcare

The research questions *RQ 2.1* through *RQ 2.3* focused on the supply and demand of healthcare services during the pandemic. Specifically, we were interested in the drivers that steered the dynamics of overall healthcare utilisation. Were the changes dominated by supply, demand or access to care?

RQ 2.1: *How did the way patients interact with health services change throughout the pandemic?*

Finding 2.1a: *Patients approached service providers for upper respiratory system-related conditions with milder symptoms than before. This coincided with an increase in popular interest in the topic in general.*

Finding 2.1b: *The largest changes in service utilisation occurred during the first weeks of the pandemic. For COVID-19-related service usage, another notable increase was observed late in the observation period. Service utilisation was relatively stable between these periods.*

Finding 2.1c: *Patients chose to disengage from healthcare services passively by booking fewer appointments rather than actively cancelling planned and booked appointments during the pandemic.*

As has already been established, healthcare utilisation was reduced across most non-communicable disease groups. Manuscript I made two observations: first, the increase in URTI-related cases coincided with public interest in the topic, as measured by Google search activity, and second, people seemed to approach URTI-related topics with milder symptoms than before.

For Manuscripts II and III, we made some observations on how national states of emergencies coincided with changes in service utilisation. The first state of emergency coincided with most changes in the patterns we noted: an increase in URTI-related appointments, marked reductions in other diagnostic activity, and rapid changes in booking and cancellation patterns. Similar changes were not present or were much smaller during the second state of emergency. These states of emergency were unprecedented shifts in legislative power in post-world-war Finland and presented a proxy for the collective sense of urgency on the need to resolve the pandemic crisis. The largest changes were observed during the first state of emergency, after which services adapted to a new equilibrium. Another large shift was observed for COVID-19 and acute infection related diagnoses after the mass vaccinations of populations, after which healthcare utilisation patterns again changed.

Finally, cancellations were a contributing factor to the reduction in service utilisation only during the first weeks of the pandemic. Contrary to some observations, our study suggests that patients opt to disengage from healthcare services passively by booking fewer appointments rather than actively by cancelling planned and booked appointments.

Attention should be focused on ensuring the overall accessibility of services. Once committed to, planned care is not more likely to be cancelled than before the onset of the pandemic. However, for the early pandemic, service providers should be prepared to face a notable increase in cancellations.

RQ 2.2: *How were healthcare supply, demand and access to care affected during the pandemic?*

Finding 2.2: *A decrease in population morbidity for some diagnosis classes, such as influenza and injuries, could provide healthcare providers with excess capacity during the crisis.*

Manuscript III demonstrated that healthcare supply, denoted by the number of available appointments or diagnostic sessions, adapted relatively quickly to changes in healthcare demand. Additionally, not all value-adding activities of the healthcare personnel were present in the data. For example, healthcare personnel conducted pandemic tracing services for exposed patients. This likely further added to a somewhat higher degree of flexibility for supply management related to the medical personnel.

One of the findings of Manuscript II was that seasonal influenza was virtually absent during the pandemic phase. These constituted an estimated 70 000 appointments less for seasonal influenza treatment than before the pandemic in the study population. Some other diagnostic groups also experienced reductions in population morbidity, such as injuries. If good hygiene practices were to be followed after the pandemic, this might have a permanent positive effect on the healthcare system, freeing up supplies to be deployed elsewhere. This reduction in seasonal influenza was also observed by Arvonen *et al.* during the early pandemic in occupational health care (Arvonen et al., 2021). During a prolonged pandemic, the reduction in service utilisation of seasonal influenza represents a latent healthcare supply that can be deployed elsewhere in the healthcare system.

One notable feature across all of the studies is the rapid speed at which change occurred, especially during the early pandemic. Digital services experienced an increase in utilisation of over 400%, and many diagnosis classes displayed reductions in diagnostic activity by half. Healthcare providers must be prepared for rapid reallocations of available resources during pandemics.

RQ 2.3: *How did the service usage react to changes in supply or demand?*

Finding 2.3: *The decrease in service utilisation was initially driven by a decrease in demand, to which supply reacted.*

In Manuscript III, we observed that the utilisation ratio decreased markedly during the early pandemic before returning to equilibrium after a period of time. Here, we expand on the results presented in Manuscript III to answer the research question. We can formulate the utilisation ratio, U, here as

$$U = \frac{B}{S} \tag{6.1}$$

, where B represents the *number of bookings* and S the *available supply* in the healthcare system. Both of these values decreased during the pandemic. The observed whiplash effect of the initial decrease and subsequent normalisation of the utilisation ratio, therefore, suggests that the number of bookings decreased more rapidly than the number of available appointments during the initial phase of the pandemic. This demand was subsequently matched by a downsizing of supply, resulting in renewed equilibria. From there, both the number of bookings and the available supply remained towards the lower tail of the confidence interval for the remainder of the observation period. This suggests that the initial drop in utilisation ratio was primarily driven by the decrease in demand to which the supply reacted, rather than the opposite, which would be identifiable with an inverted service utilisation ratio graph to the one observed.

Table 6.1. The main findings associated with each of the research questions based on the empirical articles.

Manuscript	*Related RQ*	*Finding*	*Main insight*
I, II	1.1.	1.1a.	The utilisation of URTI-related services increased markedly during the first weeks of the pandemic but decreased thereafter during the active phase of the pandemic. During the data collection period, seasonal fluctuations associated with influenza seasons could not be observed.
II	1.1.	1.1b.	The increased vaccination rates in the late pandemic preceded a notable increase in COVID-19-related service utilisation. Service utilisation during early 2022 consisted in large part of URTI-related diseases.
II	1.2.	1.2.	Diagnostic activity of services decreased on average by one fourth during the early pandemic. Only some diagnostic groups exhibited recovery of utilisation rates towards the later parts of the pandemic.
III	1.3.	1.3a.	The shift from physical to digital service production channels coincided with decreases in the utilisation of laboratory and diagnostic services.
III	1.3.	1.3b.	The pandemic may have affected patient overall care paths, including imaging and laboratory service usage.
III	1.3.	1.3c.	Digital services can act as a rapidly scalable buffer to regulate access to healthcare services during shocks.
I	2.1.	2.1a.	Patients approached service providers for upper respiratory system-related conditions with milder symptoms than before. This coincided with an increase in popular interest in the topic in general.
II	2.1.	2.1b.	The largest changes in service utilisation occurred during the first weeks of the pandemic. For COVID-19 related service usage, another notable increase was observed late in the observation period. Service utilisation was relatively stable between these periods.
III	2.1.	2.1c.	Patients chose to disengage from healthcare services passively by booking fewer appointments rather than actively cancelling planned and booked appointments during the pandemic.
III	2.2.	2.2.	A decrease in population morbidity for some diagnosis classes, such as influenza and injuries, could provide healthcare providers with excess capacity during the crisis.
III	2.3.	2.3.	The decrease in service utilisation was initially driven by a decrease in demand, to which supply reacted.

6.2 Contribution to healthcare

Throughout the pandemic, we observed a discrepancy between the predicted and observed diagnostic activity, the cumulative effect of which amounted to 5% fewer overall appointments than predicted by the end of the observation period between the beginning of 2020 and July 2022. However, Manuscript II observed that service utilisation was reduced by one-fourth during the initial phase of the pandemic, after which the service utilisation rate slowly recovered towards the pre-pandemic projection. This recovery, however, was driven in large part by the increased COVID-19-related activity during spring 2022. Most non-communicable disease groups stabilised at 10% below the predicted number of appointments or lower when compared to the observed service usage. This reduction of service usage is therefore not limited to a subset of the population or specific diseases but likely reflects real changes in service consumption patterns.

Healthcare provided arises from a medical need, which is converted to consumption when matched with adequate supply. It is unlikely that the general need for healthcare for non-communicable diseases was altered in a significant manner during the early pandemic, especially considering the nature of chronic diseases. Rather, the pandemic affected the willingness or *want* to consume healthcare as well as access to it. It is likely that the utilisation patterns of a number of conditions were left underdiagnosed in the population as a result. The possible negative effects of this require close monitoring to limit any adverse long-term effects. Such effects may surface a long time after the active phases of the pandemic and might not be easily attributable to reduced access to care during the pandemic alone.

However, not all missed care inadvertently leads to negative effects. It is probable that the more severe the condition is, the more incentivised the patient is to undergo treatment, even during a pandemic. Conversely, the majority of the forwent treatment is more likely to be non-acute or mild in nature. Some scholars have called COVID-19 a *natural experiment* in reducing overmedication and proposed measures to maintain the stricter consideration for seeking care where necessary (Moynihan et al., 2020). For example, the pharmaceutical industry has long been accused of inducing unnecessary demand or over-diagnosis for relatively harmless conditions (BMJ, 2023). In such cases, available supply could more accurately be matched to higher-value care if such demand did not fully recover after the pandemic. A similar case could be set forth with respect to disease mongering, where some diseases are popularised and overtreated in the population (Moynihan et al., 2002). The dynamic between population health and reduction in treatment during the pandemic is, therefore, likely not a linear function. While the empirical studies conducted during this thesis did not assess the severity of the missed care nor its effects on population health, we underpin the importance of such analyses at a later date. These lessons might provide us with experience in reducing unnecessary care, even if the experiment provided by COVID-19 was one brought about unwillingly.

