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Doctoral thesis

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Norwegian University of Science and Technology
Thesis for the Degree of
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Department of Sociology and Political Science

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Forord

Analysane og konklusjonane i denne avhandlinga står eg til ansvar for åleine, men arbeidet hadde ikkje vore mogeleg å gjennomføra utan god hjelp.

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Abstract

Social inequalities in health have been severely documented in many countries, between many social categories, and for many health outcomes. The persistence of these inequalities has been paired with substantial technological development within and outside of the health care system. Though being proposed as a remedy for several of the challenges facing public health in the 21st century, including health inequalities, much research has indicated that the introduction of innovative health technologies in many cases has contributed to producing and widening these inequalities. Support for technology as an inequality generator is also found among seminal theories on social inequalities in health. The fundamental cause theory has proposed that health inequalities will grow as our ability to control disease and death increases, and that access to and use of health technologies may be a pathway between social position and health outcomes. Within the diffusion of innovations theoretical framework, technologies spread across population segments unequally, reaching resourceful social groups first, reproducing and widening stratification patterns.

In this dissertation, I seek to further understand the mechanisms producing and reproducing health inequalities by asking how innovative technologies affect social inequalities in preventable health conditions. This overarching aim is empirically investigated through four secondary research objectives. The dissertation consists of an introduction and four research papers.

First, a systematic review was performed using scoping review techniques. Our search terms and inclusion criteria were concentrated on empirical, peer-reviewed articles studying technologies with an innovative component and comparing people of different social categories. From a final sample of 33 articles, we extracted that the novel research field of technology and health inequality showed thematic and methodological variety, with results mostly supporting the expectation that innovative technologies contribute to increase health inequalities. Results also suggested future research to put more emphasis on how these processes are context-dependent; how the choice of indicators (particularly of social position) may matter for conclusions; and to further explore the pathways connecting social position, innovative technologies, and health outcomes.

The second paper is a cross-national study of social inequalities in high- and low-preventable health problems, utilizing the health module in the 2014 round of the European Social Survey. Results show overall more educational gaps among health problems classified as high-preventable, but also substantial variation across genders, countries, and health problems, leading us to argue for the importance of institutional perspectives when investigating health inequalities.

In the third paper, I look at social inequalities in use of an innovative health technology, blood pressure monitors. Using the second and third wave of the Nord-Trøndelag Health Study and Norwegian data on income and education, results showed a decrease in inequalities over the two survey waves. This was interpreted as supporting a model of hierarchical diffusion, where an innovative technology over time have reached across all social strata.

Fourth, a paper investigates how technological advances, operationalized as blood pressure lowering medication, were associated with social inequalities in health outcomes. Analyses of three waves of the Nord-Trøndelag Health Study indicated that the use of medication may have had a levelling effect on systolic and diastolic blood pressure. One suggested explanation is that blood pressure medication is an innovation late in its diffusion process, where it has reached a point of saturation for people in higher socioeconomic positions, giving greater marginal returns for people with low income and education.

The findings of the empirical papers are in large supportive of the expectations derived from the fundamental cause theory and diffusion of innovations literature: the introduction of

innovative health technologies initially is associated with social inequalities in use and access, but with the potential for later levelling. However, this dissertation questions whether the widening and narrowing of inequalities result from a one-dimensional diffusion, where technologies are continuously adopted by people of lower social positions, or whether the process is more dynamic and multifaceted, with institutional contexts and the technologies' inherent characteristics among the contributing factors.

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1. Introduction

1.1. Social inequalities in health and the diffusion of innovative technology

Through decades, societal, medical, and technological development have been paired with the presence and persistence of social inequalities in health. Innovative health technologies, located within administrative bodies, health services, or targeted at individual use, have been proposed as remedies for problems such as an ageing population, the need for cost-cutting in health services, and unequal health outcomes between and within countries (Juma & Yee-Cheong, 2005; Piot, 2012; World Health Organization, 1997).

Evidence of social inequalities in health have been demonstrated at least since the mid-19th century and up to today's developed welfare states (Antonovsky, 1967), with the Black report of 1980 having a pivotal influence on the research community. Earlier debates concerning e.g. selection, causation, and risk factor proximity have by and large been replaced by a consensus among health inequality researchers that "the fundamental causes of health inequalities lie 'upstream' in the social, economic, and political environments in which we live and work" (Smith, Bambra, & Hill, 2016, p. 12). Social inequalities in health have proved to be consistent across all welfare state regimes and through numerous health indicators, such as mortality, morbidity, health behavior, and health care utilization (cf. Doorslaer, Koolman, & Jones, 2004; Mackenbach, 2019; Mackenbach et al., 2018). With evidence of these associations accumulating, several scholars have argued that it is the mechanisms and structures producing health inequalities that should be investigated (cf. Dunn, 2012; Elo, 2009).

Development in science and technology may be an inequality-generating mechanism. This idea is not novel; a health gradient between the aristocracy and the common people only occurred after the Enlightenment, and the discovery of the germ theory of disease was followed by gap in infant mortality between children of physicians and non-physicians (Cutler, Deaton, & Lleras-Muney, 2006). The social gradient has been steeper for causes of death where there have been substantial gains due to technological development, such as cardiovascular mortality, than for causes of death with less progress, such as cancer (Deaton, 2002). All in all, health inequalities have appeared to increase in tandem with our ability to prevent and cure disease (Link & Phelan, 2002). These tendencies have led to an interest in how unequal access and use of new technological remedies or medical knowledge may contribute to or produce social inequalities in health (Link, Northridge, Phelan, & Ganz, 1998). This dissertation is placed within that tradition, asking how innovative technologies affect preventable health conditions. Two theoretical approaches to health inequalities, the theories of fundamental causes and diffusion of innovations, serve as the main framework for the research questions, which is answered through a scoping literature review and quantitative analyses of cross-European and Norwegian survey data.

1.2. Research questions

How do innovative technologies affect social inequalities in preventable health conditions? That is the overarching aim of this dissertation, which is answered through four secondary objectives.

The intersection of health inequalities and innovative technologies is a novel and diverse research field, with contributions from different disciplines including sociology, economics, public health, and communication studies. A first objective is to provide a fundament for further research through a systematic literature review: an overview of the field, identifying central theoretical and empirical challenges, knowledge gaps, and future venues. Research question I – *What is the status of the literature on the field of health inequalities and innovative technologies?* – is related to how health inequalities and innovative technologies are empirically and methodologically investigated, and how they are theoretically framed.

After a knowledge base has been built, the following step is to empirically investigate whether social inequalities are present among health conditions susceptible to technological development, and how they compare to health problems where technology has lesser impact on prevention. Research question II – *How does the social gradient differ between health problems high- and low-preventable by behavior change, medical care, and health technologies?* – is operationalized in a cross-country study of social inequalities among self-reported health problems classified as high- and low-preventable to means such as behavior change, medical care, or health technologies.

The next research objective, after demonstrating the extent and variation of health inequalities among health problems preventable by technology, is to identify variation by social categories in the actual use of health-related technology. Much theoretical and empirical literature suggests that the diffusion of knowledge and technology follows certain hierarchical and temporal patterns, over time spreading from the higher to the lower social strata. Research question III – *What is the magnitude and temporal development of social inequalities in the use of blood pressure measurement technologies?* – focuses whether there are income and educational inequalities in the use of an innovative health technology, blood pressure monitors, and whether these associations change over time.

When social inequalities in technology use are accounted for, a relevant next step is to investigate whether technology is associated with inequalities in health outcomes. Innovative health technology is operationalized as blood pressure lowering medication, and Research question IV – *How does innovation in blood pressure medication affect social inequalities in blood pressure?* – is more closely related to the dissertation's primary objective. It aims to examine whether the use medication has an unequal effect across income and education categories over three waves (1986-2008) of the Nord-Trøndelag Health Study (HUNT).

2. Theory

In the following chapter, the dissertation's theoretical foundations are laid out. First, a section follows where I place the dissertation's theme and research within a greater sociological tradition, including general mechanisms of inequality, standard explanations of health inequalities and their relations to sociological theory, the sociological concepts of health, and differing perspectives on the functioning of the body and our ability to control disease and death. Then, a section on theories of health inequalities follows. Here, I present and discuss the most influential explanations of social inequalities in health proposed after the important Black report (Townsend & Davidson, 1982). Lastly, special attention is given the two theories extensively utilized in the dissertation's empirical work, the theories of fundamental causes and the diffusion of innovations.

2.1 Sociological contribution

Research on health inequalities draws on several scientific disciplines, such as sociology, epidemiology, political science, economics, and geography. In the following subsection, I show how the dissertation is informed by sociological concepts and theories.

2.1.1. Health inequalities and sociology

Many attempts have been made to make the study of health inequalities more 'sociological', most commonly by insisting on an upstream focus – on the structures generating the inequality patterns. The structure/agency debate is therefore relevant when examining the standard explanations of health inequalities. A distinguishing feature between the social selection and social causation explanations is their view on social structure as a causal force. The social causation explanations take the structural position when answering the question "What circumstances are individuals in particular social positions exposed to?", while social selection explanations focus more on human intentions when answering the question "What individuals are the different social positions exposed to?" (Elstad, 2000, p. 27). Though the major cleavage is between theories of social causation and social selection, the former explanations also differ in their views on human agency and structural aspects, with the materialist/structural explanation and the behavioral/lifestyles explanation usually located at opposite ends of the spectrum. The standard explanations' sociological connections will be returned to in sections 2.2.1. to 2.2.6.

2.1.2. Social stratification and inequality

Systematic differences between people of different social categories, such as gender, race, occupation, education, or income, have always been a central theme of sociological research. The term stratification, originally borrowed from geology, denotes a structure characterized by successive layers, and the study of social stratification is to examine the relations of this layering (Saunders, 2006). While class was the predominant stratification measure in health inequalities research, particularly in the UK, later research has often utilized different operationalizations of socioeconomic status (SES). Critics of this development have argued that a focus on SES risks overlooking relational and power distribution aspects of social stratification (Smith et al., 2016). Further, there have been claims that class should be treated as a sociological phenomenon located prior to class-associated or class-constitutive expressions such as income, occupation, or education (Krieger, Williams, & Moss, 1997; Scambler & Higgs, 1999, 2001). The stratification term can also be misleading, as it may model society as being permanently divided and arranged, and further having little room for individual social mobility (Saunders, 2006).

Whereas social stratification is an approach to the study of hierarchical social structures, social inequality describes an unequal distribution of resources vital to function in society, a socially constructed order affecting several parts of human lives (Therborn, 2013). Economic inequality has risen within most OECD countries over the last three decades, reaching in some cases historical heights (Thévenot, 2017). Social inequalities in health refer to health disparities between or within populations that are "neither inevitable nor unremediable" (Krieger, 2001). While previous debates within the field were concerned with the direction of causality and the role of individual agency, there is today consensus about the fundamental importance of socioeconomic structures on health (Smith et al., 2016). It is therefore pertinent to also pay attention to the mechanisms causing the unequal distribution of resources in society – to move "from the 'causes of the causes' to the 'causes of the structures'" (Øversveen & Eikemo, 2018). In much of the health inequalities literature, socioeconomic inequality has been treated as an independent 'first mover' outside the actual analysis (Øversveen, Rydland, Bambra, & Eikemo, 2017). To move beyond this, and study the causes of the socioeconomic structures, involves approaching the production and reproduction of inequality in the *institutional structure*, the cultural and normative patterns organizing enduring relationships; the *relational structure*, the interconnectedness and interdependence of individual actors; and the *embodied structure*, human actors' habits and skills making the production, reproduction, and transformation of the two former structures possible (J. Lopez & Scott, 2000).

Therborn (2013) have described three basic dimensions of human life, incorporating both biological and sociological aspects: human beings as *organisms*, *persons*, and *actors*. From this, he derived three forms of inequality characterizing most 20th and 21st societies. First, *vital* inequality, which shares resemblance with social inequalities in health, describing the "unequal life-chances of human organisms"; second, *existential* inequality denotes unequal accomplishment of autonomy, respect, and self-development; third, *resource* inequality provides "human actors with unequal resources to act", commonly through means such as income and wealth (Therborn, 2013, p. 49).

These inequalities are produced and sustained through four proposed mechanisms (Therborn, 2013, p. 54ff). *Distanciation* is the independent advance of some social groups and stagnation of others. *Skill-biased technological change* is an example of this, where "exogenous technological changes increased the demand for, and marginal productivity of, highly skilled workers, while it reduced the demand for low-skill workers" (Weeden & Grusky, 2014, p. 480). *Exploitation* is the advance of a superior group by extracting values from an inferior group, with slavery and serfdom (and in Marxist literature, the labor-wage relation) as examples. *Exclusion* is the hindering of access or advance through measures such as monopolization and land-rent, thus creating in- and out-groups. Weeden and Grusky (2014) have argued for the importance of institutional rents on inequality, e.g. barriers within the occupational or educational system hindering social mobility. Lastly, *hierarchization* is the institutional ranking of social groups. The civil service, the cultural hierarchy of high and low art, and the educational system can act as examples. With regards to the latter, OECD figures have shown that children of parents with low educational background themselves have substantially lower probabilities for succeeding in the educational system, and that these chances grow poorer as economic inequality increases (Thévenot, 2017). These general social mechanisms can affect a range of inequality outcomes, including health inequalities related to access and use of innovative technologies.

2.1.3. Technology, health, and society

Rogers (2003, p. 13) defined technology as "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome". When applying this definition to the field of health, technology can be interpreted as a socially constructed effort to control nature. In medical sociology, technological development has traditionally been explored at three levels: the macro level, examining how the diffusion of medical technology have impacted on societal institutions and relations; the meso level, studying the role of technology in networks and relations between health professionals; and the micro level, investigating the role of technology in the patient-physician relationship (Tjora, 2003). In a seminal article, Conrad (1979, p. 2) wrote of how medical technology, along with medical collaboration and medical ideology, is a type of medical social control, "the acceptance of a medical perspective as the dominant definition of certain phenomena". Similar perspectives have dominated medical sociologists' approaches to medical technology, often oriented towards the concept of medicalization, "the process by which some aspects of human life come to be considered as medical problems, whereas before they were not considered pathological" (Maturo, 2012, p. 123). Here, technology is viewed as an expression of power from the medical field (Zola, 1972).

A review by Casper and Morrison (2010) showed that much mid-twentieth century research had a 'black-box' or static view of the technologies in question, placing greater emphasis on the people, practices, and relations surrounding the technological objects. Later studies, particularly those belonging to the symbolic interactionist, feminist, and science and technology studies traditions, have focused more on the technologies themselves (Casper & Morrison, 2010). For instance, within actor network theory (ANT), technology and other non-human actors are attributed agency, themselves shaping and producing social relations. Lupton (2012, p. 17) used high blood pressure as an example, where factors such as medical professionals, patients, pharmaceutical companies, drugs, machinery used to produce the drugs, lifestyle adjustments, and blood pressure monitors all interact with each other in networks, shaping the everyday use of technology.

The political economy approach to medical sociology has traditionally been more related to the distribution of resources in society. One perspective has been to explore how health services' reliance on technology may reflect a tendency within western medicine to single out biomedical factors as proximate causes to disease and death, and to demand consumption of medical commodities in the healing process. Political economy perspectives draw on Marxism when they connect medicalization to depoliticization. Advances in health technology and expanding dominance of the medical sciences are seen as an expression of the ruling class; health problems are individualized and commodified, attention is drawn away from the socioeconomic factors causing the condition, and the social and economic system is maintained (Lupton, 2012). A proposed equitable alternative is to decommodify health care; to hold a holistic view on health focusing on low-cost prevention rather than the unlimited demands of technology in treatment; and to foremost seek improvement of the unequal social and economic conditions inherent in a capitalist production system, the 'upstream' determinants of health (McKee, 1988).

Studies of health inequalities and technology have not been uncritical to innovative technologies and their relation to health – for example by demonstrating that complex treatments are of less benefit to the lower educated (Goldman & Lakdawalla, 2005). Nevertheless, our review in Paper I demonstrated that in the health inequalities literature, particularly in quantitative analyses, technology and innovations have been studied with a focus on utilization and access, by that being operationalized as 'neutral' means to achieve good health, with less attention given to the technologies' particularities. This can be seen as possibly reflecting a pro-innovation bias. The classification of technologies in Paper I into *direct end-user*, *direct-use gatekeeper*, and *indirect-use gatekeeper* is an early attempt to take technologies' inherent qualities into consideration in health inequalities research. In addition, the classification and comparison of health conditions by their preventability in Paper II can represent the degree of impact society have on the human body.

Several perspectives on technology, health, and society are relevant when investigating of health inequalities. At the individual level, inequality in access and use may reflect how health technologies in a capitalist production system follow the laws of supply and demand, making them sensitive to individual resources. At the health services level, technology as a means of social control may contribute to maintaining social structures and the subsequent inequalities. At a general societal level, technological development may be exogenous to health inequalities, by giving increased health returns to education and income, or by being a driver of inequality itself, by increasing the demand for high-skilled workers and decreasing the demand for low-skilled workers, with growing wage gaps as a consequence (Glied & Lleras-Muney, 2008; Weeden & Grusky, 2014). Whichever perspective applied, technology is an essential component in the different ways human efforts can affect biological outcomes, and a fruitful entry to the study of social inequalities in health.

2.1.4. Concepts of health

Competing and complementary concepts of health are applied in research on social inequalities in health. A common division is between *disease*, *illness*, and *sickness*, where the former reflects a predominantly medical view of health and the two latter represent predominantly sociological perspectives (Hofmann, 2016). Historically, health has primarily been subject to a medical view, with *disease* as a dominating concept. Elstad (2000, pp. 18-19) describes how this view has developed, with a focus on observing deviations from normality, and finding diagnoses encompassing their causes and symptoms. This is in line with materialist and empiricist ideals, ontological and epistemological positions where the ultimate nature of the world is considered physical, and with experience being the best way of acquiring knowledge of it (Benton & Craib, 2011). Disease is thus a concept associated with an objective knowledge status, accessed through observation and examination by means of the technological and natural sciences, and with physiological, biochemical, genetic, and mental entities and events as the basic phenomena (Hofmann, 2016, p. 18).

A second approach emphasizes the inherent value of health as a general sense of well-being. Elstad (2000) compares this with a postmodern view of the body, being “a receiver of sensations” rather than being “evaluated by its capacity to work and fight” (Bauman, 1998, p. 226). This view, related to the concept of *illness*, highlights the subjective aspect of health, and suggests that health is a product of individual perception as well as of biological, chemical, or physical processes, thus placing it in a constructivist tradition. Hacking (2002/2003) wrote that to determine a concept as socially construction is to subsequently state its plasticity: saying that it can be constructed in some other way. Applying this perspective to health means to put heavier emphasis on the way health is constructed through human interaction. Some basic traits of *illness* are subjective experiences of bad or good health; suffering, pain, and well-being (Hofmann, 2016). A third concept of health is *sickness*; to view health as enabling social action, giving individuals capacity fulfill their social role according to society’s expectations (Susser, 1990). Derived from Talcott Parsons’ sick role, this is a functional concept of health, where health makes the attainment of other goals and values possible, i.e. enables them to function

(Benton & Craib, 2011). Among the basic phenomena are policies, conventions, and norms; these are accessed through participation and interaction; and the knowledge status is inter-subjective, i.e. shared by a social group (Hofmann, 2016)

Although often presented as contrasts, these perspectives are not mutually exclusive, and the choice of measurements and indicators of health in research often reflect one or several of these views. The empirical papers utilize several empirical measures of health, encompassing several theoretical concepts. Morbidity, measures of disease and illness, is by researchers within the biomedical traditions mostly associated with causes, symptoms, and connected diagnoses. Within the sociological tradition, morbidity can serve as an indicator of medical diagnoses, subjective experiences of health, and social function. Self-rated health measures can integrate the social construction of health in its operationalization, in addition to being correlated to measurements of health from the biomedical tradition. (see section 3.2.1). In Paper II, self-reported health problems are our study objects. Respondents were shown a list of health problems such as diabetes and high blood pressure and asked if they had experienced any of them during the last 12 months. In addition, respondents were asked if they ever had cancer, and symptoms of depression was measured through questions of respondents' mental well-being (European Social Survey, 2014a). Survey questions can be designed to intercept several concepts of health: Self-reports in general highlight respondents' individual perception of their health, while the use of standard medical diagnoses highlights the 'disease' aspect. The other health outcome in this dissertation, blood pressure levels, is a variable more related to the disease concept; it is measured with a special apparatus by trained personnel and increased or decreased blood pressure can be of physicians' concern without necessarily affecting patients' experience of well-being.

2.1.5. Amenable, preventable, and avoidable health outcomes

This dissertation focuses on health outcomes which can be prevented from occurring. These outcomes can be influenced by innovative technologies and can reflect social inequalities in means to prevent disease (Link & Phelan, 2010). However, the concepts of avoidable, amenable, and preventable health outcomes have been extensively debated, and further operationalized in different manners. The following section provides a brief outline of these debates and their consequences for empirical research. This literature has given most attention to mortality, but I will address the concepts' relations to morbidity in the last paragraphs.

In a comprehensive review of available research on amenable or preventable mortality, Nolte and McKee (2004) demonstrated ambiguity in the definition of the terms 'avoidable', 'amenable', and 'preventable' as well as defining 'medical care'. The latter is a broad term originally meant to cover the means available for preventing and avoiding disease and death, such as medical knowledge; health services; the resources of public, private, and voluntary institutions; and the individual responsibility of pursuing good health. 'Avoidable', 'amenable', and 'preventable' have often been used interchangeably. A clarification is attempted by Piers, Carson, Brown, and Ansari (2007, p. 5), stating that *avoidable mortality* includes *amenable and preventable conditions*, where "Amenable conditions are defined as those from which it is reasonable to expect death to be averted even after the condition has developed (…) Preventable conditions typically include those for which there are effective means of preventing the condition from occurring". Similar definitions are reflected in official statistics and evaluations, such as reports from the UK Office for National Statistics (2019). This classification relates to etiology; the health conditions' inherent characteristics define them as amenable, preventable, or neither. Other scholars have structured their classification by the institutions or actors able to influence. Tobias and Jackson (2001) described three types of avoidable mortality. Primary avoidable mortality are conditions amenable to individual behavior adjustments or population level interventions such as public health policies; secondary avoidable mortality are conditions amenable to detection and intervention in a primary health care setting; tertiary avoidable mortality are conditions which cannot be directly prevented, but where death can be avoided by medical or surgical treatment. Westerling (1993) made similar distinctions between health policy and medical care indicators of avoidable mortality. However, Nolte and McKee (2004) have questioned the assumption that health outcomes can be attributed to specific elements of health care. A relevant example is the continuing controversy on whether declining death rates from cerebrovascular disease could be attributed to medical improvement or to a decline in incident due to the delayed impact of other factors – e.g. nutrition in utero and early childhood (Nolte & McKee, 2004).

Empirical studies have located the institution or actor treating amenable disease at different levels of intervention – and with different proximity to health outcomes. Some studies have referred to medical care, medical intervention, medical treatment, medical management, or therapeutic care; others have used health care services, which included primary care, hospital care, community health services, and public health programs; others again used health services, health care, or health care delivery services; while yet others did not refer to 'care' or 'services' but more generally to medical 'knowledge' or 'technology' (Nolte & McKee, 2004, p. 34).

Preventing disease from occurring may include individual level efforts in addition to public and primary health care interventions, such as cutting back on alcohol and tobacco consumption. Though social inequalities in mortality exist among a vast range of health problems, certain patterns are detectable (Mackenbach, 2019). Kinge, Vallejo-Torres, and Morris (2015) showed that social inequalities in avoidable, amenable, and preventable mortality in Norway remained stable over the period between 1994 and 2011, with the largest inequalities among preventable causes of death. Similar trends have been demonstrated in most industrialized nations (Nolte & McKee, 2011).

Avoidable, amenable, and preventable mortality was initially intended to act as indicators of medical care quality (Piers et al., 2007). Nolte and McKee (2004) pointed to inconclusive evidence as a result of the ambiguity of the different terms and the variety of methods. They further argued that the prevalence and trends of avoidable, amenable and preventable mortality have limited value as an overall assessment of a country's health care system; these measures are better utilized as indicators of concern and starting points for future analyses. During the latter decades, these concepts has also been put to use in health inequalities research (a topic which is returned to and elaborated upon in section 2.3). Preventable health problems are relevant for the study of technology and health inequalities for several reasons. First, technological development within medicine and health care can act as determinants of health conditions' amenability and preventability – new technologies could both affect mortality figures as well as alter the definitions of amenable and preventable conditions. Second, when conditions are amenable or preventable by means of health care, medical knowledge, or individual behavior, they are also amenable to inequality structures. Some sort of human intervention is implicit in the concepts of amenability and preventability, and these interventions may be influenced by material or immaterial resources and their unequal distribution. This dissertation focuses on morbidity, and the concrete inclusion and exclusion criteria of the mortality categories are of less interest. Our ability to prevent and treat disease represents how social conditions have an impact on the human body and is therefore relevant for inequality in both morbidity and mortality contexts.

2.2. Standard explanations

Macintyre (1997, p. 724) wrote about late 19th and early 20th century debates on mortality differences between occupational classes in the UK; *hereditarians* on the one side believed biological determined natural abilities caused one's social outcome, while *interventionists* on the other side believed that the effect of poor material circumstances by far surpassed any biological inherited disadvantages. This distinction between health inequalities as social selection and social causation has since then been echoed in academic and public debates, with additional refinements of old explanations and emergence of new models emerging over the last decades. The following section gives an account of the mainstream explanations of social inequalities in health. I additionally aim to show the different ways technology can be a component in these explanatory models.

The seminal Black Report on health inequalities in the UK was commissioned by the British government in 1977 and published in 1980. The report described inequalities in mortality, morbidity, and use of health care services; analyzed the explanations for these inequalities; and provided recommendations for further research and policy development (Townsend & Davidson, 1982). The four-fold division of explanations proposed in the report – termed *artefact*, *natural/social selection*, *materialist/structural*, and *cultural/behavioral*, have set precedence for later discussions on the explanations on social inequalities in health, as well as spurring academic and political conflict (Macintyre, 1997). Eikemo and Øversveen (2019, p. 594) have argued that these divisions fundamentally are about causality, "specifically the causal relationship between social status, health, and the multiplicity of mechanisms and processes thought to mediate between them". Divisions within health inequalities research share features with some reoccurring sociological debates: Social selection vs. social causation relates to the nature vs. nurture debate, while individual behavior vs. social structures relates to agency vs. structure.

2.2.1. Artefact

A 'hard' version of the artefact explanation proposes that the evidence of social inequalities in health is entirely a product of the way health outcomes and social positions are measured and calculated, and that the relationship between them reflects changes in occupational structures rather than a causal link (Macintyre, 1997; Townsend & Davidson, 1982). The artefactual explanation thereby implies that that the observed social inequalities in health are not matters of observation, but of description – that researchers' methods and measurements are determining the depth and scope of health inequalities. A 'softer' version acknowledges the influence of measurement on inequality estimates but refuses the notion that all inequalities can be "explained away" by this factor (Macintyre, 1997, p. 727). Research from Eikemo, Skalická, and Avendano (2009) showed that low levels of morbidity and mortality were (moderately) associated with high levels of relative inequalities. However, this association does not prove causality. In addition, absolute and relative mortality inequalities show similar patterns between countries, indicating differences beyond the artefactual (Mackenbach, 2012).

2.2.2. Natural/social selection

The natural/social selection explanation presupposes, like the abovementioned hereditarian position, that social position is determined by health status. Macintyre (1997) have shown how the term 'natural' can have different connotations, implicating first that inequalities are based on biological determinants insusceptible to human agency and subsequently that there is something morally neutral about these inequalities. A 'hard' or 'direct' version of this explanation states that poor health causes social disadvantage or downward social mobility, while a 'soft' or 'indirect' version states how good health may lead to upward social mobility, how social selection may contribute to the observed gradients, and how there may exist a confounding function, third factors influencing both health and social position (Elstad, 2000; Macintyre, 1997; Mackenbach, 2012). Access to and use of health technology are less plausible as mediating mechanisms when the causal direction goes from health to social position. However, as mentioned above, technological development may act as an exogenous generator of inequality by decreasing the demand for low-skilled workers with potentially poor health, thus marginalizing this segment even further.

2.2.3. Materialist/structural

The materialist/structural explanation place emphasis on how physical and material circumstances associated with social position shape, or determine, people's life chances and health outcomes. Friedrich Engels' (2001/1845) *The Conditions of the Working Class in England*, an examination of the British proletariat's living and working conditions in the 18th and 19th century, can be termed a 'prototype' of this explanatory model (Elstad, 2000). In Engels' (2001/1845) classic study, he sees the poor health of workers in UK factories as structurally determined, an inevitable result of the capitalist modes of production. Causal power is placed at the societal level, or rather among the capitalist class, stating that

> society in England daily and hourly commits what the working-men's organs, with perfect correctness, characterise as social murder, that it has placed the workers under conditions in which they can neither retain health nor live long; that it undermines the

> vital force of these workers gradually, little by little, and so hurries them to the grave before their time (Engels, 2001/1845, p. 168).

The materialist/structural explanation was by and large espoused by the authors of the Black report, and it has been a dominant approach for studying health inequalities (Macintyre, 1997). Theoretical foundations can be found in the Marxist view of relations of production, Weberian concepts of class structure, or Durkheim's analysis of the division of labour in society (Elstad, 2000). This explanation, particularly in its hard version, takes the firmest structural position of the standard explanations. A central claim is that individuals are confronted with conditions which are outside of their sphere of influence and which further determine their health outcomes. The factors influencing health may be associated with both material and social circumstances; the individual is either way inevitably exposed to health determinants. Here, the concept of health is close to the biomedical view and the notion of a host being influenced by an environment (Elstad, 2000, pp. 43-45). This modelling of social science after the natural sciences resembles a naturalist approach to the research field (Benton & Craib, 2011).

As average prosperity has increased for most populations during the post-war decades, the 'hard' version of the explanation has lost some of its pertinence (Mackenbach, 2012). However, 'softer' versions include structural factors related to social position, such as psychosocial resources and social support (Macintyre, 1997). And despite high average levels of prosperity, material inequalities are still present in Western countries. In latter decades, these have also been associated with diseases of affluence; material disadvantages have been proved to be associated with behavioral factors such as exercise and healthy diet (Mackenbach, 2012; Nosrati, Jenum, Tran, Marmot, & King, 2017). Material deprivation may also affect the access to and availability of health innovations; the price of a new technology may be too high, low budgets may constrain governments from implementing public health innovations, and lacking infrastructure may hinder effective utilization of new technology – ICT solutions are of limited utility if the patients do not have a stable internet connection (Gonzales, Ems, & Suri, 2016).

2.2.4. Cultural/behavioral

The cultural/behavioral explanation puts more emphasis on human intentions and agency. Within this framework , a 'hard' version proposes that individuals have a scope of possibilities to decide, choose, and act in health-beneficial ways; social inequalities in health are here fully accounted for by health-damaging behavior by those in lower social positions, be that smoking, alcohol or drug consumption, diet, physical exercise, sexual behavior, or health service usage (Bartley, 2016; Smith et al., 2016). From this follows that behavior change is more effective than policy reforms in reducing health inequalities, which has been criticized as "blaming the victim" (Elstad, 2000, p. 66). In the 'softer' version, behaviors contribute to inequalities, but the individual focus of the 'hard' version is abandoned. Health behaviors are less viewed as free choices, and more as determined by circumstances, with researchers rather asking why these behaviors are overrepresented among the lower social strata – what are the structural constraints enabling these patterns (Elstad, 2000; Macintyre, 1997)? Engels' (2001/1845, p. 177) description of drinking habits among the 19th century English proletariat, is an example of way of thinking about individual behavior, where drunkenness had become "the necessary, inevitable effect of certain conditions upon an object possessed of no volition in relation to those conditions".