Manuscript III demonstrated that COVID-19 has had a wider effect on entire care pathways beyond single appointments. Shift to digital channels has co-occurred simultaneously with a reduction in diagnostic laboratory and imaging service utilisation. Lillrank has likened healthcare to a process management task, where the process manager is tasked with organising the care continuity during the overarching care episode (Lillrank, 2018). This project manager can be either the person seeking care themselves, or this management can be controlled by the healthcare provider. As the access to healthcare and public want has been altered, similarly has the process by which healthcare is administered been changed. The demand for diagnostic services, at least within these empirical findings, seems to have been lessened. This might be due to a change in referral patterns or the different patient mix during the pandemic and across different healthcare consumption channels. Nonetheless, a key insight of this thesis is that pandemics may transform healthcare by modifying the care continuity process and treatment pathways at large. As diagnostic services, especially imaging, represent a relatively expensive part of the healthcare pathway, understanding the medium- and long-term effects of the pandemic on these would aid in resource allocation during and after pandemics.

6.3 Contribution to the management of healthcare

How might service providers prepare their services to minimise the initial and subsequent impact? One possible solution would, resources permitting, be to focus on maintaining normal healthcare functions with increased attention to safe access to care. This would require the allocation of resources specifically to ensure timely and necessary access to non-pandemic healthcare services and constantly measure the impact of the pandemic on said services. At least three separate groups require care during the pandemic: first, symptomatic patients who have respiratory system-related problems and require medical attention; second, symptomatic patients who have other, non-URTI-related acute conditions; and last, non-symptomatic and non-URTI conditions for whom treatment continues in much the same manner as normally. Figure 6.1 clarifies this segmentation. These patient flows could be considered distinct classes, and necessary care could be promoted within all groups individually. Naturally, careful consideration has to be employed so that this segmentation does not increase stigma or anxiety for any part of the population.

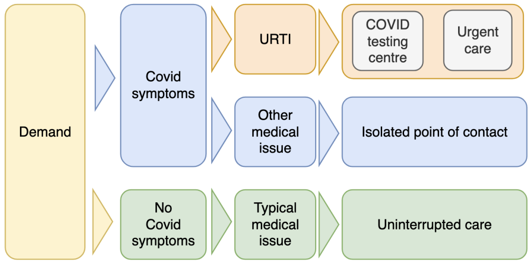

Figure 6.1. Process diagram for segmented point of access for Covid-symptomatic patients. Access to health care services for covid-symptomatic, non-covid-related patients is separated.

Ensuring necessary resources for pandemic management services likely requires some form of downsizing of non-acute care in order to protect peak capacity during any healthcare crisis. As is, it is increasingly important to direct the remaining non-acute healthcare capacity to those most in need. Individuals may need help identifying conditions that may cause long-term effects if left untreated and encouragement to seek necessary care in a manner that does not expose the individual to unnecessary risk. Mental health, cancer and cardiovascular disease patients, along with others, are among the groups which need the most support. Similar schemes have been suggested during the pandemic. In 2020, NHS first recommended separating symptomatic and non-symptomatic care with the goal of reducing non-acute care of non-COVID conditions, but this was later overturned (McConkey & Wyatt, 2023). The British Cardiovascular Society campaigned for patients to seek care where necessary, even during the pandemic (British Hearth Foundation, 2023). National information campaigns are likely effective tools to educate the public to identify and seek help for serious conditions. Simultaneously, healthcare providers should ensure that non-pandemic-related excess capability is efficiently directed to those most in need. If accurate nationwide data on this capacity were available, such resource flexibility could also be managed across different healthcare providers and actors.

Along with WHO recommendations, Finland had updated its national preparedness plan for an influenza pandemic (Sosiaali- ja Terveysministeriö, 2012). A key assumption of the plan was a relatively short pandemic, with the main phase lasting between 6 to 8 weeks (Sosiaali- ja Terveysministeriö, 2012). A prolonged pandemic likely placed significant and long-lasting stress on the healthcare system beyond what was expected. In case of a prolonged pandemic, the potential effects of missed care should be evaluated as a component of the pandemic preparedness planning, especially during interim periods of the main waves of the pandemic or as the situation allows. Some potential measures could include identifying at-risk patient groups, such as mental health and cardiovascular patients, and ensuring necessary and timely access to care for these groups with demand management, such as public information campaigns, and resource flexibility to ensure necessary capacity at points of care (Sabetkish & Rahmani, 2021).

A key insight of this study is the necessity of up-to-date data in the management of health service utilisation, especially during major shocks. As societies become increasingly better at managing pandemics and as the effects of the pandemic become more complex, the importance of such data is further highlighted. It would be desirable that nations collected a comprehensive, up-to-date and timely understanding of the status of the healthcare system, which is collected and maintained preferably by a trusted party in an automated manner. Such a party should have the mandate and resources to ensure that such data is created, centralised, and maintained as a national registry that is available to relevant national and regional healthcare actors, research communities, and the public. Information such as utilisation rates, delays to access treatment, available personnel, supplies, and emergency beds should be monitored not only during times of pandemic but also as a metric for improving everyday operations. Where such information should become available, decision-makers could utilise this information as the base on which the decisions related to the management of the pandemic are built.

So far, we have considered a market consisting of demand and supply creators and taken a *deus ex machina* intervention by the governing body as a necessary component for the functioning of this system. Over time, however, effective markets should self-regulate themselves to suit the new equilibrium. Why, then, should we actively manage the system? Keynes' famous quote, "In the long run, we are all dead", provides a key insight (Keynes, 1923). While markets here are self-regulating, they are continuously creating compounding real human health capital effects. Managerial intervention is necessary if we believe that timely interventions accelerate society's capability to return to a stable status quo, minimising social and economic risk. Human capital is far too important to be left solely to the whims of the invisible hand alone to guide.

6.4 Practical implications

Empirical evidence in this thesis suggests that the population responded well to national guidelines. The Manuscripts noted the absence of influenza, delay of acute care, and reallocation of supply to match demand. The population-level behaviour follows a path which was pre-planned for the pandemic response (Sosiaali- ja Terveysministeriö, 2012).

So far, we have presented evidence suggesting that service utilisation decreased during the pandemic. While the studies did not explore the reasons behind this phenomenon, we can hypothesise a few potential ones. Many societies, Finland included, recommended postponing non-emergency care and utilising remote services where possible. Patients may have been more wary of approaching health service providers or public spaces in general due to a perceived risk of increased probability of a possible transmission. A study in the UK reported that 47% of patients felt uncomfortable visiting a local hospital, and 20% a local GP clinic (Ipsos MORI, 2020). Access to care was reduced, and due to self-isolation due to symptoms or exposure, a considerable amount of people in the society were at any given time absent from the pool of healthcare customers, lessening demand. People might have delayed care to reserve healthcare capacity for those most in need. Public transport might be limited or unavailable, making physically accessing health services more difficult. Downsizing the non-essential services can create economic pressure on households to reduce spending, including healthcare expenditure. The interlinked societal behaviour patterns are not clearly discernible nor isolated, and likely co-affect service usage via multiple different channels (Douglas et al., 2020). These effects compound to affect the national willingness to seek or access care.

Healthcare providers were likewise affected. Shortages of medical supplies and protective equipment were very real considerations, especially early in the pandemic. Tracing and pandemic management demanded qualified personnel, which had to be sourced from existing services. Treatment of patients showing flu-like symptoms required special care and possibly designated facilities, creating pressure for points of service (Ihalainen et al., 2022). Absences of healthcare personnel due to exposure or contraction of COVID-19 were high, especially during the early pandemic (Appleby, 2021; Groenewold et al., 2020). Some healthcare personnel reported potentially traumatic experiences during the pandemic (Haravuori et al., 2020). Fluctuations in demand made shift planning more difficult.

The effects of the pandemic on the wide spectrum of health service utilisation cannot be managed through a single decision channel. There is no single lever to pull that would comprehensively control the pandemic situation. Rather, pandemic management is a multivariate optimisation problem, containing the whole spectrum of human society. Thus, the pandemic response must similarly consider the comprehensive social, economic and logistic situation. Not all variables associated with pandemic spread are controllable via management practises, and factors such as age demographic and trust in government are factors which have an effect on the pandemic spread but are indirectly rather than directly controllable by public authorities (Bollyky et al., 2022). Alongside pandemic preparedness planning, promoting common good health practises such as reduced tobacco usage, reductions in national BMI, and improved air quality may positively benefit pandemic management, even if these are not directly perceived as pandemic management tools (Bollyky et al., 2022).

A notable portion of healthcare service utilisation volume was driven by URTI-related traffic towards the later part of the observation period. The data utilised in this study does not allow analysis of the drivers behind this increase, and a number of different factors likely affected the URTI-related traffic at different points of the pandemic. Such reasons could, for example, include changes in the behavioural patterns of the population, in the dominant mutations and variants of the virus, changes in the availability of healthcare, or social and economic incentives for the population to get diagnosed. Moreover, population *needs* and subjective *wants* likely underwent changes during different phases of the pandemic. Instead of a static phenomenon that persists for the duration of the pandemic, pandemic service usage patterns should be considered dynamic in the sense that they change as pandemic phases, governmental actions, and population sentiments change. Healthcare providers should be prepared for large fluctuations in the number of patients across different phases of the pandemic. Healthcare decision-makers should also plan for and actively prepare for reacting to changes in the number of patients related to communicable diseases, especially if these coincide with otherwise limited resources. A deeper understanding of the drivers behind communicable diseases related service usage across different phases of the pandemic would allow for more effective resource planning.

Beyond the medical effects, pandemics introduce adverse socioeconomic challenges to society as well. Before the COVID-19 pandemic, Fan *et al.* estimated that the global expected cost of an upcoming pandemic, including economic effects and loss of life, to be 0.6% of global income, comparable with 0.2% to 2% for the effects of global warming (Fan et al., 2018; IPCC, 2014). Instead, global GDP decreased by 3.1% in 2020 (World Bank, 2024). Understanding and managing the pandemic response can alleviate some costs for society beyond the impact on health care alone.

6.5 Strengths and limitations

The study had access to a large, previously unexplored data set that spanned the entirety of the private outpatient health service spectrum over the pandemic. Moreover, we had access to pre-pandemic data, which enabled us to build a credible baseline estimate for service utilisation without COVID-19. Our approach takes into consideration seasonal variations in demand as well as organic expansion of health services, improving reliability.

We considered a wide range of diagnosis groups and service channels. Compared to a single-channel or single-condition study, we were able to observe the wider effects of the pandemic as they occurred and affected health service usage across multiple diagnosis groups and service production channels. For Manuscript I, we included internet searches as a proxy for popular interest in the pandemic. Manuscript III added booking and cancellation data, representing some degree of behavioural patterns in the data.

There are a number of limitations to our study. We only considered a single private healthcare service provider, focusing mainly on occupational health and private appointments. While the study population was large, it contributes mainly to the accuracy of the analyses rather than the generalisability across different populations if these differ from the study population. The results might not be representative of the larger population or generalisable within the public services. The COVID-19 pandemic was still ongoing during the study period, and the latest observations are limited to June 2022. Some phenomena concerning the late and post-pandemic periods might not be observable in the data. Our studies consisted of the working-age population and omitted children and the elderly. The patients utilising private and occupational healthcare services are more likely to be employed and have higher socioeconomic status than the wider population. Patients who switched service providers or received care in a multi-provider environment are absent or only partially represented in the data. Manuscripts II and III only considered a single geographical region, increasing within-group generalisability but limiting national representativeness. As such, future studies should aim to replicate the results on a nationally exhaustive data set.

The data set, which consisted mainly of working-age occupational healthcare and private healthcare customers, can be considered especially sensitive to the demand-supply changes during the pandemic. The share of patients who pay for their treatment out-of-pocket likely changed their demand patterns more as their personal wants and economic situation evolved over the pandemic. The choice of the data set thus highlights the phenomena. On the other hand, this amplification of behavioural patterns may be absent or different for other patient populations.

A strength of the study is the coverage of the records. As all healthcare visits in Finland are recorded with an accompanying ICD-10 diagnosis code, the data set is complete in the sense that it contains all available diagnoses for the study periods. However, these diagnoses may contain errors due to mistyping or confusion on the applicable diagnosis code. Especially during the early pandemic, instructions for recording respiratory infection patients were often confusing. While this study employed data on care utilisation across a wide range of diagnoses and service production channels, it was not exhaustive on the full spectrum of healthcare services. Notably, dental care and social services were not included in the scope of this study and would benefit from future research on service utilisation during the pandemic.

Like all studies with calculated estimates, the study is sensitive to the accuracy of the individual models in the studies. Predictive models are less accurate over long time periods, and may introduce uncertainty in the results especially towards the later parts of the pandemic.

Some contemporary discussion has highlighted the limitations of using purely retrospective registry-based studies to assess the effects of the pandemic on population health in general (Corrao et al., 2022). Indeed, our study was retrospective and limited to observing utilisation rates. Causality is generally difficult or impossible to ascertain retroactively for any set of phenomena. Similarly, the study focused only on service utilisation without considering the effect of said care on population health. One of our main findings was the reduction in service utilisation patterns, but the effect of this reduction on population health is yet uncertain. Health outcomes may take years to manifest and require attentive research.

6.6 Further research opportunities

There are a number of interesting research venues for future scholars. The effects of the decrease in service utilisation are not yet fully understood. Future scholars should monitor changes in population health closely to detect issues as early as possible to enable timely intervention. High-quality longitudinal studies are required to assess the severity and effect of missed care during the pandemic. Furthermore, the general socio-economic effects should be isolated from these effects and likewise studied. Together, both the potential medical issues emerging from changes in health service consumption as well as general changes in the socioeconomic status of many members of the population changed markedly during the pandemic, and both have the potential to introduce yet unforeseen long-term health challenges to society. A better understanding of these effects would enable more impactful healthcare management during crises.

Our studies did not explore the reasons behind the changes in service consumption patterns. We hypothesised a number of plausible reasons for the decreased health service utilisation, but these reasons should be verified in subsequent studies. Observed changes in service utilisation result from changes in the dynamic of supply and demand, which are subsequently affected by a number of latent factors. Isolating these would benefit managers by further defining how managerial actions affect supply, demand and overall service utilisation. Pandemic is only one of the possible external factors in a healthcare system crisis. An analysis of these factors of health service usage could therefore contribute to understanding the effects of other shocks such as natural crises or economic depression on the healthcare system. Additionally, a more qualitative approach to exploring the phenomena would complement the quantitative analysis. The *what* and *why* of managerial actions conducted during the pandemic would benefit a more comprehensive picture of the overall management of the pandemic. Our analysis of health service production would likewise benefit from a more nuanced analysis at different phases of the pandemic. While our studies focused on supply via the number of available bookings and booking rates, future scholars could further explore how healthcare supply specifically was affected during the different phases of the pandemic.

Our studies demonstrated that health service utilisation decreased numerically across a number of diagnosis groups. Future research should be focused on studying if the nature of care provided changed and if service consumption patterns or care paths were fundamentally altered during the pandemic. This could represent a qualitative change in care in addition to a quantitative change in utilisation. For example, we concluded, based on indirect evidence, that over the course of the pandemic, upper respiratory tract infection-related patients sought care with milder symptoms than before, suggesting a systematic change in health service consumption patterns. Similarly, the decreased health service utilisation activity could be due to patients changing service consumption patterns towards more acute conditions. The simultaneous rise of self-diagnosis via at-home testing and increased low-level healthcare service channels, such as digital service channels, create further research venues on the qualitative changes in health service consumption during and after the pandemic the pandemic.

As has been established, this study should be replicated with data from multiple providers spanning the whole spectrum of service providers in Finland. This study considered only private care service utilisation patterns. Future studies should expand these analyses to contain both private and public care service channels, as well as consider all-source health service utilisation. National and international perspectives on the topic would provide future decision-makers with a more comprehensive understanding of how care utilisation patterns react to pandemic shocks.

Lastly, this study would benefit from replication in other geographical settings. Studies in other geographic areas could elucidate the culture-specificity of the findings and improve their generalisability to a wider global audience for future pandemic management.

7. Conclusions

> But for me, there is neither Monday nor Sunday: there are days which pass in disorder, and then, sudden lightning like this one. Nothing has changed, and yet everything is different.
> –Jean-Paul Sartre, *Nausea*

This dissertation has explored the effects of the COVID-19 pandemic on healthcare service demand, usage and supply and how these evolved during the pandemic. We demonstrated that service utilisation for private outpatient services decreased notably during the pandemic, possibly introducing long-term stress on the healthcare system if not accounted for. We observed that this change was uniform across most diagnosis classes and service production channels. We also identified that pandemics may affect the entirety of the patient journey. We underpin the importance of up-to-date data in the management of healthcare during shocks. Ensuring timely access to healthcare services for at-risk patient groups should be considered a component of comprehensive pandemic preparedness planning during a prolonged pandemic and as the pandemic situation allows.

Pandemics are systemic shocks with medical and socio-economic dimensions. Managing both simultaneously is increasingly important in the future. Perhaps the key issue is that pandemic management is a systemic issue in which the treatment is managed on the populational level. To ensure a sufficient level of quality care beyond the infections, even during pandemic crises, we need to better understand the dynamics of pandemics and be better prepared to combat the reduction in service usage while treating the pandemic.

Lim *et al.* (2004) remarked in their observations on how SARS affected the unprepared Ontario area: "Given the post-SARS introspection and planning that is now occurring, the public will expect that future outbreaks be well managed with as little disruption to the health-care system as possible. There will be no tolerance for repeating the same mistakes. It is only by learning from the past that we can successfully achieve this for the future (Lim et al., 2004)." These lessons are as relevant now as they were 20 years ago.