Relevant here is also the concept of *habitus*, an individual's dispositions to act, largely determined by her location in the social structure, where lifestyle choices are treated as distinguishing practices between social classes (Cockerham, 2005; Cockerham, Rütten, & Abel, 1997). Within the cultural/behavioral model, adopting an innovation is an individual choice, implying that equal access to innovative technology lead to unequal use and further inequalities in health outcomes (Zibrik et al., 2015). Health technology would then be a determinant placed downstream in the causal chain; social inequalities in e.g. cancer screening would be explained by lacking health agency rather than by insufficient coverage (Link et al., 1998).

2.2.5. Psychosocial

Studies following the Black report showed that the and cultural/behavioral explanations was insufficient in explaining the social gradient in illness and mortality. For example, results from the Whitehall study of London civil servants showed that only a minor part of mortality inequalities by employment was explained by traditional behavioral risk factors such as cholesterol, smoking, and blood pressure (Rose & Marmot, 1981). The material/structural explanation was also challenged: while the overall standard of living and average life expectancy had increased in the post-war decades, social inequalities in health had simultaneously persisted (Elstad, 2000; Link & Phelan, 1995).

The psychosocial explanation also leans on the social causation model and does not deny the importance of material and behavioral factors on health. However, most emphasis is placed on how social inequalities in health are products of social interaction, with income inequality at the societal level as an independent variable, and its consequences for social relations as a source of bad health (Elstad, 1998, 2000). The health determinants of the psychosocial approach are located in the structure rather than with the actor, typically social inequality and associated concepts such as social capital and social cohesion, related to the Durkheimian concept of social facts: "their [the facts'] source is not the individual, their substratum can be no other than society, either the political society as a whole or some one of the partial groups it includes (…)" (Durkheim, 1895/2003, p. 27; Elstad, 1998; Muntaner & Lynch, 1999). The research of Wilkinson (1996, 1999) have been essential, as it has shown how high levels of income inequality have been associated with poor population health and large health inequalities. One way of explaining these findings has been that how health outcomes can be caused by feelings of stress associated with relative deprivation, feelings of subordination or inferiority, and a lack of social cohesion (Elstad, 1998; Smith et al., 2016). Technology's potential function in the psychosocial approach could be related to how the health determinants of social cohesion and social capital may affect the diffusion patterns of innovative health technology. In societies with low levels of contact and trust between social groups, the spread of innovations across all social strata will be slower (Rogers, 2003). Assuming a hierarchical diffusion pattern, innovative health technologies will thus reach poorer groups later in societies with large income inequalities – potentially leading to inequalities in health outcomes.

One line of critique against the psychosocial approach argues that the causal link between income inequality and social cohesion is yet to be proven, that the model "shies away from the central issue of what produces inequality in the first place" (Muntaner & Lynch, 1999, p. 71). Other critiques have been on methodological grounds, such as Judge's (1995) claim that an approach leaning heavily on income inequality is too monocausal and sensitive to the choice of indicators. The theoretical basis of Wilkinson's work has also been questioned: if social phenomena such as cohesion and relative deprivation are dependent on the level of income inequalities, we end up with a model where "social life is more or less directly determined by material structures" (Elstad, 1998, p. 611). Wilkinson (1999, p. 540) has on the other hand argued that the powerful influence of social status on health, "the subjective impact of structural inequalities" deserves attention regardless of methodological or theoretical uncertainties.

2.2.6. Welfare state

For many of the explanations above, social institutions are treated as more or less static and neutral contexts where individuals' position in the social structure is the main structural force. Freese and Lutfey (2011) have suggested that future directions in health inequality research should integrate institutional agency and investigate 'institutional spillovers'; the ways in which welfare state and health care institutions potentially contribute to the production and reproduction of social inequalities in health.

Institutional perspectives on health inequalities have taken different forms. Beckfield and colleagues (2015, p. 230) have sought to construct a theoretical framework sensitive to how "the same individual- or household-level causes vary in their effects across institutional settings". Their framework is made up by the processes of *redistribution* (channeling resources), *compression* (setting lower and upper bounds for the social determinants of health), *mediation* (intervening on the social determinants), and *imbrication* (reinforcing or cross-cutting policies) (Beckfield et al., 2015). Empirical studies of the relations between welfare state characteristics and health inequalities have typically taken the form of comparative and multilevel analyses. In an analytical review, Bergqvist, Yngwe, and Lundberg (2013) identified three main approaches within this research: an expenditure approach, a regime approach, and an institutional approach. Within the first tradition, studies have found support for the hypothesis that more generous welfare states show smaller health inequalities, using indicators of social spending as a measure welfare generosity (cf. Álvarez-Gálvez & Jaime-Castillo, 2018; Dahl & van der Wel, 2013). Further have Eikemo with colleagues (2008; 2008) compared health inequalities in different welfare state regimes, finding that contrary to prior expectations, the Scandinavian welfare states did not show the smallest social inequalities in health, neither when measured by education nor income. The regime approach is, according to Bergqvist and colleagues (2013), the least conclusive direction of research. Lastly, research utilizing institutional welfare characteristics such as active labour market policies, benefit generosity, income inequality, and employment protection have proved comprehensive welfare states to have smaller inequalities (Van der Wel, Dahl, & Thielen, 2011). Welfare institutions are increasingly employing innovative technologies to provide services and secure access; while the medical and social control element has received much attention, implications for health inequalities have remained largely unexplored.

2.3. Fundamental cause theory

During the 1990s, the dominant position health inequality research, what can be termed as an epidemiological paradigm, was subject to several critiques. One of their claims was that the epidemiological tradition had become "prisoners of the proximate", arguing that epidemiology had "become a set of generic methods for measuring associations of exposure and disease in individuals" (McMichael, 1999; Pearce, 1996, p. 679). In the reigning paradigm, social position had the role of a placeholder: a collection of risk factors, e.g. smoking, drinking, exercise or diet, associated with health outcomes. Critics from within the epidemiological field argued that this was a reductionist approach which decontextualized the risk factors and individualized the explanations into life style choices; they called for a development of theory to match that of methods (McMichael, 1999; Pearce, 1996). Since these inequalities had persisted over several decades, they could not be solely explained by the usual proximate risk factors, as the magnitude and distribution of these had shifted substantially during the same period. Health outcomes were surrounded by a web of causal factors – but where was the spider? (Krieger, 1994). A more encompassing theoretical framework was needed, and an early attempt of formulating alternative explanation model can be found in House, Kessler, and Herzog (1990):

> The variety of advantages in power, prestige, knowledge, and monetary resources (….) that accrue to members of higher SES strata may repeatedly enable them to avoid health hazards more readily or to mobilize health-protective factors, no matter what hazards or protective factors are most important at a given time.

This was a call for a glance upstream the river of causality connecting social position and health. House and colleagues (1990) encouraged social epidemiologists look beyond the causes of risk and disease, and search for "basic causes", a term originating from Lieberson (1985, p. 185): ”On the one hand, there are the superficial or surface causes that appear to be responsible for a given outcome; on the other hand, there are the basic causes that are actually generating the outcome". For there to be a basic or fundamental causality, several pathways connect two phenomena, meaning that intervening factors cannot fully explain the association – in this case between social position and health.

The call from House and colleagues (1990) was echoed in a seminal 1995 article, where Link and Phelan formulated the first sketch of a more coherent theory, "Social Conditions as Fundamental Causes of Disease". Here, they argued for contextualizing the disease-proximate risk factors, and encouraged health inequality researchers to ask why and under which social conditions people were exposed to risk factors (Link & Phelan, 1995). By defining time- and context-dependent risk factors as ‘intervening mechanisms’, Link and Phelan (1995) placed causal force at a higher level, with socioeconomic inequality being the fundamental cause of health inequality. With that, they moved away from a view of social position, class, or status as a placeholder for causes of mortality or morbidity that had not yet been discovered. Their argument rested on how social inequalities in health have persisted over decades, although the influence and relative importance of different risk factors have come and gone (Freese & Lutfey, 2011). In a later article, Phelan, Link, Diez-Roux, Kawachi, and Levin (2004, p. 266) referred to Durkheim’s (2006/1897) *Suicide* when they wrote of how “social factors weren’t just a contributor to patterns of suicide but a central, irreducible determinant of those patterns”, and argued that the if socioeconomic status was merely a placeholder, its association with mortality would disappear. As the association between socioeconomic status and mortality persisted through years of social and medical advances, they suggested that this fundamental causal relationship was maintained through the replacement by other risk factors – an example is the way poor housing and sanitation was replaced by health behavior and lifestyle as a source of health inequalities (Phelan et al., 2004). This explanation of health inequalities’ persistence has been by Mackenbach (2012) been lifted as one of the theory’s advantages. Link and Phelan (2010) have described the fundamental cause theory (FCT) using Merton’s (1968, p. 39) concept of ‘middle-range theory’, meaning that it lies between our day-to-day working hypotheses and “the all-inclusive systematic efforts to develop a unified theory that will explain all the observed uniformities of social behavior, social organization, and social change”. Such theories are closely embedded with empirical investigation, and although they involve abstractions, they are close enough to our observations of the world to be subject of testing (Merton, 1968).

Rather than providing concrete explanations of how specific measures of social position – e.g. ‘the usual suspects’ of income, education, and occupation – are etiologically associated with health outcomes through proximate causes and risk factors, the FCT directed attention towards the unequal distribution of vital, flexible resources (Lutfey & Freese, 2005). Money, knowledge, power, prestige, and social connections are the resources mentioned in most contexts (cf. Link & Phelan, 1995; Link & Phelan, 2002; Phelan, Link, & Tehranifar, 2010). These are flexible in terms of having application value in many health-relevant contexts; they can shape both individual behavior and individuals’ access to broader contexts such as health-beneficial working and living conditions (Phelan & Link, 2005). The flexible resources are therefore not representing fixed layers in a stratified society but can rather be regarded as expressions of upstream inequality, a general unequal pattern of distribution.

The application of these resources represent mechanisms through which inequalities at the societal level (structure) are linked to behavior at the individual level (agency) – without attributing full causal power to neither level. Resources are clearly related to distribution at the structural level – of material wealth, of social welfare, of equal opportunities – while they still imply the need for "health-directed human agency": a purposive actor to utilize her resources to gain health advantages (Link & Phelan, 2002, p. 732). Freese and Lutfey (2011, p. 71) described resources in the FCT as an ambiguous concept, a "workhorse construct" sometimes stretched to where it fits best. I interpret this point as an underlining of how the FCT represents a *synthetic* approach to explanations, one which is made with a certain kind of argument: simple, exclusive, or even elegant. This view on explanations emphasizes the logical syntax of a phenomenon, the way the explanation puts its parts together (Abbot, 2004). Hempel and Oppenheim (1948) formalized the synthetic explanation into a description of the empirical phenomenon to be explained – explanandum, and conditions and general laws – explanans. One problem with such a model is how the explanans rest on certain unobservable idealizations. An example is the concept of cause, which Kant was first to show that cannot be directly derived from experience in itself (Benton & Craib, 2011). Synthetic explanations are also dependent on definitions to link the described concepts in the observed phenomena to concepts in theory. These 'bridging' definitions may involve substantial knowledge claims which is left untested by experience (or impossible to empirically observe) (Benton & Craib, 2011).

FCT's concept of resources bridges social position with the means to affect health outcomes, enabling the theory to explain the association and historical development between social position and health in a logical coherent, elegantly formulated framework. Flexible resources associated with, but not reduced to, socioeconomic status affect health through different mechanisms in different contexts, while the basic nature of the relationship, the social gradient in health, is preserved. Freese and Lutfey (2011; Lutfey & Freese, 2005) used the term *meta-mechanism* to describe how multiple concrete mechanisms are generated to connect social position and health in different contexts, a "durable narrative" for health inequalities' persistence. Could one reason for the FCTs popularity could be what Mackenbach (2012, p. 764) termed "an elegant reformulation of the problem" – a logical coherent synthetization of structural and intentional explanations?

Link and Phelan (2010) described of three sets of empirical 'facts' from the health inequalities research showing support for the FCT. First, when comparing preventable and nonpreventable mortality rates over time, the former has had a more rapid decline, indicating simply that people utilize their resources to avoid death through technological innovations and increasing knowledge of medicine and healthy behaviors. Examples of supportive findings are Mackenbach, Stronks, and Kunst (1989), using occupational classes in the UK and Netherlands; Korda and Butler (2006) and Piers et al. (2007), using aggregated socioeconomic status (SES) measures in Australia; and Masters, Hummer, and Powers (2012), using ethnicity and educational attainment in the US. Second, the FCT predicts an SES gradient in preventable mortality, indicating that disease and death amenable to human agency will reflect the fundamental inequality in resources present in most societies. This 'fact' is supported by results from Westerling, Gullberg, and Rosén (1996) using occupational categories in Sweden; from Dahl, Hofoss, and Elstad (2007) using educational attainment in Norway; and from Mackenbach with colleagues (2015; 2017), using educational attainment on harmonized cross-European mortality data. The third 'fact' states that the SES association with mortality is stronger for preventable than for nonpreventable mortality, indicating that the fundamental cause of social conditions will play a lesser role for less preventable diseases and deaths. Song and Byeon (2000), Phelan et al. (2004), and Masters, Link, and Phelan (2015) are among the supportive findings. The third 'fact' has also been supported when morbidity has been the health outcome; Willson (2009) used educational attainment and income on self-reported cancer and heart disease in the US and Canada, while Bränström, Hatzenbuehler, Pachankis, and Link (2016) used sexual orientation as a measure of social position when analyzing diagnoses in Swedish health care registry data. Paper II also follows this approach by comparing educational inequalities among self-reported health problems with high and low preventability doing, with results by and large supporting the FCT.

A central point of the FCT is how social position and health is connected through changeable and context-dependent mechanisms (Link & Phelan, 2010). Innovative health technologies make a fruitful case for investigating this feature of the theory; first, as they represent means through which people can prevent and/or postpone disease and death; second, as they make a good case for comparing SES gradients from before and after their introduction; third, as technologies are human inventions, they can act as indicators of the social impact on health outcomes (Link et al., 1998). In addition, adding a temporal dimension of diffusion to the FCT could counter one of its shortcomings (Zapata-Moya, Willems, & Bracke, 2019). This is exemplified by Masters et al. (2015), demonstrating how the association between education and mortality varied between gender and ethnic groupings, meaning that the same flexible resource has a stronger health-beneficial effect in some contexts compared to others. The authors suggested two responses to this challenge: One, to elaborate the theory and identify the circumstances making the differential effect of resources. Second, to accept the limitations in the theory's generality, and specify other middle range theories with which the FCT can interact (Masters et al., 2015). This dissertation aims at a combination of the two; it explores how the diffusion of innovations framework can provide contexts between which the effect of flexible resources can vary, while also adding theoretical substance to FCT explanations.

Several studies have made use of a technology-approach to the FCT; examples of innovative technologies include cancer screening (Gadeyne et al., 2017; Link et al., 1998), cholesterol-lowering drugs (Chang & Lauderdale, 2009), and coronary heart surgery (Korda, Clements, & Dixon, 2011). Papers III and IV follow up this research over two steps; first, by looking at the social gradient in technology use over time – operationalized in Paper III as the use of blood pressure monitors. Second, by testing the effect of a medical innovation on the social gradient in a health outcome – operationalized in Paper IV as blood pressure lowering medication and systolic/diastolic blood pressure levels.

2.5. The diffusion of innovations

An alternative explanation of social inequalities in health have been to focus on how medical innovations are spread over a population (Mackenbach, 2012). Examples include medical technology utilized by professionals or individual end-users, where research has shown socioeconomic inequalities or 'lags' in the adaption of such devices. Knowledge and information are other health-beneficial assets where diffusion processes could be relevant; both doctors and patients may adjust their behavior according to new available information, and social position may shape these adjustments; examples include between-country inequalities in the 'smoke-quitting' epidemy (Pampel, 2002), inequalities between high- and low-status physicians in adopting innovative treatment regimens (Coleman, Menzel, & Katz, 1959; Rogers, 2003), and unequal knowledge of vaccines and screenings between individuals with different educational backgrounds (Zapata-Moya et al., 2019).

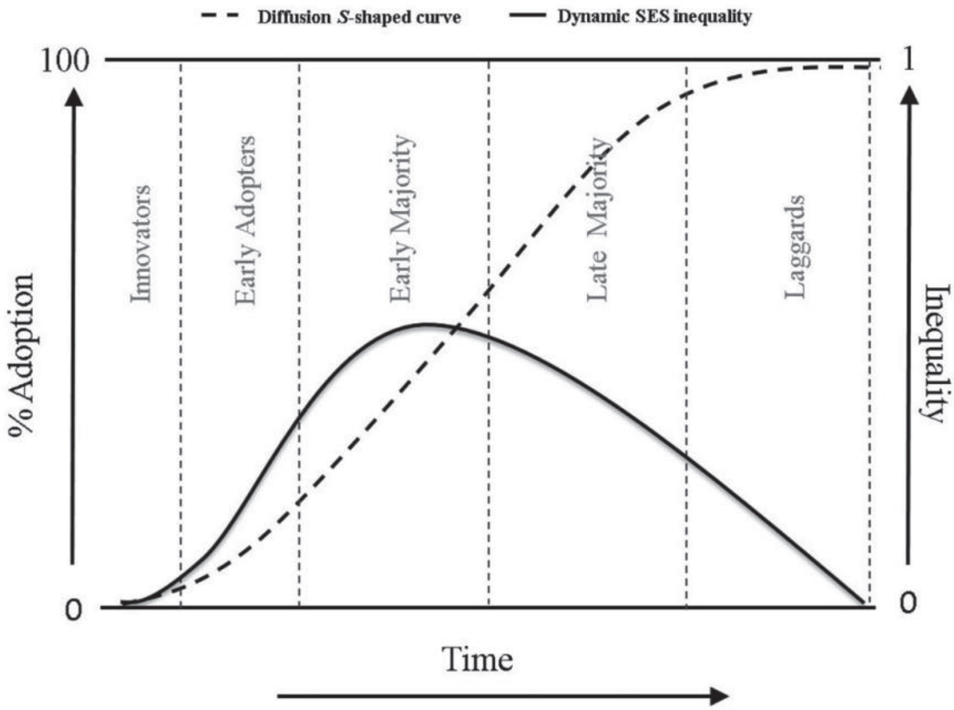
In Mackenbach's (2012) review of health inequality explanations, the diffusion of innovations theory (DoI) is described as a theory "focusing on the value of resources for health gain". In comparison with other theories, the DoI is particularly well suited to explain how social gradients are present among "diseases of affluence" in recent decades, where individual behavior has had a greater impact on the overall disease burden compared to e.g. sanitation or working conditions. Olshansky and Ault (1986) suggested that we in 1986 had reached a fourth phase in the so-called epidemiological transition, labelled “The age of delayed degenerative diseases”, where the risk of dying from the “degenerative and man-made” diseases prevailing in the third phase have, through behavior change and health care advances, been pushed back to occur in older ages. Following the diffusion approach, people in higher social positions are earlier adopters of behavior change and medical developments, with the consequence of widening inequalities in the fourth epidemiological transition phase (Mackenbach, 2012).

The concept of diffusion in the social sciences is strongly associated with Rogers’ (2003, pp. 5-6) theories on the diffusion of innovations, where diffusion is described as an example of social change, “the process by which alteration occurs in the structure and function of a social system” and further defined as “the process in which an innovation is communicated through certain channels over time among the members of a social system”. These four elements – innovation, communication channels, time, and social system – should be recognizable in all diffusion studies. Four ideal types of actors in the diffusion process have been identified: innovators, early adopters, early majority, late majority, and laggards. Vital here is the relative dimension of innovativeness, “the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system” (Rogers, 2003, p. 280). Some of Rogers’ (2003) characteristics of adopters may be linked to traditional operationalizations of socioeconomic status within the health inequality literature, either directly (e.g. educational attainment and wealth) and indirectly (e.g. literacy, social status, and social mobility).

The generalized characteristics of adopters also share features with the more theoretical FCT notion of flexible resources. Although ambiguous, these concept enable us to think of and analyze social inequalities in health as a result of more than merely material structures, and to make *inferences* – to move from ’thin’ description of facts and towards ’thicker’ descriptions including meaning – a mixture of observing, penetrating, and finding out about something (Swedberg, 2012). More specifically, by combining the FCT with a DoI perspective, we may view socioeconomic status as an expression of abilities, strategies, social connections, and knowledge – relevant in a context of rapid innovation and individualization within the health field, exemplified by concepts such as ‘patient empowerment’ (Roberts, 1999).

Socioeconomic gaps have proved to be a frequent consequence of innovation. Early and late adoption is associated with high and low SES prior to the diffusion, potential explanatory factors being the attitudes towards innovations and technology, the monetary costs of an innovation, the tendency of ideas and innovations to trickle across rather than trickle down social categories, and the windfall profits going to early adopters and generating relative inequalities in outcomes (Rogers, 2003). Figure 1 displays how an inequality perspective can be integrated in a DoI framework. The dotted line represents the rate of adoption (left y-axis), while the solid line represents the degree of socioeconomic inequality in adoption (right y-axis). In this stylization, inequality is at its highest in mid-adoption, before the late majority has adopted the innovation.

Figure 1: Social inequalities and the diffusion of innovations



Source: Zapata-Moya et al. (2019).

Conceptually, *the social system* is one of four elements in Rogers' (2003, p. 24) model, with its structure defined as patterned arrangements giving stability and regularity to human behavior. Though the concepts and generalizations in diffusion research to a large degree have focused on the actors' available resources and assume individual agency in adopting innovations, the structures in which the innovations are diffused are also of relevance. Rogers (2003) wrote of how diffusion research have been criticized for having a pro-diffusion bias –

with that tending to blame the individual agent for his/her lacking adoption of an innovation rather than the structural constraints for diffusion. Nevertheless, several studies have suggested the importance of the structural features. Diffusion research on the adoption of new coffee varieties in Colombia and irrigation wells in Bangladesh and Pakistan showed that two diffusion processes with similarities at the innovation- and adopter-level produced unequal outcomes: In social systems with large structural inequalities, the adoption of an innovation led to a widening of inequalities, leading Rogers (2003, p. 463) to formulate the following generalization: "A system's social structure partly determines the equality versus inequality of an innovation's consequences". A social system with high degree of inequality may affect an individual's probability of adopting an innovation – through processes such as the ability to cooperate and the spheres of contact across social strata.

Related to inequality is the structural characteristic of homophily – whether the "individuals who interact are similar in certain attributes, such as beliefs, education, socioeconomic status, and the like" (Rogers, 2003, p. 19). A high degree of homophily in the social system makes effective and rewarding communication more probable, with that increasing the diffusion rate (Rogers, 2003). Using experimental data, Centola (2011) showed how health behavior was diffused more effectively in homophilous networks, the degree of homophily increased both access to the innovation and the likelihood of adopting it. In two articles using the longitudinal Framingham Heart Study, Christakis and Fowler (2007) found that personal relationships had a significant influence on the diffusion of obesity, and that there was a greater probability of smoking cessation to diffuse between friends who both were high educated, i.e. in relationships which combined a high degree of homophily with high social status (Christakis & Fowler, 2008).

The findings above resonate with several theories on social inequalities in health. In the FCT, structural inequality is placed 'upstream' in the causal chain leading to health inequalities, influencing a range of potential health outcomes through more proximate mechanisms – including the adoption of health-beneficial innovations (Link & Phelan, 1995). The distribution of resources – structural inequality – will be a stronger determinant of health consequences from a diffusion process than any characteristic of the innovation or individual adopter. This element of persistence is also supported by Rogers' (2003) generalization (although less unconditionally than in the FCT): inequality in structure may lead to inequality in diffusion process and outcome, independent of innovation or adopters' characteristics. From this follows the prediction shared by the FCT: as our ability to control disease and death increases with medical innovation and development, inequalities in outcome follows as long as there is structural inequality (Link & Phelan, 2002).

Much research investigating the interplay between diffusion of innovations and health inequalities has focused the adoption of healthy and unhealthy behaviors. For example, an overall decline in smoking-related cardiovascular mortality, most likely because of increasing awareness of tobacco's harmful effects, have been paired with growing inequalities. Studies have indicated that cigarette smoking (and cessation) has followed a hierarchical diffusion pattern both within and between countries (cf. Giskes et al., 2005; Lopez, Collishaw, & Piha, 1994; Pampel et al., 2015). Pampel (2002) used multilevel data from 15 European nations, finding that a variable measuring national cigarette diffusion significantly contributed to increasing social inequalities in smoking, while the variable measuring inequality had an opposite effect, suggesting that social status has been a stronger predictor of smoking in egalitarian societies. Support for the diffusion hypothesis was also found in Elstad's (2013) study of gender, educational and geographical inequalities in Norwegians' alcohol, exercise, and smoking habits over the years 1975-2005. Results indicated hierarchically diffusion, particularly for frequent alcohol use, and that the social gradient for non-smoking was inverted during the study years.

The *inverse care law* and *inverse equity hypothesis* are related to the DoI explanation of health inequalities (Mackenbach, 2012). The former concept originates from a landmark study by Julian Tudor Hart (1971). He drew on national statistics and personal experiences in medical practice and described how principles of market distribution within the medical sector in the UK had led to impoverished populations receiving insufficient health care, consequently formulating the inverse care law: "The availability of good medical care tends to vary inversely with the need for it in the population served" (Hart, 1971, p. 405). Diffusion and adoption of innovative technology was not within the scope of the inverse care law. However, both theories imply that the distribution of a common good follow a hierarchical socioeconomic pattern, with a widening of inequalities as a result.

The similarities between these two approaches are reflected in Victora and colleagues' (2005; 2018; 2000) formulation of an *inverse equity hypothesis*, focusing on unequal coverage and effect of public health programs and interventions. This hypothesis was tested on outcome indicators, such as program coverage, and infant mortality and innovative public health interventions such as vaccines, vitamin supplementation, antenatal care, skilled birth delivery in health facilities, and safe water. Results showed socioeconomic inequalities between and within countries, and that relative inequalities declined when coverage increased (Victora et al., 2005; 2018; 2000). By mainly being applied to public health intervention, focus has been on structural features such as coverage, and less on individual adoption and use of health innovations.

In a critical account of the DoI perspective in public health research, Lindbladh, Lyttkens, Hanson, and Östergren (1997) noted that many researchers used the term 'follow' when describing hierarchical diffusion between people of different social positions, arguing that 'to follow' may "contain a meaning which is absent from terms such as 'to spread' or 'diffuse', a meaning which could imply a causal relationship" (Lindbladh et al., 1997, p. 325). Diffusion studies thus implicitly assume social role modelling in diffusion studies, a causal mechanism by and large unproved in their empirical results. Lindbladh and colleagues (1997) propose the habitus concept as a viable perspective when explaining behavior change across social strata. Rather than imitating the behavior of the rich and well educated, people's different, objective life-chances are transformed into subjective strategies and motivations, leading to different life choices. Finding meaning and pleasure in looking after one's body, e.g. by adapting to new medical information or adopting innovations, is a virtue to those free from urgency; likewise may reluctancy be a "choice of necessity", an expression of a 'one knows what one has, but never what one is going to have'-philosophy associated with a more restricted range of opportunities. Lindbladh and colleagues (1997, p. 327) further argued that the processes described in DoI-inspired research often assume one-sided social role modelling, and could benefit from including external factors, such as the market:

> If an increase in the consumption of, for example, low-fat provisions could be shown among low-income households, this may be primarily an effect of changes in the availability, pricing and presentation of commodities in the supermarkets and need not have anything to do with major health-related trends among the so-called 'leading' social classes

From this excerpt follows that social inequalities in adopting an innovation is contingent on not only understanding or appreciating its health benefits, nor on the inter-personal influence across social strata, but also on market logics of supply and demand mediating the diffusion process.

Mackenbach (2012), Rogers (2003), and Lindbladh et al. (1997) have all emphasized the importance of financial resources in early stages of diffusion, when innovations may be particularly expensive. This is an example of a specific pathway, the correlation between price and adoption rate, which connects social position to innovation adoption and further to health inequalities. However, this mechanism is primarily relevant early in a diffusion process, in a context where the use of the innovation is dependent on individual agency, as opposed to some medical technologies where health professionals act as gate-keepers. As noted by both Mackenbach (2012) and Lindbladh et al. (1997), perspectives from the cultural capital tradition may complement the DoI by offering more specific diffusion-related pathways between social position and health throughout the adoption process. As mentioned above, the explanation power of cultural capital perspectives on health inequalities relates to how the leading causes of disease and mortality in the last decades have been associated with individual behavior (Mackenbach, 2012). Cultural capital approaches to health inequalities share the DoI's assumption of hierarchical relations, but additionally assumes more two-way interactions and negotiations in the diffusion process, where resources relevant for adopting innovations "derive from past experiences and largely habitual, embodied ways of thinking and organizing action" (Shim, 2010, p. 5). Cultural capital may influence adoption directly through knowledge, networks, and communication skills, and more indirectly through more subtle signals and actions of social distinction following life-course influences on one's dispositions to act. The concept can thus serve as both an instrumental and a symbolic resource to the adaption of health-beneficial innovations (Shim, 2010; Vandebroeck, 2016).

3. Data and methods

This section contains descriptions and considerations relating to the data sources, key variables, and methods used in this dissertation. First follows some notes on analytical strategy. The next subsection is on data sources. Then, issues related to key variables across all studies will be addressed. In section 3.3, I discuss the methods used, with their associated benefits and constraints. Lastly, I address general and overarching limitations and their consequences for the dissertation's research.

The scoping review study underlined how the intersection of health inequalities and technology is a field in its initial phase, drawing from several theoretical and methodological traditions. Without abandoning methodological quality and transparency, the quantitative studies therefore aim at exploring patterns and complexity rather than asserting causality, prioritizing 'vigor over rigor' (Adler, Bush, & Pantell, 2012). Paper II compares the educational gradients among high- and low-preventable health problems across Europe; the etiological pathways between education and each condition is of less interest than the structures generating the overall pattern of larger inequalities among high-preventable problems. Paper III and IV utilize a rich data material to investigate the role of technology in the context of the Norwegian universal health care system, with emphasis being on the mechanisms related to the observed patterns. Hedström and Swedberg (1998) used the association between class and health as an example of how statistical analyses fall short unless the generative mechanisms connecting the dependent and independent variables are explicitly introduced and discussed, stating that a such association "is essentially an indicator of our inability to specify properly the underlying explanatory mechanisms" (Hedström & Swedberg, 1998, p. 11). The complex pathways connecting social position, health outcomes, and technology, combined with a novel research field returning diverse findings, makes it difficult to pinpoint clear-cut causal chains empirically. Intervening mechanisms are rather explicated through the strategy of abduction: observing a fact, naming it, and using one's scientific intuition to formulate a central concept based on it (Swedberg, 2012).

3.1. Data sources

In this section, I describe and discuss the three sources of data used in the four articles: the research articles reviewed in Paper I, the European Social Survey in Paper II, and the Nord-Trøndelag Health Study in Paper III and IV.