References

Abedi, V., Olulana, O., Avula, V., Chaudhary, D., Khan, A., Shahjouei, S., Li, J., & Zand, R. (2021). Racial, Economic, and Health Inequality and COVID-19 Infection in the United States. *Journal of Racial and Ethnic Health Disparities*, *8*(3), 732–742. https://doi.org/10.1007/s40615-020-00833-4

Alexander, G. C., Tajanlangit, M., Heyward, J., Mansour, O., Qato, D. M., & Stafford, R. S. (2020). Use and Content of Primary Care Office-Based vs Telemedicine Care Visits During the COVID-19 Pandemic in the US. *JAMA Network Open*, *3*(10). https://doi.org/10.1001/jamanetworkopen.2020.21476

Appleby, J. (2021). NHS sickness absence during the covid-19 pandemic. *BMJ*, *372*, n471. https://doi.org/10.1136/bmj.n471

Arsenault, C., Gage, A. D., Kim, M. K., Kapoor, N. R., Akweongo, P., Amponsah, F., Aryal, A., Asai, D., Awoonor-Williams, J. K., Ayele, W., Bedregal, P., Doubova, S. V., Dulal, M., Gadeka, D. D., Gordon-Strachan, G., Mariam, D. H., Hensman, D., Joseph, J. P., Kaewkamjonchai, P., . . . Kruk, M. E. (2022). COVID-19 and resilience of healthcare systems in ten countries. *Nature Medicine*. https://doi.org/10.1038/s41591-022-01750-1

Arvonen, M., Raittinen, P., Niemenoja, O., Ilmonen, P., Riihijärvi, S., Särkkä, S., & Viitasaari, L. (2021). Nationwide infection control strategy lowered seasonal respiratory infection rate: Occupational health care perspective during the COVID-19 epidemic in Finland. *Infectious Diseases*, *53*(11), 839–846. https://doi.org/10.1080/23744235.2021.1944661

Banerjee, A., Chen, S., Pasea, L., Lai, A. G., Katsoulis, M., Denaxas, S., Nafilyan, V., Williams, B., Wong, W. K., Bakhai, A., Khunti, K., Pillay, D., Noursadeghi, M., Wu, H., Pareek, N., Bromage, D., McDonagh, T. A., Byrne, J., Teo, J. T. H., . . . Hemingway, H. (2021). Excess deaths in people with cardiovascular diseases during the COVID-19 pandemic. *European Journal of Preventive Cardiology*, *28*(14), 1599–1609. https://doi.org/10.1093/eurjpc/zwaa155

Bauer-Staeb, C., Davis, A., Smith, T., Wilsher, W., Betts, D., Eldridge, C., Griffith, E., Faraway, J., & Button, K. S. (2021). The early impact of COVID-19 on primary care psychological therapy services: A descriptive time series of electronic healthcare records. *eClinicalMedicine*, *37*. https://doi.org/10.1016/j.eclinm.2021.100939

Beveridge, W. I. B. (1991). The chronicle of influenza epidemics. *History and philosophy of the life sciences*, *13*(2), 223–234.

Blomster, P., & Simpura, J. (2001). Lama, elinolot ja sosiaali- ja terveyspalvelujen kysyntä. *Yhteiskuntapolitiikka*, (66), 329–343. https://urn.fi/URN:NBN:fi-fe201209116716

BMJ. (2023). Too much medicine | The BMJ. Retrieved January 1, 2024, from https://www.bmj.com/too-much-medicine

Bollyky, T. J., Hulland, E. N., Barber, R. M., Collins, J. K., Kiernan, S., Moses, M., Pigott, D. M., Jr, R. C. R., Sorensen, R. J. D., Abbafati, C., Adolph, C., Allorant, A., Amlag, J. O., Aravkin, A. Y., Bang-Jensen, B., Carter, A., Castellano, R., Castro, E., Chakrabarti, S., . . . Dieleman, J. L. (2022). Pandemic preparedness and COVID-19: An exploratory analysis of infection and fatality rates, and contextual factors associated with preparedness in 177 countries, from Jan 1, 2020, to Sept 30, 2021. *The Lancet*, *399*(10334), 1489–1512. https://doi.org/10.1016/S0140-6736(22)00172-6

Box, G. E. P., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2016). *Time series analysis: Forecasting and control* (Fifth edition). John Wiley & Sons, Inc.

Bradshaw, J. (1972). Taxonomy of social need. *Problems and progress in medical care : essays on current research, 7th series*, 71–82.

Brauner, J. M., Mindermann, S., Sharma, M., Johnston, D., Salvatier, J., Gavenčiak, T., Stephenson, A. B., Leech, G., Altman, G., Mikulik, V., Norman, A. J., Monrad, J. T., Besiroglu, T., Ge, H., Hartwick, M. A., Teh, Y. W., Chindelevitch, L., Gal, Y., & Kulveit, J. (2021). Inferring the effectiveness of government interventions against COVID-19. *Science*, *371*(6531), eabd9338. https://doi.org/10.1126/science.abd9338

British Hearth Foundation. (2023). Covid and your heart. Retrieved October 7, 2023, from https://www.bhf.org.uk/informationsupport/coronavirus-and-you

Chang, H. J., Huang, N., Lee, C.-H., Hsu, Y.-J., Hsieh, C.-J., & Chou, Y.-J. (2004). The impact of the SARS epidemic on the utilization of medical services: SARS and the fear of SARS. *American Journal of Public Health*, *94*(4), 562–564. https://doi.org/10.2105/ajph.94.4.562

Corrao, G., Cantarutti, A., Compagnoni, M. M., Franchi, M., & Rea, F. (2022). Change in healthcare during Covid-19 pandemic was assessed through observational designs. *Journal of Clinical Epidemiology*, *142*, 45. https://doi.org/10.1016/j.jclinepi.2021.10.015

Culyer, A. J., & Wagstaff, A. (1993). Equity and equality in health and health care. *Journal of health economics*, *12*(4), 431–457. https://doi.org/https://doi.org/10.1016/0167-6296(93)90004-X

de Haas, M., Faber, R., & Hamersma, M. (2020). How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: Evidence from longitudinal data in the Netherlands. *Transportation Research Interdisciplinary Perspectives*, *6*, 100150. https://doi.org/10.1016/j.trip.2020.100150

Delardas, O., Kechagias, K., Pontikos, P. N., & Giannos, P. (2022). Socio-Economic Impacts and Challenges of the Coronavirus Pandemic (COVID-19): An Updated Review. *Sustainability*, *14*(15), 9699–9699. https://doi.org/10.3390/su14159699

Descartes, R. (1899). *Filosoofinen kirjasto II: Metodin esitys. Mielenliikutuksien tutkiskelu, metafyysillisiä mietelmiä*. Suomalaisen Kirjallisuuden Seura.

Dolan, B. (2020). Unmasking History: Who Was Behind the Anti-Mask League Protests During the 1918 Influenza Epidemic in San Francisco? https://doi.org/10.34947/M7QP4M

Douglas, M., Katikireddi, S. V., Taulbut, M., McKee, M., & McCartney, G. (2020). Mitigating the wider health effects of covid-19 pandemic response. *BMJ*, m1557. https://doi.org/10.1136/bmj.m1557

Dron, L., Kalatharan, V., Gupta, A., Haggstrom, J., Zariffa, N., Morris, A. D., Arora, P., & Park, J. (2022). Data capture and sharing in the COVID-19 pandemic: A cause for concern. *The Lancet Digital Health*, *4*(10), e748–e756. https://doi.org/10.1016/S2589-7500(22)00147-9

ECDC. (2017). Influenza pandemic preparedness plans. Retrieved November 19, 2023, from https://www.ecdc.europa.eu/en/seasonal-influenza/preparedness/influenza-pandemic-preparedness-plans

Emerging Infectious Diseases. (2013). Etymologia: Quarantine. *Emerging Infectious Diseases*, *19*(2), 263–263. https://doi.org/10.3201/eid1902.ET1902

Fan, V. Y., Jamison, D. T., & Summers, L. H. (2018). Pandemic risk: How large are the expected losses? *Bulletin of the World Health Organization*, *96*(2), 129–134. https://doi.org/10.2471/BLT.17.199588

Feral-Pierssens, A.-L., Claret, P.-G., & Chouihed, T. (2020). Collateral damage of the COVID-19 outbreak: Expression of concern. *European Journal of Emergency Medicine*, 10.1097/MEJ.0000000000000717. https://doi.org/10.1097/MEJ.0000000000000717

Fernandes, N. (2020). Economic Effects of Coronavirus Outbreak (COVID-19) on the World Economy. https://doi.org/10.2139/ssrn.3557504

Fitzsimmons, J. A., & Fitzsimmons, M. J. (2004). *Service management: Operations, strategy, and information technology*. Irwin/McGraw-Hill.

Flaxman, S., Mishra, S., Gandy, A., Unwin, H. J. T., Mellan, T. A., Coupland, H., Whittaker, C., Zhu, H., Berah, T., Eaton, J. W., Monod, M., Ghani, A. C., Donnelly, C. A., Riley, S., Vollmer, M. A. C., Ferguson, N. M., Okell, L. C., & Bhatt, S. (2020). Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature*, *584*(7820), 257–261. https://doi.org/10.1038/s41586-020-2405-7

Geismar, C., Nguyen, V., Fragaszy, E., Shrotri, M., Navaratnam, A. M. D., Beale, S., Byrne, T. E., Fong, W. L. E., Yavlinsky, A., Kovar, J., Hoskins, S., Braithwaite, I., Aldridge, R. W., & Hayward, A. C. (2023). Symptom profiles of community cases infected by influenza, RSV, rhinovirus, seasonal coronavirus, and SARS-CoV-2 variants of concern. *Scientific Reports*, *13*(1), 12511. https://doi.org/10.1038/s41598-023-38869-1

Ghendon, Y. (1994). Introduction to pandemic influenza through history. *European Journal of Epidemiology*, *10*(4), 451–453. https://doi.org/10.1007/BF01719673

Giordano, P. (2020). *Tartunnan aikaan*. Aula & Co.

Groenewold, M. R., Burrer, S. L., Ahmed, F., Uzicanin, A., Free, H., & Luckhaupt, S. E. (2020). Increases in Health-Related Workplace Absenteeism Among Workers in Essential Critical Infrastructure Occupations During the COVID-19 Pandemic - United States, March-April 2020. *MMWR. Morbidity and mortality weekly report*, *69*(27), 853–858. https://doi.org/10.15585/mmwr.mm6927a1

Groff, D., Sun, A., Ssentongo, A. E., Ba, D. M., Parsons, N., Poudel, G. R., Lekoubou, A., Oh, J. S., Ericson, J. E., Ssentongo, P., & Chinchilli, V. M. (2021). Short-term and Long-term Rates of Postacute Sequelae of SARS-CoV-2 Infection: A Systematic Review. *JAMA Network Open*, *4*(10), e2128568. https://doi.org/10.1001/jamanetworkopen.2021.28568

Grossman, M. (2017). On the concept of health capital and the demand for health. In *Determinants of health: An economic perspective* (pp. 6–41). Columbia University Press.

Haelermans, C., Korthals, R., Jacobs, M., Leeuw, S. d., Vermeulen, S., Vugt, L. v., Aarts, B., Prokic-Breuer, T., Velden, R. v. d., Wetten, S. v., & Wolf, I. d. (2022). Sharp increase in inequality in education in times of the COVID-19-pandemic. *PLOS ONE*, *17*(2), e0261114. https://doi.org/10.1371/journal.pone.0261114

Haravuori, H., Junttila, K., Haapa, T., Tuisku, K., Kujala, A., Rosenström, T., Suvisaari, J., Pukkala, E., Laukkala, T., & Jylhä, P. (2020). Personnel Well-Being in the Helsinki University Hospital during the COVID-19 Pandemic—A Prospective Cohort Study. *International Journal of Environmental Research and Public Health*, *17*(21), 7905. https://doi.org/10.3390/ijerph17217905

Hartnett, K. P., Kite-Powell, A., DeVies, J., Coletta, M., Boehmer, T. K., Adjemian, J., & Gundlapalli, A. V. (2020). Impact of the COVID-19 Pandemic on Emergency Department Visits - United States, January 1, 2019-May 30, 2020. *Morbidity and Mortality Weekly Report*, *69*(23), 699–704. https://doi.org/10.15585/mmwr.mm6923e1

Hellens, O. v. (1929). Tarttuvien tautien vastustamista koskeva lainsäädäntö. In *Kotilieden lääkärikirja* (pp. 186–191). WSOY.

Holmberg, M., & Lundgren, B. (2018). Framing post-pandemic preparedness: Comparing eight European plans. *Global Public Health*, *13*(1), 99–114. https://doi.org/10.1080/17441692.2016.1149202

HUS. (2020). HUS valmis sitoutumaan mittavaan rajaliikennetestaukseen – odottaa valtioneuvostolta selkeää toimeksiantoa | HUS. Retrieved June 24, 2024, from https://www.hus.fi/ajankohtaista/hus-valmis-sitoutumaan-mittavaan-rajaliikennetestaukseen-odottaa-valtioneuvostolta

HUS. (2023). Hoidon saatavuutta koskeva selvitys. Retrieved June 27, 2024, from https://hus-julkaisu.tweb.fi/ktwebscr/fileshow?doctype=7&docid=1393502

Hyndman, R. J., & Athanasopoulos, G. (2018). *Forecasting: Principles and Practice*. OTexts.

Hyndman, R. J., Athanasopoulos, G., Bergmeir, C., Caceres, G., Chhay, L., O'Hara-Wild, M., Petropoulos, F., Razbash, S., Wang, E., & Yasmeen, F. (2023). *Forecast: Forecasting functions for time series and linear models*. https://pkg.robjhyndman.com/forecast/

Hyndman, R. J., & Khandakar, Y. (2008). Automatic Time Series Forecasting: The **forecast** Package for *R*. *Journal of Statistical Software*, *27*(3). https://doi.org/10.18637/jss.v027.i03

Ihalainen, R., Gärdström, H., Hiiri, A., Ylitalo-Katajisto, K., Arvonen, A., & Lillsunde, P. (2022). Sosiaali- ja terveydenhuollon palvelujärjestelmän varautuminen mahdolliseen seuraavaan epidemia-aaltoon : Selvitysryhmän raportti. *2022*. https://urn.fi/URN:ISBN:978-952-00-9696-0

Inglin, L., Wikström, K., Lamidi, M.-L., & Laatikainen, T. (2022). The adverse effect of the COVID-19 pandemic on health service usage among patients with type 2 diabetes in North Karelia, Finland. *BMC Health Services Research*, *22*(1), 725. https://doi.org/10.1186/s12913-022-08105-z

IPCC. (2014). Climate change 2014: Synthesis report. In *Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change* (p. 408).

Ipsos MORI. (2020). *The Health Foundation COVID-19 Survey* (tech. rep.). Retrieved September 18, 2023, from https://www.health.org.uk/sites/default/files/2020-06/Health-Foundation-2020-COVID-19-Polling-v2.pdf

Jäntti, S. (2024). *Provision of Acute Care Services During the COVID-19 Pandemic in Finland*. Tampere University. https://urn.fi/URN:ISBN:978-952-03-3327-0

Johansson, A. L. V., Larønningen, S., Skovlund, C. W., Kristiansen, M. F., Mørch, L. S., Friis, S., Johannesen, T. B., Myklebust, T. Å., Skog, A., Pettersson, D., Birgisson, H., Virtanen, A., Malila, N., Pitkäniemi, J., Tanskanen, T., Tryggvadóttir, L., Ursin, G., & Lambe, M. (2022). The impact of the COVID-19 pandemic on cancer diagnosis based on pathology notifications: A comparison across the Nordic countries during 2020. *International Journal of Cancer*, *151*(3), 381–395. https://doi.org/10.1002/ijc.34029

Johnston, R., & Clark, G. (2005). *Service operations management: Improving service delivery*. Pearson Education.

Karreinen, S., Rautiainen, P., Keskimäki, I., Satokangas, M., Viita-aho, M., & Tynkkynen, L.-K. (2023). Pandemic preparedness and response regulations in Finland: Experiences and implications for post-COVID-19 reforms. *Health Policy*, *132*, 104802. https://doi.org/10.1016/j.healthpol.2023.104802

Kela. (2023). Kelan työterveyshuoltotilasto 2021. https://helda.helsinki.fi/items/f569fe81-7b40-476d-bf92-1076cb2d99cd

Kestilä, L., Kapiainen, S., & Mesiäislehto, M. (2021). Covid-19-epidemian vaikutukset hyvinvointiin, palvelujärjestelmään ja kansantalouteen. https://urn.fi/URN:ISBN:978-952-343-865-1

Keynes, J. M. (1923). *A tract on monetary reform*. Cosimo Classics.

Kim, K., Tandi, T., Choi, J., Moon, J., & Kim, M. (2017). Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak in South Korea, 2015: Epidemiology, characteristics and public health implications. *Journal of Hospital Infection*, *95*(2), 207–213. https://doi.org/10.1016/j.jhin.2016.10.008

Konttinen, M., Eriksson, E., Karjalainen, J., Mäkelä, P., Noro, A., Rautavaara, A., Tuori, T., & Viialainen, R. (2000). Sosiaali- ja terveydenhuollon palvelukatsaus 2000. https://urn.fi/URN:NBN:fi-fe201211089655

Kotler, P. (2001). *Marketing management, millenium edition*. Prentice-Hall, Inc.