3.1.1. Literature review

Systematic searches were performed by two research librarians in the databases Medline, Scopus and ISI Web of Science. Our first search returned 4139 articles. After a screening based on title and keywords, 465 articles were included in the second round. After another screening, based on the reading of abstracts, 51 articles went through to the final round of full-text reading. The final sample consisted of 33 studies.

In the final sample, case studies from Australia, USA, China, Sweden, Taiwan, and Canada were included, in addition to cross-national studies of European and OECD countries. Measures of technology included both personal and health service technology. Race, education, and income were the most used social position variables. Outcome measures were mortality, differences in use and uptake, and knowledge and attitudes.

3.1.2. European Social Survey

Paper II utilized the seventh round of the European Social Survey (ESS), "a biennial, academically driven, cross- sectional, pan-European social survey that charts and explains the interactions between Europe's changing institutions and the attitudes, beliefs, and behaviour patterns of its diverse populations" (Eikemo, Bambra, Huijts, & Fitzgerald, 2017). This survey consists of a constant core module including variables on trust, politics, well-being, religion, identity, gender, household, socio demographics, and human values. In addition, each survey wave includes two rotating modules (European Social Survey, 2019). In 2014, the ESS included a module on the social determinants of health with variables measuring life style and healthy behavior, health care use and access, childhood conditions, housing conditions, working conditions, and a set of self-reported mental and physical health problems. Interviews were conducted face-to-face in respondents' homes through 2014 and 2015 in 21 European countries (also including Israel). Response rates varied from 31% in Germany to 68% in Czech Republic, which were similar to previous ESS waves. Several measures were taken in order to ensure quality across countries, including omnibus tests, pilot surveys, cognitive interviews, reliability and validity prediction, advance translation, and consultations with country coordinators (Eikemo et al., 2017).

We limited our sample to respondents between the ages of 25 and 69. One reason for the lower cut-off point was to limit the possibility of respondents not having completed their planned education. Institutionalized individuals were not included in the ESS study population. This may represent a problem, as institutionalization may be an indicator of poor physical and/or mental health (Eikemo et al., 2017). The reason for our upper cut-off at 69 was therefore to limit the risk of a selection effect, as we suspected non-institutionalized respondents at age 70 and above, who in addition were willing to participate in a survey like the ESS, to be in unrepresentatively good health.

Questions on health problems were not available for Estonia, while data on cancer were missing from the Czech sample. All in all, the grand ESS sample included 40,185 respondents, while our study sample included 25,473 respondents. We used the country- and region-specific post-stratification weights included in the ESS dataset in order to adjust for sampling design bias and reduce sampling error and non-response bias (European Social Survey, 2014b).

3.1.3. Nord-Trøndelag Health Study

The Nord-Trøndelag Health Study (HUNT) was first performed during 1984 to 1986. Based on census data, all inhabitants of Nord-Trøndelag county above the age of 19 were invited by mail. Approximately 77,000 individuals participated, resulting in a response rate of 89%. HUNT1 consisted of modules on blood pressure, diabetes, lung disease, and quality of life. Health professionals measured systolic and diastolic blood pressure, height, and weight, in addition to performing a screen examination. Respondents completed two questionnaires, one was attached to the invitation letter, another was handed out at the clinical examination and to be returned by mail. Questionnaires in HUNT1 included topics such as self-reported health problems, personal environment, lifestyle and habits, and family medical history. The second HUNT wave (HUNT2) was performed over the years 1995 to 1997. Ca. 65,000 respondents participated, giving a response rate of 70%. Approximately 47,000 of HUNT2 respondents had also participated in HUNT1. In addition to a set of new themes and variables, including a venous blood sample, the modules on blood pressure, diabetes, and quality of life was repeated. As in HUNT1, the study consisted of clinical measurements and questionnaire responses. HUNT3, the third HUNT wave, was conducted during 2006 to 2008. 50,807 respondents participated in the last wave, with a response rate of 54%. Approximately 37,000 respondents participated in both HUNT2 and HUNT3, while over 27,000 respondents participated in all three study waves. The data was collected by clinical examination and questionnaires, including questions on self-reported illness, diseases, behavioral risk factors, and socioeconomic position (Krokstad et al., 2012). A fourth HUNT wave was carried out from 2017 to 2019, but data from this wave was not available when this research project was conducted.

Nord-Trøndelag county has a fairly stable and homogenous population, with low migration rates over the study years. The county is mostly rural populated with six small towns and is relatively representative of Norway with regards to geography, economy, industry, and sources of income, age distribution, morbidity and mortality. However, the county score lower than the Norwegian average on income, proportion of higher educated, and smoking prevalence. Stability, representativity and fairly high response rates makes HUNT well suited for studies employing epidemiological methods (Holmen et al., 2003).

The two studies using HUNT data in this dissertation utilized the repeated measurements of blood pressure and questionnaires on cardiovascular health. HUNT data was linked to national registry data on income and education, made possible by an 11-digit personal identification number included HUNT data. The Norwegian national statistics agency SSB provided the registry data and the HUNT Research Centre created a project-specific identifier to link the datasets; the data utilized in research was thus deidentified. All participation in the HUNT studies was voluntary, and all respondents have given written consent to use data for research purposes. HUNT2 and HUNT3 was approved by the Regional Committee for Medical and Health Research Ethics (REC), which was yet to be established at the time of HUNT1. The study protocol for this research project also received a separate approval by REC.

3.2. Key variables

In the following sections, I describe and discuss methodological and conceptual issues concerning the key variables used in the quantitative studies of this dissertation: Paper II, III, and IV. The first two are outcome variables specific for the two data sources used, ESS and HUNT. The third subsection treats variables measuring social position, and addresses some common and some specific issues regarding the operationalization of variables in the three studies.

3.2.1. Self-reported health problems in ESS

The outcome variables utilized in Paper II, are responses to the question "Which of the health problems on this card have you had or experienced the last 12 months?". Respondents could mark heart or circulation problems; high blood pressure; breathing problems such as asthma attacks, wheezing, or whistling breathing; allergies; back or neck pain; muscular or joint pain in hand and arm; muscular or joint pain in foot or leg; problems related to your stomach or digestion; problems related to a skin condition; severe headaches; and diabetes. Secondly, the questionnaire contained a question on cancer: "Do you have or have you ever had any of the health problems listed on this card? If yes, is that currently or previously?" Respondents could mark cancer affecting any part of the body; leukaemia; malignant tumour; malignant lymphoma; melanoma, carcinoma, or other skin cancer. Current or previous cancer were coded as 1. A last outcome variable was constructed using an eight-question battery on depressive symptoms based on the Center for Epidemiologic Studies Depression Scale (CES-D). Respondents were here asked whether they during the last week had felt depressed; felt everything they did was an effort; slept restlessly; were happy; felt lonely; enjoyed life; felt sad; and felt they could not get going. Answer categories included "None or almost none of the time", "Some of the time", "Most of the time", "All or almost all of the time" or "Don't know". We calculated a mean score rescaled to vary between 0 and 1. We included respondents with answers on at least six items with no zero-variance, i.e. had not given the same score on all items. The ESS also included data on respondents' height and weight, making it possible to calculate a body mass index (BMI) as a measure of obesity. We did not include this measure, as we considered BMI as a somewhat blunt measure, and we were also unsure whether to treat it as a health problem or as a lifestyle indicator.

Self-reports of health have been a common outcome measure in public health research. Validity studies have proved a consistent association over time between self-reports and more clinical concepts on health, such as mortality and disability (Bopp, Braun, Gutzwiller, & Faeh, 2012; Ferraro, Farmer, & Wybraniec, 1997; Idler & Benyamini, 1997). Comparisons between self-reports of chronic diseases and physician-reported medical histories have shown substantial accuracy (Dalstra et al., 2005). Self-reports of diabetes have proved to be an accurate measure, while survey respondents have tended to underestimate self-reported hypertension (Goldman, Lin, Weinstein, & Lin, 2003; Johnston, Propper, & Shields, 2009; Kehoe, Wu, Leske, & Chylack Jr, 1994; Kriegsman, Penninx, Van Eijk, Boeke, & Deeg, 1996). Self-reports of muscular and joint health problems have shown less accuracy (Haapanen, Miilunpalo, Pasanen, Oja, & Vuori, 1997; Kriegsman et al., 1996). Dalstra and colleagues (2005) argued that based on available evidence, there is a greater probability of underestimating social inequalities in self-reported health problems, as the socioeconomic disadvantaged have shown a tendency of underreporting (see also Kehoe et al., 1994).

An important aspect of Paper II was the classification of the health problems from the questionnaire as high- or low-preventable. Similar classifications have been made for both mortality and morbidity, with Phelan and colleagues (2004) setting precedence. However, this is to our knowledge, the first classification and comparison on the basis of self-reported cross-national survey data. Preventability, amenability, and avoidability are contested concepts, and the ambiguity of some of the health problems in ESS further complicates the classification. Rather to classify health problems as more and less amenable, conditions "from which it is reasonable to expect death to be averted even after the condition has developed", we chose to focus on their preventability, whether "there are effective means of preventing the condition from occurring" (Piers et al., 2007, p. 5).

For health problems such as cancer, it is difficult to determine the actual preventability – what is the role of genetics, lifestyle choices, health care, or medical innovation in preventing cancer? Phelan and colleagues' (2004) classification served as a guide, and when direct equivalents were difficult to find, we searched the literature for evidence on the conditions' preventability. Though some of the listed problems more or less correspond to concrete medical diagnoses – such as diabetes, high blood pressure, and cancer, other may cover a range of diagnoses – such as headaches or various pains. Our general response to these classification issues is to keep an open, exploratory approach to our findings, following the advice from Nolte and McKee (2004) that preventability classifications and subsequent findings are not unambiguous evidence but rather indications of patterns and mechanisms suggesting a way forward.

Symptoms of depression were measured differently from the other dependent variables. The scale was constructed by adding up eight items, and the variable did therefore not show the prevalence of depression in the ESS population, but rather the occurrence of depressive symptoms. Descriptive statistics showed a fairly low mean score, with approximately 50% of the sample having a score below 0.2, meaning that we have analyzed variance in a population with little overall depressive symptoms, and that results should be interpreted in light of this.

3.2.2. Blood pressure levels, medication, monitors, and covariates

Blood pressure levels, blood pressure monitors, and blood pressure medication was used when investigating inequality patterns in use and outcomes of innovative health technologies. Blood pressure is an important indicator of cardiovascular which have previously proved to have a pronounced social gradient (Strand & Tverdal, 2006). It is also a field within health care where we have seen substantial advances during recent decades in use and development of medication and measuring equipment (cf. Gu, Burt, Dillon, & Yoon, 2012; Moe, Getz, Dahl, & Hetlevik, 2010).

Systolic and diastolic blood pressure was measured by trained nurses or technicians using a Dinamap 845XT (Critikon) based on oscillometry. HUNT participants had been seated for two minutes before the device was started, and the mean of the second and third reading was used; this to limit the risk of white-coat hypertension – where blood pressure levels are artificially high when measured by professionals at health care facilities (Holmen et al., 2003; Kleinert et al., 1984). The variable for blood pressure medication was self-reported: the answers "currently" or "previously" on the question "Are you taking medication for high blood pressure?". In Kehoe and colleagues' (1994) comparison of survey respondents and physicians reports of medication use, hypertension drugs showed high sensitivity and specificity rates, meaning a low risk for over- and underreporting. In Paper III, use of blood pressure monitoring technology was operationalized through three variables: Answers "Yes" to the questions "Do you have a blood pressure monitor at home?", "Have you used a 24 hour blood pressure monitor?", and "Have you ever measured your blood pressure yourself at home?". The first question was included only in HUNT2, the second only in HUNT3, the third question in both HUNT2 and HUNT3.

A vital point in the study design is the diffusion status of the selected technology – blood pressure medication and monitors. These studies are of single technologies without a comparative element, the degree of diffusion is not operationalized as a variable in the analyses. I have therefore chosen not to attempt to quantify the degree of adoption of blood pressure medication and monitors. Descriptive statistics and research reports on the development of medication and monitors are used as indicators on how far along the process has come. In Paper III, I compare the social gradient in technology use between survey waves HUNT2 and HUNT3; it is assumed that there has been an ongoing diffusion of the innovative technology between the two data measuring points. Table 1 displays the amount of the HUNT population, in total and by SES categories, using blood pressure medication and having experience with blood pressure monitors. The three questions on blood pressure monitors were asked to respondents who had shown indications of cardiovascular disease in the health examinations (HUNT3), or by reporting blood pressure medication use (HUNT2). Medication use increased across all SES categories for each survey wave, as did the percentage of respondents ever having measured their blood pressure at home from HUNT2 to HUNT3. These are crude, unweighed prevalence figures, and the different questions on monitor use are not directly comparable, but they can nevertheless act as indicators of an overall development. We can observe that the SES-technology association is inverted in the case of BP medication; this association also persists when adjusting for BP levels.

Table 1: Blood pressure medication and monitor use over three HUNT waves (%)

	HUNT1 (1984-1986)	HUNT2 (1995-1997)	HUNT3 (2006-2008)
Taking medication for high blood pressure			
Full HUNT sample	13.0	14.2	22.2
Top income quartile group	5.4	6.1	10.9
Bottom income quartile group	26.2	31.6	46.4
Tertiary education	4.9	7.0	12.5
Primary education	18.4	22.1	33.3

Ever having measured blood pressure at home			
Full CVD sample	-	9.8	17.5
Top income quartile group	-	22.5	25.5
Bottom income quartile group	-	6.0	13.7
Tertiary education	-	21.7	23.9
Primary education	-	6.0	14.2
Having a blood pressure monitor at home			
Full CVD sample	-	4.7	-
Top income quartile group	-	9.5	-
Bottom income quartile group	-	3.5	-
Tertiary education	-	10.4	-
Primary education	-	2.9	-
Having used a 24-hour blood pressure monitor			
Full CVD sample	-	-	27.4
Top income quartile group	-	-	31.8
Bottom income quartile group	-	-	24.2
Tertiary education	-	-	29.2
Primary education	-	-	25.1

In Paper IV, where systolic and diastolic blood pressure were the outcome variables, lifestyle and biomedical control variables were added to the model. The selection of these were based on Holmen and colleagues' (2016) study using the same data material. Body mass index and heart rate was measured in the HUNT health examination, while the questionnaire included self-reports on age, smoking, exercise, diabetes, and myocardial infarction. Holmen et al. (2016) also included glucose and cholesterol levels as variables, but blood samples were not drawn in HUNT1, and I wanted to include all survey waves in my analysis. Correlations between the lifestyle and biomedical variables did not indicate multicollinearity.

3.2.3. Educational attainment and income

Education and income were the two measures of social position used the three quantitative papers of this dissertation. In the ESS, respondents' educational level was asked as a country-specific question, before the ESS team coded responses into seven categories corresponding to the International Standard Classification of Education (ISCED I, II, IIIa, IIIb, IV, V, VI). We created a tripart variable consisting of no education or only primary education completed (ISCED I, II), secondary level degree completed (ISCED IIIa, IIIb, IV), and tertiary level degree completed (ISCED V, VI). The ESS also contains an education variable measured as completed years of education. This variable has proved to be an adequate predictor of social status, but with low comparability across undifferentiated and tracked educational systems (Schneider, 2010; Schröder & Ganzeboom, 2013). In sensitivity analyses using the continuous education variable, results were similar to the categorical variable based on ISCED. Norwegian registry data on education used in Paper III and IV were coded into the same three categories as above, based on the ISCED classification.

The association between education and health seems well supported. In a review study, Kröger, Pakpahan, and Hoffmann (2015) found more support for a social causation explanation when the socioeconomic indicators were income or education, compared to indicators related to the labour market. Compared to other measures, education has the advantage of stability; after a certain age, a person's educational status is not likely to change, making health selection less likely than for other measures of social position such as occupation, income, or wealth (Elo, 2009). Findings have indicated that education has had a growing impact on mortality, largely because mortality figures among the highest educated dropping steeply, with a possible explanation for the increasing health returns of education fast-paced socio-technological developments (Hayward, Hummer, & Sasson, 2015).

With regards to the standard explanations of health inequalities, education makes a good fit in explanatory models based on material factors, behavioral factors, as well as abstract flexible resources. Montez and Friedman (2015) have suggested three explanations for a causal relation between education and health. First, education may have an impact on health through the resources and rewards it gives access to, such as jobs with decent working conditions and autonomy, economic security, social networks, and knowledge about risky and beneficial behavior. This way of treating education as a proxy for income, occupation, or concepts such as socioeconomic status or social class is common in many studies where data on income is not is not available or considered too sensitive (Braveman et al., 2005). Second, causality may be inverse; poor health (especially in childhood) may affect one's chances and abilities to attend higher levels of education. Third, the association may be spurious, with factors such as genetics or personality traits effecting both educational attainment and health outcomes. When Cutler and Lleras-Muney (2010) investigated the relations between education and health behavior, they found that economic and knowledge-related indicators each explained about 30% of the educational gradient. Social networks associated with education showed less explanation power, while the impacts of personality factors and attitudes had no statistically significant impact on the educational gradient in health behavior.

The impact of income on health have also proved to be substantial. Both in US and European populations, the income gradient in mortality has remained stable or grown steeper during the recent decades (Chetty et al., 2016; Kinge et al., 2019; Mortensen et al., 2016). Associations have also been proved between income and health behaviors as well as morbidity measures (Johnston et al., 2009; Östergren, Martikainen, Tarkiainen, Elstad, & Brønnum-Hansen, 2019). In Paper III and IV, registry data on yearly income was coded into quartile groups. There was a large portion of the sample listed with zero income. Through personal communication with Statistics Norway, I was ensured that this in was not a coding error; a tax base of zero could mean being out of employment but not eligible for social benefits, but also to receive money through other means than traditional salary, such as tax-exemptible income from private or public sources. Low-educated, young, and old people were overrepresented in the zero-income group, which could support the validity of income as a SES measure in this context. Sensitivity tests were performed where zero-income respondents were excluded; results were similar but less robust.

3.3. Methods

In the following section, I address methodological issues in the four papers of the dissertation. This includes descriptions of the methods used and brief discussions of potential pitfalls.

3.3.1. Scoping review

The methodological framework for Paper I was the scoping review. This is an approach to investigating the knowledge status in a research field where less emphasis is placed on pre-defined research questions and formal synthetization of the studies included in the review; focus is rather on broader topics where the knowledge base is narrow and where relevant studies may have a heterogenous nature, with an aim of evaluating the scope of the research and suggesting future venues (Arksey & O'Malley, 2005; Pham et al., 2014).

A total of 21 search terms were drawn from four categories: *public health (health, epidemiology, health care, medic*, public health)*, *social inequality (eqit*, inequit*, equal*, inequal*, disparit*, SES, social class, education*, income)*, *technology and innovation (technolog*, innovate*, treatment, screen*)*, and *theoretical foundation (fundamental cause, resource, diffusion of innovation)*. After initial testing and optimizing of search strings, our first search resulted in 4139 articles. Only peer-reviewed, original research articles were included. This first sample was divided into four subsets and screened based on titles and key words by four researchers, where articles needed independent relevance approval from at least two researchers to advance to the secondary screening. The second round included 465 studies, which three researchers sorted on the basis of abstracts; independent approval from all three were necessary for an article to advance to the last sorting stage. The last screening sample consisted of 51 studies, which also included three new studies found through 'hand searching', where full-text reading from three researchers resulted in a final sample of 33 studies. Full unanimity was required for a study to be excluded. This systematic design aimed at ensuring validity and methodological quality.

3.3.2. Logistic and OLS regression

Logistic regression was used in Paper II and III, due to the dichotomous dependent variables. In analyses of symptoms of depression in Paper II, traditional OLS regression techniques were used. By default, this cross-sectional approach can only prove associations, not a causal relationship, and we have therefore been cautious in drawing conclusions on causality in these analyses.

The standard coefficient formats in logistic regression, logits and odds ratios, may be difficult to interpret; we therefore chose to report effects mainly as marginal predictions, estimating the probability of having a health problem or using technology at different levels of income and education, with other covariates in the model set as observed. These predictions are presented graphically with 95% confidence intervals, inviting to "inference by eye" (Cumming & Finch, 2005). In Paper III, one of the dependent variables, asking whether respondents ever had measured their blood pressure at home, were repeated over two survey waves. However, panel data regression techniques were considered unsuited, as the panel was unbalanced, with few respondents answering the same question in both surveys. In the logistic regression models used in Paper III, the standard errors were therefore adjusted for clustering on the respondent identification variable, meaning that the model controlled for the correlation of the error term on each individual respondent.

It has been argued that logistic regression models, due to unobserved heterogeneity, are unsuited for comparing effects across samples, particularly logits and odds ratios (Allison, 1999; Mood, 2010). In Paper II, where the study population was stratified into gender- and country-specific samples, we reported marginal effects and we did not directly compare effect sizes across samples – but rather explored general trends and the differences between high- and low-preventable health problems.

3.3.3. Fixed effects regression

In Paper IV, the panel data was balanced, and the dependent variables were continuous, making it possible to run an individual level fixed effects (FE) model. When investigating health inequalities, factors such as personality traits, cognitive abilities, and genetic dispositions could plausibly influence both the dependent and independent variables in the regression model. The advantage of FE models is that these unmeasured variables, assuming they are time-invariant, are controlled for, thereby limiting the probability of spurious relationships (Petersen, 2004). In a FE model, estimates are based on deviations from a within-unit mean, i.e. each respondent's change on the dependent and independent variables over the survey waves (Halaby, 2004). This further means that only time-variant variables can be included in the models.

In the case of blood pressure and medication use, there is a possible selection issue. I wanted to investigate the effect of medication use on blood pressure levels, and whether this effect varied by education or income. However, there is a possibility that respondents with high blood pressure are more likely to use blood pressure lowering medication. In an FE model, estimates are only based on each respondents' change in blood pressure or medication use and not on variation between respondents, which substantially reduces the selection bias. To further control for changes over time affecting all respondents similarly, a survey wave dummy was also included in the models.

Mummolo and Peterson (2018) have argued that doing an FE regression is both a substantial and a methodological choice, and that the former aspect is often overlooked. For example, choosing to analyze only within-unit changes could potentially reduce much of the total variation of the dependent variable. Two proposed remedies, which is utilized in Paper IV, is to clarify in the discussion that only within-unit variance is analyzed, and to not discuss estimated effects that are larger than actual within-unit changes in the data.

3.4. Limitations

The discussions above show that there are limitations to the data material and methods used in this dissertation. In the following, I address more general methodological limitations and their potential effect on results and discussions.

In the review study, limitations are connected to the exclusion of potentially relevant studies as a result of our search terms and inclusion criteria. Grey literature was excluded as we wanted to limit our sample to peer-reviewed research, with a possible consequence being that 'close to practice' reports of technology implementation have been excluded. Second, we only included articles with a comparison of subpopulations by social categories, as this was the best fit in our theoretical framework. Initial searches returned much literature on technology implementations in low- and middle-income countries without this within-country comparative approach. These studies could nevertheless have contributed to our final knowledge base by demonstrating how technology can improve – or fail to improve – the health of vulnerable populations. Global perspectives on health inequalities may therefore be underrepresented in the review study. Lastly, in order to limit our study to explicitly innovative technologies, articles investigating medical treatment techniques and policy innovations were excluded, as we saw potential biases in assessing their innovativeness. This choice may have ruled out studies where theoretically relevant mechanisms was addressed, but where the innovation status was unclear.

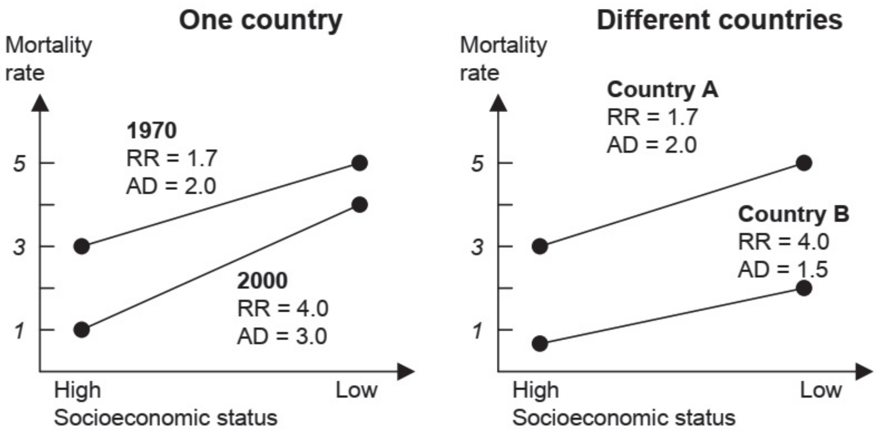
The data material in Paper II, the European Social Survey, is also associated with some limitations. First, operationalizing health conditions as questions in a survey is a challenge, as self-reports may deviate from clinical standard. However, findings from this module of the ESS are comparable to other sources, such as the World Health Organization's (2014) reports on noncommunicable diseases. Second, the preventability classification has been mentioned as a limitation. Results indicate greater social inequalities among the problems classified as high-preventable, which could act as a validation of our classification – though that is a somewhat tautological point. Our classification has its basis in the research literature, but we welcome validation studies, for instance by computing pooled variables with all combinations of health problems, regress them on age and education, and compare social gradients and model fit.

Thirdly, issues related to response rates and non-response bias are present in all survey data. With ESS response rates ranging from 31% to 68%, the included study populations may vary in representability. There may further be selection issues connected to the non-responses, potentially along vital dimensions such as age, education, and health. As aforementioned, a potential bias related to health inequalities is the exclusion of the institutionalized population – how this differs from the non-institutionalized population on our variables of interest, and whether barriers for institutionalization differ between countries. This could, along with the aforementioned limitations connected to logistic regression, make comparisons between study countries problematic. However, the main aim of Paper II was not to directly compare effect sizes across countries, but rather to detect variation and prepare ground for further research. Cross-sectional surveys have in general issues concerning causality, but despite these shortcomings, by asking the same questions to a large number of people in different countries at the same time, they remain a useful tool for comparative research on associations between social phenomena.

The richness and extent of HUNT data makes it very well suited for sociological and epidemiological research. The main limitation concerns the response rates falling from 89% in HUNT1 to 54% in HUNT3. Non-responder studies using questionnaires and register data showed more a pronounced decrease among men and younger adults, and that non-participants had higher prevalence of CVDs, diabetes mellitus, psychiatric disorders, lower socioeconomic status, and higher mortality rates compared to the participants (Krokstad et al., 2012). This could indicate a selection bias, where the respondents remaining in the HUNT study are of better health and more affluent than non-responders, potentially leading to an underestimation of social inequalities in health outcomes.

At a more general level, an ongoing debate in the quantitative health inequalities research are the advantages and drawbacks of using absolute or relative measures of inequality. Figure 2 shows a hypothetical model of how temporal changes in mortality inequalities may be interpreted differently using absolute and relative indicators. In the left panel, total mortality decreases, while absolute and relative inequalities increase – the latter more than the former. In the right panel, country A shows smaller relative inequalities but larger absolute inequalities than country B. Which measure should health inequality researchers choose? When all groups improve, and the group with the worst initial health has a smaller rate of improvement, relative inequalities increase while absolute inequalities decrease. Proponents of relative inequality have therefore argued that relative measures are better for tracking progress, since a reduction in relative inequalities implies both a reduction in absolute inequalities and that disadvantaged groups improve relatively faster (Harper et al., 2010, pp. 8-9).

Figure 2: Absolute and relative inequalities in health



Source: Krokstad (2004)

Ultimately, to focus on absolute or relative inequalities is a value judgement as well as a methodological choice. Harper and colleagues (2010) have argued that relative inequality implicitly assumes an egalitarian position where equality between groups is of more importance than overall public health developments. Unless made explicit, this assumption could affect conclusions; Pareto-like situations where all social groups have experienced absolute health improvements could be described as unfortunate developments unless the relative relationship has improved. The authors suggested that researchers for one, should avoid to uncritically rely on a single inequality measure, and second, should strive for transparency and identify the moral judgements implicit in their choice of indicator (Harper et al., 2010).

First, in the papers using quantitative methods, relative measures of inequalities were supplemented by prevalence differences in initial bivariate analyses in addition to post-estimated predictive margins. Though the latter is not directly measuring absolute differences, it provides information about the absolute probability of given outcomes. Second, concerning implicit assumptions: By several indicators, health is distributed as a gradient in the population, affecting all layers of society; one motivation for investigating health inequalities and innovative technology was to understand the mechanisms behind this fundamental stratification of society. In that respect, an egalitarian point of departure was considered beneficial.

Lastly, though the social causation explanations have become mainstream in sociology as well as social epidemiology, advances within neighbouring fields have suggested the importance of hereditary confounders such as personality traits (cf. Chapman, Fiscella, Kawachi, & Duberstein, 2009; Nabi et al., 2008). Examples relevant for this dissertation could be openness to innovative technologies, adherence to medical advice, and genetic dispositions towards non-communicative health problems and high blood pressure. The analyses performed in Paper II, III, and IV do not adjust for such factors, though the use of FE regression in Paper IV controls for time-invariant unmeasured variables. However, the role of genetic variation should not be overrated; the actual impact of genetic variants, their interactions with the environment, and their role as determinants for both social and health outcomes appears marginal (Mackenbach & de Jong, 2018). An example is Brandkvist and colleagues (2019), who used HUNT data to compare people by their genetic disposition for obesity, finding that though genetic dispositions mattered for the risk of obesity, the main contributor to a high BMI was the social environment. Mackenbach (2010) has argued that though social inequalities in health may have a genetic component, this does not make them inevitable, unremediable nor fair, and further discoveries of the contributions of genes should not inhibit action within research and policy.

4. Summary of papers

4.1. Paper I: Innovative technologies and social inequalities in health: A scoping review of the literature

In this article, published in Plos One on April 3, 2018, Weiss, Rydland, Øversveen, Jensen, Solhaug, and Krogstad gave an overview of the research field of health inequalities and innovative technologies from 1996 to 2016. The motivation for the paper was a tendency of proposing technological innovations as a solution to many present health challenges, while theoretical predictions and empirical results suggested a downside to this development – social inequalities in adopting and benefiting from innovative health technology. We aimed to increase the knowledge base and provide a foundation for further research in the field by assessing results from published research where social inequalities and innovative medical technology were the objects of study. Subsequently, we wished to explore how innovative health technology was defined as a concept, how social inequality was measured, and how the causal mechanisms between technology and health inequalities were explained. Systematic searches in the databases Medline, Scopus and ISI Web of Science was followed by several rounds of screening, resulting in a corpus of 33 studies.

Using scoping review techniques, the article did not aim at a quantifying the results from our study population, but rather to explore broad research questions and synthetize knowledge in a fairly new and interdisciplinary field. We found a majority of quantitative studies using the ‘usual suspects’ of socioeconomic and demographic variables to measure inequality. These variables included ascriptive factors such as age, gender, and ethnicity; factors oriented towards material resources such as income, education, and occupation; and geographic location, often utilizing the urban/rural divide. The outcome variables included access, distribution, and use of technologies, in addition to inequalities in morbidity and mortality as consequences of technology adoption. The health technologies were mainly designed for and used within the health care system and could be classified into three categories based on their relationships with the end-user: *direct end-user technologies*, *direct-use gatekeeper technologies*, and *indirect-use gatekeeper technologies*.