Krammer, F. (2020). SARS-CoV-2 vaccines in development. *Nature*, *586*(7830), 516–527. https://doi.org/10.1038/s41586-020-2798-3

Kuitunen, I., Ponkilainen, V. T., Launonen, A. P., Reito, A., Hevonkorpi, T. P., Paloneva, J., & Mattila, V. M. (2020). The effect of national lockdown due to COVID-19 on emergency department visits. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *28*(1), 1–8. https://doi.org/10.1186/s13049-020-00810-0

Lai, A. G., Pasea, L., Banerjee, A., Hall, G., Denaxas, S., Chang, W. H., Katsoulis, M., Williams, B., Pillay, D., Noursadeghi, M., Linch, D., Hughes, D., Forster, M. D., Turnbull, C., Fitzpatrick, N. K., Boyd, K., Foster, G. R., Enver, T., Nafilyan, V., ... Hemingway, H. (2020). Estimated impact of the COVID-19 pandemic on cancer services and excess 1-year mortality in people with cancer and multimorbidity: Near real-time data on cancer care, cancer deaths and a population-based cohort study. *BMJ Open*, *10*(11), e043828. https://doi.org/10.1136/bmjopen-2020-043828

Lange, S. J., Ritchey, M. D., Goodman, A. B., Dias, T., Twentyman, E., Fuld, J., Schieve, L. A., Imperatore, G., Benoit, S. R., Kite-Powell, A., Stein, Z., Peacock, G., Dowling, N. F., Briss, P. A., Hacker, K., Gundlapalli, A. V., & Yang, Q. (2020). Potential indirect effects of the COVID-19 pandemic on use of emergency departments for acute life-threatening conditions — United States, January–May 2020. *American Journal of Transplantation*, *20*(9), 2612–2617. https://doi.org/10.1111/ajt.16239

Le secrétariat général de la défense et de la sécurité nationale. (2011). National "influenza pandemic" prevention and response plan. https://sante.gouv.fr/IMG/pdf/PlanPandemieGrippale-Version_Anglais.pdf

Lee, W.-E., Woo Park, S., Weinberger, D. M., Olson, D., Simonsen, L., Grenfell, B. T., & Viboud, C. (2023). Direct and indirect mortality impacts of the COVID-19 pandemic in the United States, March 1, 2020 to January 1, 2022. *eLife*, *12*, e77562. https://doi.org/10.7554/eLife.77562

Levin, A. T., Hanage, W. P., Owusu-Boaitey, N., Cochran, K. B., Walsh, S. P., & Meyerowitz-Katz, G. (2020). Assessing the age specificity of infection fatality rates for COVID-19: Systematic review, meta-analysis, and public policy implications. *European Journal of Epidemiology*, *35*(12), 1123–1138. https://doi.org/10.1007/s10654-020-00698-1

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K. S., Lau, E. H., Wong, J. Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., ... Feng, Z. (2020). Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia. *New England Journal of Medicine*, *382*(13), 1199–1207. https://doi.org/10.1056/NEJMoa2001316

Lillrank, P. (2018). *The logics of healthcare: The professional's guide to health systems science*. Taylor & Francis.

Lillrank, P., Groop, P. J., & Malmström, T. J. (2010). Demand and Supply–Based Operating Modes—A Framework for Analyzing Health Care Service Production. *The Milbank Quarterly*, *88*(4), 595–615. https://doi.org/10.1111/j.1468-0009.2010.00613.x

Lim, S., Closson, T., Howard, G., & Gardam, M. (2004). Collateral damage: The unforeseen effects of emergency outbreak policies. *Lancet Infectious Diseases*, *4*(11), 697–703. https://doi.org/10.1016/s1473-3099(04)01176-4

Ljung, G. M., & Box, G. E. (1978). On a measure of lack of fit in time series models. *Biometrika*, *65*(2), 297–303.

Lönnrot, E. (2009). *Kalevala*. Otava.

Ludvigson, S., Ma, S., & Ng, S. (2020). *COVID-19 and The Macroeconomic Effects of Costly Disasters* (tech. rep. w26987). National Bureau of Economic Research. Cambridge, MA. https://doi.org/10.3386/w26987

Macinko, J., Woolley, N. O., Seixas, B. V., Andrade, F. B. d., & Lima-Costa, M. F. (2020). Health care seeking due to COVID-19 related symptoms and health care cancellations among older Brazilian adults: The ELSI-COVID-19 initiative. *Cadernos de Saúde Pública*, *36*, e00181920. https://doi.org/10.1590/0102-311X00181920

Mäkijärvi, M. (2022). *Koronapeli*. Otava.

Mankiw, N. G. (2021). *Principles of economics*. Cengage Learning.

Mann, D. M., Chen, J., Chunara, R., Testa, P. A., & Nov, O. (2020). COVID-19 transforms health care through telemedicine: Evidence from the field. *Journal of the American Medical Informatics Association*, *27*(7), 1132–1135. https://doi.org/10.1093/jamia/ocaa072

Mansfield, K. E., Mathur, R., Tazare, J., Henderson, A. D., Mulick, A., Carreira, H., Anthony Matthews, Matthews, A., Bidulka, P., Gayle, A., Forbes, H., Cook, S., Wong, I. C. K., Wong, A. Y. S., Strongman, H., Wing, K., Warren-Gash, C., Cadogan, S. L., Smeeth, L., ... Langan, S. (2021). Indirect acute effects of the COVID-19 pandemic on physical and mental health in the UK: A population-based study. *The Lancet Digital Health*, *3*(4). https://doi.org/10.1016/s2589-7500(21)00017-0

Marijon, E., Karam, N., Jost, D., Perrot, D., Frattini, B., Derkenne, C., Sharifzadehgan, A., Waldmann, V., Beganton, F., Narayanan, K., Lafont, A., Bougouin, W., & Jouven, X. (2020). Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: A population-based, observational study. *The Lancet. Public Health*, *5*(8), e437–e443. https://doi.org/10.1016/S2468-2667(20)30117-1

Masroor, S. (2020). Collateral damage of COVID-19 pandemic: Delayed medical care. *Journal of Cardiac Surgery*, *35*(6), 1345–1347. https://doi.org/10.1111/jocs.14638

Mathieu, E., Ritchie, H., Ortiz-Ospina, E., Roser, M., Hasell, J., Appel, C., Giattino, C., & Rodés-Guirao, L. (2021). A global database of COVID-19 vaccinations. *Nature Human Behaviour*, *5*(7), 947–953. https://doi.org/10.1038/s41562-021-01122-8

Matveinen, P. (2023). *Terveydenhuollon menot ja rahoitus 2020 : Koronaepidemian aiheuttama terveydenhuollon menojen kasvu näkyi etenkin erikoissairaanhoidon ja perusterveydenhuollon avohoidossa*. Terveyden ja hyvinvoinnin laitos. https://urn.fi/URN:NBN:fi-fe2023050841652

McConkey, R., & Wyatt, S. (2023). Exploring the fall in A&E visits during the pandemic. Retrieved September 13, 2023, from https://www.health.org.uk/news-and-comment/charts-and-infographics/exploring-the-fall-in-a-e-visits-during-the-pandemic

McLaughlin, J. M., Khan, F., Pugh, S., Swerdlow, D. L., & Jodar, L. (2022). County-level vaccination coverage and rates of COVID-19 cases and deaths in the United States: An ecological analysis. *The Lancet Regional Health – Americas*, *9*. https://doi.org/10.1016/j.lana.2022.100191

Meyerowitz-Katz, G., & Merone, L. (2020). A systematic review and meta-analysis of published research data on COVID-19 infection fatality rates. *International Journal of Infectious Diseases*, *101*, 138–148. https://doi.org/10.1016/j.ijid.2020.09.1464

Michelen, M., Manoharan, L., Elkheir, N., Cheng, V., Dagens, A., Hastie, C., O'Hara, M., Suett, J., Dahmash, D., Bugaeva, P., Rigby, I., Munblit, D., Harriss, E., Burls, A., Foote, C., Scott, J., Carson, G., Olliaro, P., Sigfrid, L., & Stavropoulou, C. (2021). Characterising long COVID: A living systematic review. *BMJ Global Health*, *6*(9), e005427. https://doi.org/10.1136/bmjgh-2021-005427

Moynihan, R., Heath, I., & Henry, D. (2002). Selling sickness: The pharmaceutical industry and disease mongering. *BMJ : British Medical Journal*, *324*(7342), 886–891. https://doi.org/10.1136/bmj.324.7342.886

Moynihan, R., Johansson, M., Maybee, A., & Lang, E. (2020). Covid-19: An opportunity to reduce unnecessary healthcare. *BMJ*, *370*. https://doi.org/10.1136/bmj.m2752

Naseer, S., Khalid, S., Parveen, S., Abbass, K., Song, H., & Achim, M. V. (2023). COVID-19 outbreak: Impact on global economy. *Frontiers in Public Health*, *10*. Retrieved January 6, 2024, from https://www.frontiersin.org/articles/10.3389/fpubh.2022.1009393

Ndwandwe, D., & Wiysonge, C. S. (2021). COVID-19 vaccines. *Current Opinion in Immunology*, *71*, 111–116. https://doi.org/10.1016/j.coi.2021.07.003

Nguyen, H. (2011). The principal-agent problems in health care: Evidence from prescribing patterns of private providers in Vietnam. *Health Policy and Planning*, *26*, i53–i62. https://doi.org/10.1093/heapol/czr028

OECD. (2021). State of Health in the EU: Finland. Country Health Profile 2021. https://doi.org/10.1787/2e74e317-en

OECD. (2023). *Finland: Country Health Profile 2023*. Retrieved April 29, 2024, from https://doi.org/10.1787/e7af1b4d-en

Olsen, K. R., Anell, A., Häkkinen, U., Iversen, T., Ólafsdóttir, T., & Sutton, M. (2016). General practice in the Nordic countries. *Nordic Journal of Health Economics*, *4*(1), 56–67. https://doi.org/10.5617/njhe.2801

Paananen, R., Ristikari, T., Merikukka, M., & Gissler, M. (2013). Social determinants of mental health: A Finnish nationwide follow-up study on mental disorders. *Journal of Epidemiology and Community Health*, *67*(12), 1025–1031. https://doi.org/10.1136/jech-2013-202768

Palmén, O. (2021). Economic Effects of the COVID-19 Pandemic – Evidence from Panel Data in the EU. Retrieved April 29, 2024, from http://urn.fi/URN:ISBN:978-952-367-524-7