When explaining the mechanisms connecting social position, innovative health technology, and health outcomes, the included studies drew on several perspectives, among those the social determinants of health framework, the fundamental cause theory, diffusion of innovation, and health and digital literacy. We argued that there is a lack of sensitivity regarding how these pathways are context-dependent, and how choosing specific measurements of social inequality, technology, and health outcomes could lead to different results.

My contribution to this article was in conceptualization and study design; data screening, analyses, writing, reviewing, and editing.

4.2. Paper II: Educational inequalities in high- vs. low-preventable health conditions: Exploring the Fundamental Cause Theory

This paper aimed to explore whether there were different social gaps or gradients between health conditions classified as high- and low-preventable. Our main hypothesis, derived from earlier research, was that the influence of one’s position in the social structure has a stronger influence on health problems with a high degree of preventability – for instance by health care efforts, individual behavior changes, or use of health technology. This way of ‘testing’ the fundamental cause theory has been well established in previous research; a common approach is to compare causes of death amenable and non-amenable to medical care or behavior change (cf. Mackenbach et al., 2015; Mackenbach et al., 2017; Phelan et al., 2004). This paper is among the first to employ this approach to a cross-European morbidity setting.

We used the seventh wave of the European Social Survey, which included a module on the social determinants of health. Our dependent variables were self-reports of health problems over the last 12 months, which subsequently were classified as high-preventable (back or neck pain, breathing problems, cancer, depression, diabetes, heart or circulation problem, high blood pressure, muscular or joint pain in foot or leg, muscular or joint pain in hand or arm, stomach or digestion related) and low-preventable (allergies, severe headaches, skin condition related). Educational attainment served as a measure of SES. Age-adjusted regression analyses were performed for men and women on each separate variable and on pooled high- and low-preventable conditions variables. Overall, there was a larger proportion of educational gaps, where the primary educated had a significantly higher probability of health problems than the tertiary educated, among the high- than among the low-preventable conditions. This pattern, indicating support for the fundamental cause theory, was supported by our analyses of pooled condition variables.

The prevalence and strength of the educational gaps varied between conditions and countries. Additionally, a model including a gender-education interaction variable indicated that the effect of high education on high-preventable health conditions was stronger among women than men. This led us to argue for a stronger integration of institutional perspectives to better explain the different pathways between socioeconomic status, gender, and various health outcomes in different national contexts.

This study has established a foundation for further research by supporting the explanation power of the fundamental cause theory, while also pointing out how preventive measures, such as technology, have an unequal distribution. Erling Solheim and Terje Andreas Eikemo were co-authors. My contribution was study design, performing a literature review, and writing the background, discussion, and conclusion sections.

As of November 2019, this paper is under review with the journal *Social Science and Medicine*.

4.3. Paper III: Monitoring the social gradient: Inequalities in use of blood pressure monitors in the HUNT study

The third paper aimed to investigate the social gradient in use of blood pressure monitors, a common innovative health technology, and whether they were stabile over time. Expectations from previous research on technology and health inequalities was that there would be inequalities in use, and that these inequalities would decrease as the technology became more widely adopted across all social strata.

Data from the Nord-Trøndelag Health Study (HUNT) was linked to Norwegian registries. The dependent variables were self-reports of having measured blood pressure at home, having a blood pressure monitor at home, and having used a 24-hour blood pressure monitor. Explanatory SES variables were income quartiles and educational attainment, and control variables were age, systolic and diastolic blood pressure, gender, and survey wave. Results showed that education was significantly associated with having a blood pressure monitor at home (in 1997), but not associated with having used a 24-hour blood pressure monitor (in 2008). In addition, interaction terms between SES measures and survey wave showed that the social gradient in ever having measured one's blood pressure at home was stronger in 1997 than in 2008.

Results from these analyses indicated a hierarchical adoption pattern, with that supporting the diffusion of innovation theory. They further suggested that use of innovative health technology could be a mechanism connecting inequalities in flexible resources to health outcomes.

As of November 2019, this paper has been submitted to the journal *Technology in Society*.

4.4. Paper IV: Medical innovations can reduce social inequalities in health: An analysis of blood pressure and medication in the HUNT study

In this study, I aimed to combine the insights and approaches from the previous papers and investigate how technological innovations could contribute to the association between socioeconomic status and health outcomes. My technology indicator was blood pressure medication, an innovation which since the 1960s has become a widespread remedy against hypertension. I argued that this is an innovation late in its diffusion process, plausibly reaching the whole population, from early adopter to laggard.

The study utilized panel data from the HUNT Survey, waves one through three. Fixed effects regression analyses were performed; control variables included age, survey wave, and a series of lifestyle and biomedical factors. Analyses were stratified by gender, and two measures of blood pressure (systolic and diastolic) and SES (educational attainment and income quartile) were utilized. In the final models, I found an interaction term between medication use and SES to be negatively associated with diastolic and systolic blood pressure, suggesting that the medication had a social levelling effect. Effect sizes were small, but statistically significant, and comparable across both blood pressure measures and genders.

In the discussion section, I first addressed the socioeconomic inequalities in blood pressure levels throughout all statistical models. I discussed other plausible working mechanisms than unequal use of blood pressure medication, such as use of other blood pressure-related remedies, unequal use of health care services, unequal treatment by medical professionals, and differences in diet not intercepted by the models' controls. Second, I addressed the levelling effect of medication. With blood pressure medication being an innovation late in its diffusion process, adoption across all social categories was expected in accordance with the diffusion of innovations theory. In the discussion of the levelling effect of medication, I suggested that inequalities in the accumulation and prevention of other risk factors, i.e. that people of high SES may treat their blood pressure with additional measures to prescription medication, made the marginal effect of medication smaller. Relatively large inequalities were found between medication adopters and non-adopters of low SES. I discuss how resources additional to those associated with education and income can be relevant for health inequalities.

As of November 2019, this paper is under review with the journal *Health Sociology Review*.

5. Discussion

In this chapter, I present my findings and place them in an empirical and theoretical context. First, results are summarized. Then, they are compared to an empirical and theoretical framework following two thematic lines: how technology relates to the mechanisms connecting social position and health outcomes; and how a richer conceptualization of resources could benefit future studies within this field.

The overarching aim of the dissertation was: How do innovative technologies affect social inequalities in preventable health conditions? To answer this, secondary research objectives were pursued in four papers: I) What is the status of the literature on the field of health inequalities and innovative technologies? II) How does the social gradient differ between health problems high- and low-preventable by behavior change, medical care, and health technologies? III) What is the magnitude and temporal development of social inequalities in the use of blood pressure measurement technologies? IV) How does innovation in blood pressure medication affect social inequalities in blood pressure? Empirically, the four studies found

I) that most literature suggest social inequalities in use and effect of innovative health technologies, while pathways and measurement sensitivity was underacknowledged.

II) more educational gaps among high- than low-preventable conditions, with variation between countries, genders, and conditions suggesting benefits from integrating institutional perspectives

III) income- and education-related inequalities in the use of blood pressure monitoring equipment, which appeared to decrease over time

IV) that blood pressure medication may have a levelling effect in social inequalities in blood pressure levels, possibly due to it being late in its diffusion process

These results show that social inequalities are larger among high-preventable health conditions, that innovative technologies may be a contributing factor to these inequalities, and that the association between SES and health technologies is reduced over time. The studies differ in design, methods, and data, but all findings support aspects of the FCT and DoI, suggesting that unequal diffusion of innovative technologies can be a relevant mechanism contributing to the association between social position and health. In addition, the patterns of hierarchical diffusion predict a levelling in use, access, and effect of health technologies. However, placed in a wider sociological context, the results also challenge some aspects of the theoretical frameworks of health inequalities. In the following, I discuss these consequences and suggest issues that should concern future research and policy making.

5.1. Mechanisms

The reviewed literature and the empirical analyses have all demonstrated social inequalities in health or health-related outcomes. Inequalities are found in high-preventable health problems, in use of blood pressure monitors during early stages of diffusion, and for non-users of blood pressure medication. These patterns are contrasted by smaller inequalities in low-preventable health problems, in use of blood pressure monitors late in the diffusion process, and among the adopters of blood pressure medication. Persisting or increasing health inequalities through technological developments and expanding welfare and health care services have by many been labelled ‘ironic’, ‘paradoxical’, or ‘puzzling’ (Link, 2008; Mackenbach, 2012). The irony or paradox is rooted in an underlying assumption that these advances should lead to a levelling of inequalities. The FCT represents a break with this assumption. Due to the differing access and use of innovations, this relationship is not ironic but causal; health inequalities persist or increase *because* and not *despite* of societal and technological progress, leading to the prediction that health inequalities will increase in tandem with our ability to control disease and death (Freese & Lutfey, 2011).

This dissertation shows that though inequalities in general are larger for diseases where preventability is high, technological advances can over time contribute to a levelling. How do these findings compare against the different understandings of health inequalities amidst technological advances? For one, they suggest that technologies late in the diffusion process may give lesser returns on education and income, i.e. have stronger effects on the lower social strata, thereby indicating a silver lining of the social gradient – "help is on the way" (Cutler et al., 2006, p. 117). Second, the fact that the adoption of blood pressure medication appears to have a stronger effect for low-SES respondents add weight to the argument that associations between social position, technology, and health outcomes should not be treated as static and linear (Braveman, Egerter, & Williams, 2011). Innovative technologies exist and operate in a social environment; they affect and are affected by developments in the social structure such as institutional reforms, educational expansion, economic cycles, and cultural atmosphere.

On a similar note, Mackenbach (2017) has argued that the diffusion of smoking and the following inequalities are dynamic rather than laws of nature. Both the smoking and the smoke-cessation 'epidemic' reached Southern Europe later than Northern Europe, possibly explained by delayed economic and cultural modernization accompanied by behavior change. While smoking now is marginalized as a low-status phenomenon in Northern Europe, thus generating social inequalities in mortality, this development is not necessarily 'waiting to happen' in Southern Europe. Several other social forces may affect these inequality patterns, such as advances within prevention and treatments, which appear to be adopted in Southern Europe at a faster pace than the Northern smoking inequalities.

Returning to Lupton's (2012: 17) example of blood pressure medication, she lists an array of pathways between researchers developing a drug, doctors adopting it, and patients taking it, aiming to show how "the technology itself is an active agent in the network of knowledge and practice that surrounds the treatment of high blood pressure". The decreasing inequalities in blood pressure monitor use and apparent levelling effect of blood pressure medication may be the results of more than diffusion processes ending in adoption across all social strata. As noted in the paper, patients' use and effect of monitors and medication may depend on factors such as and formal and informal obstacles to receiving treatment, potential side effects of different medications, and the accumulation of individual risk factors.

Applying perspectives from the medicalization tradition could inform and add nuance to these findings. Such perspectives are not unfamiliar to the health inequalities field. An example is Buffel, Dereuddre, and Bracke's (2015) study of the medicalization of unemployment, where people in unemployment or insecure jobs showed increased use of antidepressants and health care services, irrespective of mental health status. This approach could similarly be employed to the study of health inequalities and innovative technologies, e.g. within blood pressure treatment. Increased use and effect of blood pressure medication and monitors could indicate that blood pressure increasingly being defined and treated as a symptom of disease, regardless of its effect on the patients' well-being. A relevant research question could be how these medicalization processes are distributed across the social strata.

Future research and policy making could also benefit from differentiating and comparing technologies, to better emphasize specific, inherent features and their relations to social inequalities in health outcomes. In Paper I, we categorize the technologies from our reviewed articles as *direct end-user, direct-use gatekeeper*, and *indirect-use gatekeeper*. These categories build on the interaction between individuals' experience of control and the health care professionals' regulation of the technologies. In future research, they may be fruitful concepts when making inferences about the mechanisms connecting SES, technology, and health outcomes. These categories could for example be deployed when comparing the role of agency vs. structure in the use of health technologies; when exploring how the medical professions understand and carry out their role as gatekeepers; and when investigating how the access to technologies are affected by the organization of health care and external pressures. In Paper III, I discussed how blood pressure monitors can be classified as both *direct-use gatekeeper* and *direct end-user* – they can be assigned to a patient by a physician but are also available on the open market – and the implications this may have for the interpretation of results. Here, I suggested how the level of technology gatekeeping affects the relative importance of material and immaterial patient resources.

As noted in the review study, most of the studied technologies have been located within the health care systems. However, innovative health technologies have increasingly become available for personal use. These are less regulated by public bodies, with less available data as a consequence. Nevertheless, this is for several reasons a field with research potential. One example is genome sequencing, where increasing computer capacity have made these types of test available to the public through commercial companies. While a total 14 companies offered health related genetic tests in 2002, the number today is over 250 globally. The risk of future diseases, personal characteristics, family or ethnic relationships, pharmacogenetics, and exercise and diet are some of the tests being offered (Olsson, 2019). Health benefits from these tests are uncertain; findings from Turnwald and colleagues (2019) indicated that knowledge of genetic risk for disease could alter health behavior to the worse. At the health care side, Vogt, Green, Ekstrøm, and Brodersen (2019) have argued that precision medicine based on Big Data, such as genomics, data from imaging, electronic health records, social media, new biosensors, and self-tracking technologies, can lead to overdiagnosis and overmedicalization, possibly making it more challenging to prioritize and determine clinical importance. Lastly, though these tests have become more commonly available, they are still associated with a substantial economic cost. If we see a development where high-SES patients participate in these tests and subsequently expect follow-up from the health care services, a two-tier system with increased inequalities may be the result.

Though the results from this dissertation's empirical papers suggest support for hierarchical diffusion patterns as a mechanism connecting the fundamental cause of social conditions to health outcomes, there are also less straightforward interpretations. Initial inequalities may be levelled out as the innovation is diffused, but this is not necessarily a 'natural' consequence of technology implementation. Knowledge and awareness of inequality pathways and mechanisms should be present at all stages of technology implementation within the health care sector. There may be a silver lining to the technology-induced social gradient, but it is most likely the result of multifaceted processes rather than unidimensional diffusion.

5.2. Resources

Although the FCT notion of 'resources' have both material and immaterial aspects, the latter is seldom operationalized in empirical research (Mackenbach, 2012). Many studies in the FCT tradition assume an association between resources such as money, knowledge, power, prestige, and social connections, and measurable individual-level socioeconomic characteristics such as income, wealth, educational attainment, occupation, or social class. In this dissertation, measures of educational attainment and income are meant to intercept the material and immaterial features of the resources concept. When discussing results, I address independent causal pathways between education, income, and health outcomes as well as more overarching mechanisms. Here, these indicators of SES reflect flexible resources which can also be applicable in other settings.

Several scholars have highlighted how different measures of social position are connected to health outcomes through different pathways (Elo, 2009; Grundy & Holt, 2001; Regidor, 2006). Particularly have the use, or lacking use, of social class spurred some debates. Some scholars have claimed that the use of several class-associated factors instead of more 'direct' measures of social class risks 'explaining away' the influence of class positions, class relations, and class societies as overarching, structural phenomena (Smith et al., 2016).

Braveman and colleagues (2005) have advocated greater measurement sensitivity in the health inequality research, stating that "One size does not fit all" – different indicators of social position should yield different conclusions. Adding to this is Deaton's (2002, p. 14) claim that though socioeconomic status may be a convenient term, it is "unhelpful for policy discussions". Others again argue that the focus on unidimensional measures of social position may overlook multifactorial and intersectional effects (Gkiouleka, Huijts, Beckfield, & Bambra, 2018; Veenstra & Abel, 2019). Investigating specific pathways for specific measures without falling into reductionism is a balancing act; though income, education, occupation, and other indicators of social position have different implications for health, attempts to disentangle each effect may ultimately end up with saying something very specific about something very little. Mackenbach and de Jong (2018) have written of how new (quasi-) experimental methods have come far in identifying genuine, independent causal effects of socioeconomic status on health, but with a potential cost: Differences in years of education or monthly income may not capture the full extent of social inequality as it is recognized in sociological research. Individual experiences of power relations and the cumulative, interacting effects from living in socioeconomic disadvantage over a life-course are more challenging to measure – but equally important to investigate. Although resources in the FCT can be considered ambiguous, they are able to intercept the continuous impact of social conditions on health, emphasizing how socioeconomic disadvantage is detrimental to health in several contexts. By applying such a perspective, this dissertation can identify similar mechanisms in both a cross-sectional analysis of ESS data as well as longitudinal studies using HUNT data.