Palmgren, S., & Karvonen, E. (2023). *Terveys- ja sosiaalipalvelujen henkilöstö 2021 : Lähes kolmannes terveys- ja sosiaalipalvelujen henkilöstöstä työskentelee yrityssektorilla* (tech. rep. Tilastoraportti 67/2023, 4.12.2023. THL.). Retrieved February 28, 2024, from https://www.julkari.fi/handle/10024/147894

Parotto, M., Gyöngyösi, M., Howe, K., Myatra, S. N., Ranzani, O., Shankar-Hari, M., & Herridge, M. S. (2023). Post-acute sequelae of COVID-19: Understanding and addressing the burden of multisystem manifestations. *The Lancet Respiratory Medicine*, *11*(8), 739–754. https://doi.org/10.1016/S2213-2600(23)00239-4

Patel, S. Y., Mehrotra, A., Huskamp, H. A., Uscher-Pines, L., Ganguli, I., & Barnett, M. L. (2020). Trends in Outpatient Care Delivery and Telemedicine During the COVID-19 Pandemic in the US. *JAMA Internal Medicine*, *181*(3), 388–391. https://doi.org/10.1001/jamainternmed.2020.5928

Pearce, R. (2020). Twitter.com. Retrieved September 10, 2023, from https://twitter.com/_rospearce/status/1235603201648402432

Petropoulos, F., Apiletti, D., Assimakopoulos, V., Babai, M. Z., Barrow, D. K., Taieb, S. B., Bergmeir, C., Bessa, R. J., Bijak, J., Boylan, J. E., Browell, J., Carnevale, C., Castle, J. L., Cirillo, P., Clements, M. P., Cordeiro, C., Oliveira, F. L. C., De Baets, S., Dokumentov, A., ... Ziel, F. (2022). Forecasting: Theory and practice. *International Journal of Forecasting*, *38*(3), 705–871. https://doi.org/10.1016/j.ijforecast.2021.11.001

Potter, C. (2001). A history of influenza. *Journal of Applied Microbiology*, *91*(4), 572–579. https://doi.org/10.1046/j.1365-2672.2001.01492.x

R Core Team. (2018). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rahimi, F. S., Afaghi, S., Tarki, F. E., Goudarzi, K., & Alamdari, N. M. (2020). Viral Outbreaks of SARS-CoV1, SARS-CoV2, MERS-CoV, Influenza H1N1, and Ebola in 21st Century; A Comparative Review of the Pathogenesis and Clinical Characteristics. *School of Medicine Students' Journal*, *2*(3), 1–8. https://doi.org/10.22037/smsj.v2i3.30455

Rigby, I., Michelen, M., Cheng, V., Dagens, A., Dahmash, D., Lipworth, S., Harriss, E., Cai, E., Balan, V., Oti, A., Joseph, R., Groves, H., Hart, P., Jacob, S., Blumberg, L., Horby, P. W., & Sigfrid, L. (2022). Preparing for pandemics: A systematic review of pandemic influenza clinical management guidelines. *BMC Medicine*, *20*(1), 425. https://doi.org/10.1186/s12916-022-02616-6

Roy, C. M., Bollman, E. B., Carson, L. M., Northrop, A. J., Jackson, E. F., & Moresky, R. T. (2021). Assessing the indirect effects of COVID-19 on healthcare delivery, utilization and health outcomes: A scoping review. *The European Journal of Public Health*, ckab047. https://doi.org/10.1093/eurpub/ckab047

Sabetkish, N., & Rahmani, A. (2021). The overall impact of COVID-19 on healthcare during the pandemic: A multidisciplinary point of view. *Health Science Reports*, *4*(4), e386. https://doi.org/10.1002/hsr2.386

Santana, I. R., Mason, A., Gutacker, N., Kasteridis, P., Santos, R., & Rice, N. (2023). Need, demand, supply in health care: Working definitions, and their implications for defining access. *Health Economics, Policy and Law*, *18*(1), 1–13. https://doi.org/10.1017/S1744133121000293

Sartre, J.-P. (1964). *Nausea*. New Directions Publishing Corporation.

Schnitzler, L., Janssen, L. M. M., Evers, S. M. A. A., Jackson, L. J., Paulus, A. T. G., Roberts, T. E., & Pokhilenko, I. (2021). The broader societal impacts of COVID-19 and the growing importance of capturing these in health economic analyses. *International Journal of Technology Assessment in Health Care*, *37*(1), e43. https://doi.org/10.1017/S0266462321000155

Shah, G. H., Shankar, P., Schwind, J. S., & Sittaramane, V. (2020). The Detrimental Impact of the COVID-19 Crisis on Health Equity and Social Determinants of Health. *Journal of Public Health Management and Practice*, *26*(4), 317–319. https://doi.org/10.1097/PHH.0000000000001200

Sosiaali- ja Terveysministeriö. (2006). Kansallinen varautumissuunnitelma influenssapandemiaa varten. http://urn.fi/URN:NBN:fi-fe201504223213

Sosiaali- ja Terveysministeriö. (2012). Kansallinen varautumissuunnitelma influenssapandemiaa varten. http://urn.fi/URN:ISBN:978-952-00-3347-7

Spiteri, G., Fielding, J., Diercke, M., Campese, C., Enouf, V., Gaymard, A., Bella, A., Sognamiglio, P., Sierra Moros, M. J., Riutort, A. N., Demina, Y. V., Mahieu, R., Broas, M., Bengnér, M., Buda, S., Schilling, J., Filleul, L., Lepoutre, A., Saura, C., … Ciancio, B. C. (2020). First cases of coronavirus disease 2019 (COVID-19) in the WHO European Region, 24 January to 21 February 2020. *Eurosurveillance*, *25*(9). https://doi.org/10.2807/1560-7917.ES.2020.25.9.2000178

Stevenson, W. J. (2007). *Operations management* (9th Edition). McGraw-Hill Irwin.

Sud, A., Torr, B., Jones, M. E., Broggio, J., Scott, S., Loveday, C., Garrett, A., Gronthoud, F., Nicol, D. L., Jhanji, S., Boyce, S. A., Williams, M., Riboli, E., Muller, D. C., Kipps, E., Larkin, J., Navani, N., Swanton, C., Lyratzopoulos, G., ... Turnbull, C. (2020). Effect of delays in the 2-week-wait cancer referral pathway during the COVID-19 pandemic on cancer survival in the UK: A modelling study. *The Lancet. Oncology*, *21*(8), 1035–1044. https://doi.org/10.1016/S1470-2045(20)30392-2

Sutherland, K., Chessman, J., Zhao, J., Sara, G., Went, A., Dyson, S., & Levesque, J.-F. (2020). Impact of COVID-19 on healthcare activity in NSW, Australia. *Public Health Research & Practice*, *30*(4). https://doi.org/10.17061/phrp3042030

Sydenstricker, E. (1931). The incidence of influenza among persons of different economic status during the epidemic of 1918. *Public Health Reports (1896-1970)*, 154–170.

Taubenberger, J. K., Morens, D. M., & Fauci, A. S. (2007). The Next Influenza PandemicCan It Be Predicted? *JAMA*, *297*(18), 2025–2027. https://doi.org/10.1001/jama.297.18.2025

Taxiarchi, V. P., Senior, M., Ashcroft, D. M., Carr, M. J., Hope, H., Hotopf, M., Kontopantelis, E., McManus, S., Patalay, P., Steeg, S., Webb, R. T., Abel, K. M., & Pierce, M. (2023). Changes to healthcare utilisation and symptoms for common mental health problems over the first 21 months of the COVID-19 pandemic: Parallel analyses of electronic health records and survey data in England. *The Lancet Regional Health – Europe*, *32*. https://doi.org/10.1016/j.lanepe.2023.100697

Terveyden ja hyvinvoinnin laitos. (2020). THL on päivittänyt ohjeet COVID-19-virusinfektion kirjaamisesta potilastietoihin – varmistamattomalle koronaepäilylle oma ICD-10-koodi - THL. Retrieved December 29, 2023, from https://thl.fi/-/thl-on-paivittanyt-ohjeet-covid-19-virusinfektion-kirjaamisesta-potilastietoihin-varmistamattomalle-koronaepailylle-oma-icd-10-koodi

Terveyden ja hyvinvoinnin laitos. (2023). Jonot kiireettömään erikoissairaanhoitoon kasvoivat edelleen joulukuussa 2022 – hoitovelan purkaminen on hidasta - THL. Retrieved June 27, 2024, from https://thl.fi/-/jonot-kiireettomaan-erikoissairaanhoitoon-kasvoivat-edelleen-joulukuussa-2022-hoitovelan-purkaminen-on-hidasta

Terveyden ja hyvinvoinnin laitos. (2024). *Perusterveydenhuollon avosairaanhoidon vastaanoton asiakkaiden käyntisyyt vuonna 2021-2023 - THL* (tech. rep. Tilastoraportti 36/2024, 12.6.2024. THL). Suomen virallinen tilasto, Perusterveydenhuollon avosairaanhoidon vastaanoton asiakkaiden käyntisyyt. THL. Retrieved June 16, 2024, from https://thl.fi/tilastot-ja-data/tilastot-aiheittain/terveyspalvelut/perusterveydenhuollon-kayntisyyt

Tessema, G. A., Kinfu, Y., Dachew, B. A., Tesema, A. G., Tesema, A. G., Assefa, Y., Alene, K. A., Atsede Fantahun Aregay, Ayalew, M. B., Bezabhe, W. M., Ayele Geleto Bali, Dadi, A. F., Duko, B., Erku, D. A., Kahsu Gebrekidan, Tadesse, K., Gebremariam, K. T., Lemlem Gebremichael, Gebreyohannes, E. A., ... Tesfay, F. H. (2021). The COVID-19 pandemic and healthcare systems in Africa: A scoping review of preparedness, impact and response. *BMJ Global Health*, *6*(12). https://doi.org/10.1136/bmjgh-2021-007179

The Bible. (2016). *The Bible, English Standard Version (ESV)*. Crossway.

Tilastokeskus. (2022). Kuolleisuuden kasvun syynä ennen kaikkea koronavirustauti vuonna 2022 - Tilastokeskus. Retrieved February 28, 2024, from https://stat.fi/julkaisu/cl8mlgiehwn8z0cvzmey6j7sr

Truong Nguyen, P., Kant, R., Van den Broeck, F., Suvanto, M. T., Alburkat, H., Virtanen, J., Ahvenainen, E., Castren, R., Hong, S. L., Baele, G., Ahava, M. J., Jarva, H., Jokiranta, S. T., Kallio-Kokko, H., Kekäläinen, E., Kirjavainen, V., Kortela, E., Kurkela, S., Lappalainen, M., ... Smura, T. (2022). The phylodynamics of SARS-CoV-2 during 2020 in Finland. *Communications Medicine*, *2*(1), 1–9. https://doi.org/10.1038/s43856-022-00130-7

Tynkkynen, L.-K., Keskimäki, I., Karanikolos, M., & Litvinova, Y. (2023). Finland: Health system summary.

Valonen, K. (2020). *Koronaepidemian ensimmäinen vaihe Suomessa vuonna 2020* (Tutkintaselostus 6/2021 Onnettomuustutkintakeskus).

Varanka, J., Määttä, S., Gullichsen, I., Tapanainen-Thiess, J., Pohjola, i., Voipio-Pulkki, L.-M., Lehtimäki, L., Volk, R., Rissanen, P., Salminen, M., Railavo, J., Sovala, M., Spolander, M., Tikka, T., Nederström, H., Pirhonen, E.-R., Auranen, K., Leino, T., & Vänskä, S. (2021). COVID-19-epidemia ja sen vaikutukset Suomessa : Keskipitkän aikavälin skenaarioita. *2021*. https://urn.fi/URN:ISBN:978-952-383-634-1

Vasterman, P. L., & Ruigrok, N. (2013). Pandemic alarm in the Dutch media: Media coverage of the 2009 influenza A (H1N1) pandemic and the role of the expert sources. *European Journal of Communication*, *28*(4), 436–453. https://doi.org/10.1177/0267323113486235

Vindrola-Padros, C., Andrews, L., Dowrick, A., Djellouli, N., Fillmore, H., Gonzalez, E. B., Javadi, D., Lewis-Jackson, S., Manby, L., Mitchinson, L., Symmons, S. M., Martin, S., Regenold, N., Robinson, H., Sumray, K., Singleton, G., Syversen, A., Vanderslott, S., & Johnson, G. (2020). Perceptions and experiences of healthcare workers during the COVID-19 pandemic in the UK. *BMJ Open*, *10*(11), e040503. https://doi.org/10.1136/bmjopen-2020-040503

Wagstaff, A. (1986). The demand for health: Theory and applications. *Journal of Epidemiology & Community Health*, *40*(1), 1–11. https://doi.org/10.1136/jech.40.1.1

Wahl-Jorgensen, K. (2020). Coronavirus: How media coverage of epidemics often stokes fear and panic. Retrieved September 13, 2023, from http://theconversation.com/coronavirus-how-media-coverage-of-epidemics-often-stokes-fear-and-panic-131844

Wallis, P., & Nerlich, B. (2005). Disease metaphors in new epidemics: The UK media framing of the 2003 SARS epidemic. *Social Science & Medicine*, *60*(11), 2629–2639. https://doi.org/10.1016/j.socscimed.2004.11.031

Wang, H., Paulson, K. R., Pease, S. A., Watson, S., Comfort, H., Zheng, P., Aravkin, A. Y., Bisignano, C., Barber, R. M., Alam, T., Fuller, J. E., May, E. A., Jones, D. P., Frisch, M. E., Abbafati, C., Adolph, C., Allorant, A., Amlag, J. O., Bang-Jensen, B., ... Murray, C. J. L. (2022). Estimating excess mortality due to the COVID-19 pandemic: A systematic analysis of COVID-19-related mortality, 2020-21. *The Lancet*. https://doi.org/10.1016/s0140-6736(21)02796-3

Wang, H., Li, X., Li, T., Zhang, S., Wang, L., Wu, X., & Liu, J. (2020). The genetic sequence, origin, and diagnosis of SARS-CoV-2. *European Journal of Clinical Microbiology & Infectious Diseases*, *39*(9), 1629–1635. https://doi.org/10.1007/s10096-020-03899-4

Weinstein, M. C., Torrance, G., & McGuire, A. (2009). QALYs: The basics. *Value in Health*, *12*(Suppl1), S5–S9. https://doi.org/10.1111/j.1524-4733.2009.00515.x

Whitaker, M., Elliott, J., Bodinier, B., Barclay, W., Ward, H., Cooke, G., Donnelly, C. A., Chadeau-Hyam, M., & Elliott, P. (2022). Variant-specific symptoms of COVID-19 in a study of 1,542,510 adults in England. *Nature Communications*, *13*(1), 6856. https://doi.org/10.1038/s41467-022-34244-2

Wilhelm, J., & Helleringer, S. (2019). Utilization of non-Ebola health care services during Ebola outbreaks: A systematic review and meta-analysis. *Journal of Global Health*, *9*(1), 010406–010406. https://doi.org/10.7189/jogh.09.010406

Williams, R., Jenkins, D. A., Ashcroft, D. M., Brown, B., Campbell, S., Carr, M. J., Cheraghi-Sohi, S., Kapur, N., Thomas, O., Webb, R. T., & Peek, N. (2020). Diagnosis of physical and mental health conditions in primary care during the COVID-19 pandemic: A retrospective cohort study. *The Lancet. Public health*, *5*(10). https://doi.org/10.1016/s2468-2667(20)30201-2

World Bank. (2024). World Bank Open Data. Retrieved January 24, 2024, from https://data.worldbank.org

World Health Organization. (1946). Constitution of the World Health Organization. Retrieved January 1, 2024, from https://www.who.int/about/accountability/governance/constitution

World Health Organization. (2009). *Pandemic influenza preparedness and response: A WHO guidance document*. https://iris.who.int/handle/10665/44123

World Health Organization. (2017a). *Joint external evaluation of IHR core capacities of the Republic of Finland 2017* (tech. rep.). Retrieved June 17, 2024, from https://www.who.int/publications/i/item/WHO-WHE-CPI-2017.24-report

World Health Organization. (2017b). *Pandemic influenza risk management: A WHO guide to inform and harmonize national and international pandemic preparedness and response* (tech. rep.). World Health Organization.

World Health Organization. (2020). WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Retrieved January 1, 2024, from https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

World Health Organization. (2023a). Statement on the fifteenth meeting of the IHR (2005) Emergency Committee on the COVID-19 pandemic. Retrieved January 1, 2024, from https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic

World Health Organization. (2023b). WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data. Retrieved May 22, 2023, from https://covid19.who.int/

World Health Organization. (2023c). WHO COVID-19 Research Database. Retrieved November 6, 2023, from https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/

World Health Organization. (2023d). Coronavirus disease (COVID-19): WHO fact sheet on coronavirus disease (COVID-19), including symptoms, treatment, prevention and WHO's response. Retrieved December 29, 2023, from https://www.who.int/news-room/fact-sheets/detail/coronavirus-disease-(covid-19)

Wu, Z., & McGoogan, J. M. (2020). Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72314 Cases From the Chinese Center for Disease Control and Prevention. *JAMA*, *323*(13), 1239–1242. https://doi.org/10.1001/jama.2020.2648

Xiao, J., Dai, J., Hu, J., Liu, T., Gong, D., Li, X., Kang, M., Zhou, Y., Li, Y., Quan, Y., He, G., Zhong, R., Zhu, Z., Huang, Q., Zhang, Y., Huang, J., Du, Q., Li, Y., Song, T., . . . Ma, W. (2021). Co-benefits of nonpharmaceutical intervention against COVID-19 on infectious diseases in China: A large population-based observational study.

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Pandemics have wide-reaching effects on health service utilisation and diagnostic activity beyond the virus itself. This thesis analyses how the Finnish private healthcare service utilisation, diagnostic activity, and booking patterns were affected between January 2020 and June 2022 during the COVID-19 pandemic. Notably, health service usage and diagnostic activity declined markedly during the COVID-19 pandemic across most diagnosis classes and across several service production channels, persisting for a long period after the onset of the pandemic. These changes may introduce pressure on the healthcare system in the future. The thesis also underlines the importance of up-to-date data for healthcare providers and policymakers in the management of health service utilisation.

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