A vital component of the resources concept is flexibility; they are health-beneficial through various circumstances and for a range of health outcomes. How to best reflect this flexibility when investigating linear relationships between health outcomes and measures of socioeconomic status, remains a question. The findings of Masters and colleagues (2015) indicated that the same resources may predict different health outcomes in different contexts. Findings from Paper II add to this, as the associations between education and the high- and low-predictable health problems vary considerably by country and gender. Findings from Paper

III and Paper IV demonstrated that stages in the diffusion process could represent these different contexts; the return from education- and income-associated resources diminished as innovations related to blood pressure management was diffused over the study years. With that, the results also supported the Korda and colleagues (2011), as they argue for including a temporal aspect when investigating health inequalities and innovative technologies: Inequality effects of technology implementation may be interpreted as a consequence of diffusion, with further changes in inequality patterns at the stairs.

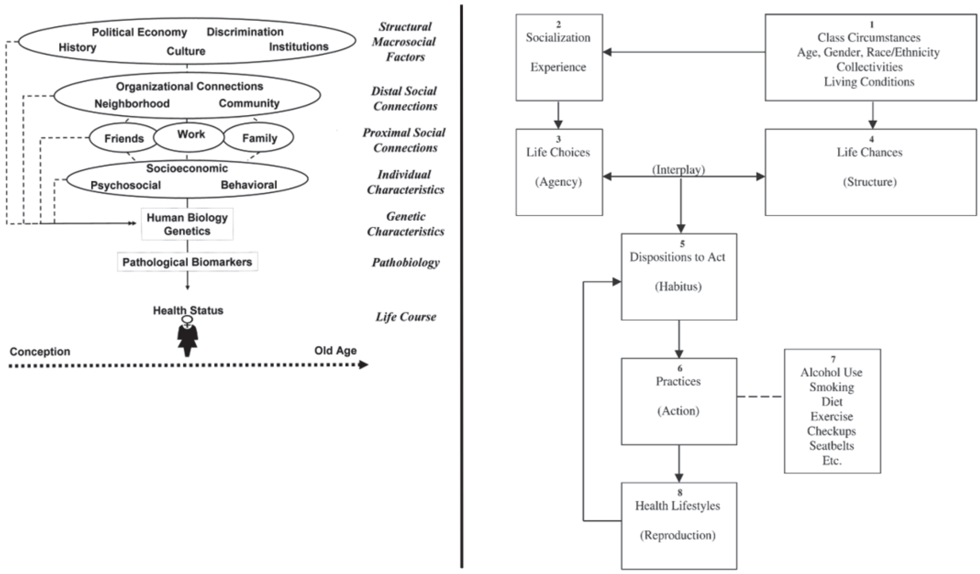
Nevertheless, whether our understanding and operationalizations of resources are rich enough to intercept the causal pathways remains unclear. Mainstream theories on health inequalities seem to implicate that 'good health' is something equally sought after by people of all social positions, that disadvantageous lifestyles and interactions with health care services are results of lacking resources alone. Pepper and Nettle (2017) have written of how health-detrimental behavior by people in lower social strata in fact may be appropriate responses to contexts where they experience low control over extrinsic mortality risks. Health improvement measures may be easier to prioritize for people whose life situations are characterized by control, fulfillment, and prospects of economic security (Deaton, 2002; Freese & Lutfey, 2011). These insights suggest that the motivation and preference for health improvement, which again may affect the inclination to use complicated technological health innovations, is not equally distributed. Could initial inequalities in monitor use be explained by different motivations for reducing one's blood pressure? As argued in Paper III, informal processes and immaterial resources, e.g. knowledge, motivation, and social networks, may be of special importance when investigating technology-related inequalities in health care systems operating by universalistic principles. Encompassing welfare state arrangements have only partly been able to eradicate inequalities in material resources, while inequalities in immaterial resources may not have been reduced at all (Mackenbach, 2019). Approaches offered by cultural health capital perspectives could be of relevance here, as they invite to and explore how people's health and bodies are subjects to symbolic power and acts of social distinction. An example from Vandebroeck's (2016) research is how the lower classes reject docility and self-control in areas such as eating, drinking, and smoking, while Flemmen, Hjellbrekke, and Jarness (2017) have shown how the middle and upper classes in egalitarian Norway exhibit a taste for healthier food. These are tendencies which very likely could be extended to technology use.

Another approach to revitalize the resource concept could be to identify collective resources at the structural level, such as social benefits and health- and welfare services (Sjöberg, 2017). In a study of surgical innovation, Miller, Saigal, Banerjee, Hanley, and Litwin

(2008) found surgeon characteristics to be more important than patient characteristics in explaining the diffusion of innovative surgery. In a Norwegian context, Elstad (2018) found that somatic hospital consultations had a significant educational gradient, while Brekke, Holmås, Monstad, and Straume (2018) demonstrated how GPs treated low-educated and low-income patients differently with regards to consultation length and medical tests. Präg, Wittek, and Mills (2016) have shown that less egalitarian and more paternalistic doctor-patient relationships have a negative association with self-rated health for low educated, but not for the medium and higher educated. All findings indicate how institutional factors may contribute to inequalities in health outcomes within a universal health care context. Adding to this, Korda and colleagues (2011) have suggested a stronger emphasis on the important role of health practitioners in diffusion studies, such as their attitudes towards innovative technologies and perceptions of their patients' resources. In Paper IV, the diffusion of blood pressure medication is described. In its later stages, medication is the preferred treatment of hypertension, presumably being used across all social strata. The levelling effects of medication on social inequalities in blood pressure levels may be associated with this 'free' diffusion, but also by other factors located within the health care services, such as (intentionally or unintentionally) differentialized treatment regimens for people in different socioeconomic positions.

For future researchers and policy makers, it is also worth considering how features of the Norwegian health care system may create dynamics rewarding a particular set of resources; many technologies are produced by commercial companies operating by financial incentives – but introduced to a system operating by universalistic principles, nevertheless oriented towards cost-cutting and following restrictions. Figure 3 is a stylized display of how a model inspired by cultural health capital (right) can be more dynamic than a traditional social determinant model (left). Put simply: Structural traits such as class relations and living conditions constitutes structures. The interplay of life choices and life chances affect health practices, which again contribute to the reproduction of the structures. A dynamic model allows for resources at the individual and structural level to interact, producing and reproducing patterns of health inequalities, rather than being at the downstream end of a causal chain.

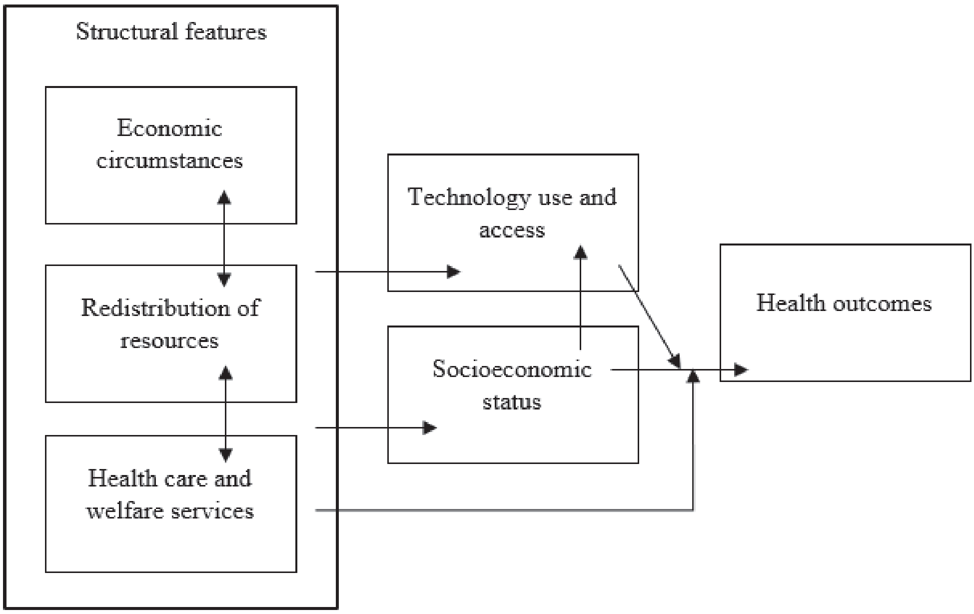
Figure 3: Social determinants vs. Cultural health capital



Source: Kaplan (2004) and Cockerham (2005)

How do innovative technologies affect which resources are available, and not available, at the system level for people of different social positions? As mentioned above, the study of health inequalities' structural causes should also address the *causes of the structures* and would therefore benefit from incorporating theoretical perspectives on the production and reproduction of inequalities. Results from Paper II suggested that the association between educational resources and health problems preventable by technological innovations varied substantially between the study countries, which can be regarded as an invitation to pursuit comparative studies. For example, could patient empowerment technologies lead to high-educated patients benefitting while the lower educated stagnate – what Therborn (2013) termed *distanciation*? Another relevant perspective could be Beckfield and colleagues' (2015) *institutional imbrication*, e.g. an overlap between hierarchization from the educational system and complex treatments dependent on personal agency, such as if the digitalization of patient-physician communication makes resources associated with educational attainment particularly beneficial. This would follow up previous calls (cf. Beckfield, Olafsdottir, & Sosnaud, 2013; Freese & Lutfey, 2011) on emphasizing institutional agency and logics, and potentially incorporate technology diffusion as a structural and political feature. Figure 4, inspired by Cockerham's (2005) dynamic model, is an attempt to illustrate that technology use and access can be influenced by both structural and individual socioeconomic factors, in addition to being a confounder between social position and health outcomes.

Figure 4: Suggestive framework for studies of technology and health inequalities



5.3. Concluding remarks

The research performed in this dissertation have demonstrated that though there is a growing and diverse literature indicating that innovative technologies may be a contributing factor to health inequalities and innovative technologies, more research is needed to investigate how specific technologies and indicators of social position have different pathways to health outcomes. These pathways will also differ between contexts: social inequalities were greater among self-reported health problems preventable by measures such as health technologies, but these associations varied between countries, health problems, and genders. Lacking integration of structural factors have been mentioned as a shortcoming with the mainstream theories in the health inequalities field, including the fundamental cause theory. The diffusion of innovation framework is proposed as a way of expanding the theory, with stages in the diffusion process adding context in which the flexible resources can be employed. This implies treating technology use not only as an independent, confounding factor between an individual's available resources and health outcomes, but also how technologies are embedded in the social structure. Results indicate support for diffusion following a socioeconomic hierarchical pattern, with initial social inequalities before later levelling. However, interpreting the findings also question whether equality in use and access is an inevitable consequence of free diffusion, or whether other mechanisms have been at play, such as varying motivation or health preferences, institutional obstacles, or appropriate responses to difficult life situations. New explanatory models should identify how material and immaterial health-beneficial resources are produced and reproduced at different levels and different stages in the process.

Diffusion patterns are not natural laws, and equal access, use, and effect of innovative health technologies does not follow automatically after the introduction of an innovation. The aforementioned 'silver lining' in health technology needs political and professional curation. Innovations in health technology have been proposed to solve several of the problems facing public health in the immediate future. The present research has shown that the introduction of new technologies may lead to initial inequalities, but with potential for later levelling. Potential inequality aspects need to be considered when introducing new technologies, both with regards to the society where the technology is introduced and the inherent features of the technology, its complexity and otherwise dependence on individual resources.

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Paper I:
Innovative Technologies and Social Inequalities in Health: A Scoping Review of the Literature

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RESEARCH ARTICLE

Innovative technologies and social inequalities in health: A scoping review of the literature

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Abstract

The aim of this study was to systematically review the range, nature, and extent of current research activity exploring the influence of innovative health-related technologies on social inequalities in health, with specific focus on a deeper understanding of the variables used to measure this connection and the pathways leading to the (re)production of inequalities. A review process was conducted, based on scoping review techniques, searching literature published from January 1, 1996 to November 25, 2016 using MEDLINE, Scopus, and ISI web of science. Search, sorting, and data extraction processes were conducted by a team of researchers and experts using a dynamic, reflexive examination process. Of 4139 studies collected from the search process, a total of 33 were included in the final analysis. Results of this study include the classification of technologies based on how these technologies are accessed and used by end users. In addition to the factors and mechanisms that influence unequal *access* to technologies, the results of this study highlight the importance of variations in *use* that importantly shape social inequalities in health. Additionally, focus on health care services technologies must be accompanied by investigating emerging technologies influencing healthy lifestyle, genomics, and personalized devices in health. Findings also suggest that choosing one measure of social position over another has important implications for the interpretation of research results. Furthermore, understanding the pathways through which various innovative health technologies reduce or (re)produce social inequalities in health is context dependent. In order to better understand social inequalities in health, these contextual variations draw attention to the need for critical distinctions between technologies based on how these various technologies are accessed and used. The results of this study provide a comprehensive starting point for future research to further investigate how innovative technologies may influence the unequal distribution of health as a human right.

Competing interests: The authors have declared that no competing interests exist.

Introduction

Despite expectations to the contrary, social inequalities in health appear to be increasing in many of the world's most developed countries during an era of rapid innovative technological development [1–3]. As the quantification of health in modern society intensifies and innovative health technologies become the cornerstone of this transition, the connection between technology and health is garnering increased attention [4–7]. Recent years have witnessed an era of intensified technology use in health care services [8] as well as developments in personalized medicine and the use of big data for health purposes. These advances have promoted a growing dependency on technology in society and the collection of advanced information, including that of the personal genome, which are then used to influence the decisions and behaviors of not just ordinary citizens but also health personnel, private companies, and large institutions [9–11]. These innovations are generally seen as positive developments, improving the diagnostics and treatment of disease as well as general public health, however their wider societal implications can be questioned [10, 12–14]. It appears likely that these technologies could be improving general public health but at the cost of increasing inequalities in health [13, 15].

Various publications have addressed the importance of further investigating the potential implications that the rapid development and increased prioritization of various technological innovations in health have on the health of society as a whole [3, 10–12, 16, 17]. Other studies have empirically investigated the production of inequalities in health due to the advent of innovative technologies [18–20]. These studies demonstrate that individuals of higher socioeconomic status (SES) are the first to adopt, and benefit most from, the introduction of innovative technologies in health, creating social inequalities in health where they were once very low or nonexistent, or in some cases even inverting these inequalities (where improved health outcomes have moved from lower SES groups to higher SES groups). This phenomenon is further illustrated by results demonstrating larger social inequalities in health among populations suffering from illnesses for which effective preventive or treatment techniques have been developed [21]. These studies provide a starting point for investigating additional mechanisms that may explain the (re)production of social inequalities in health [22, 23]. As the rate of innovative health technology intensifies, a better understanding of this perspective is becoming increasingly important.

Still missing from the literature is a broad foundation from which to further investigate and explain the connection between technological innovations and social inequalities in health. The following questions are still in need of clarification:

- How are *innovative health technologies* defined in a social inequalities context?
- What are the implications of using various measurements of social inequality?
- How do existing studies explain the potential relationship between *innovative* health technology and social inequalities in health?
- How may *innovative* health technologies reduce or (re)produce social inequalities in health?

The aim of this study, therefore, was to systematically review the range, nature, and extent of current research activity exploring the influence of innovative health technologies on social inequalities in health, with specific focus on a deeper understanding of the variables used to measure this connection and the pathways leading to its (re)production.

Methods

A systematic search process was conducted, based on scoping review techniques, [24, 25] for literature published from January 1, 1996 to November 25, 2016 using the following databases:

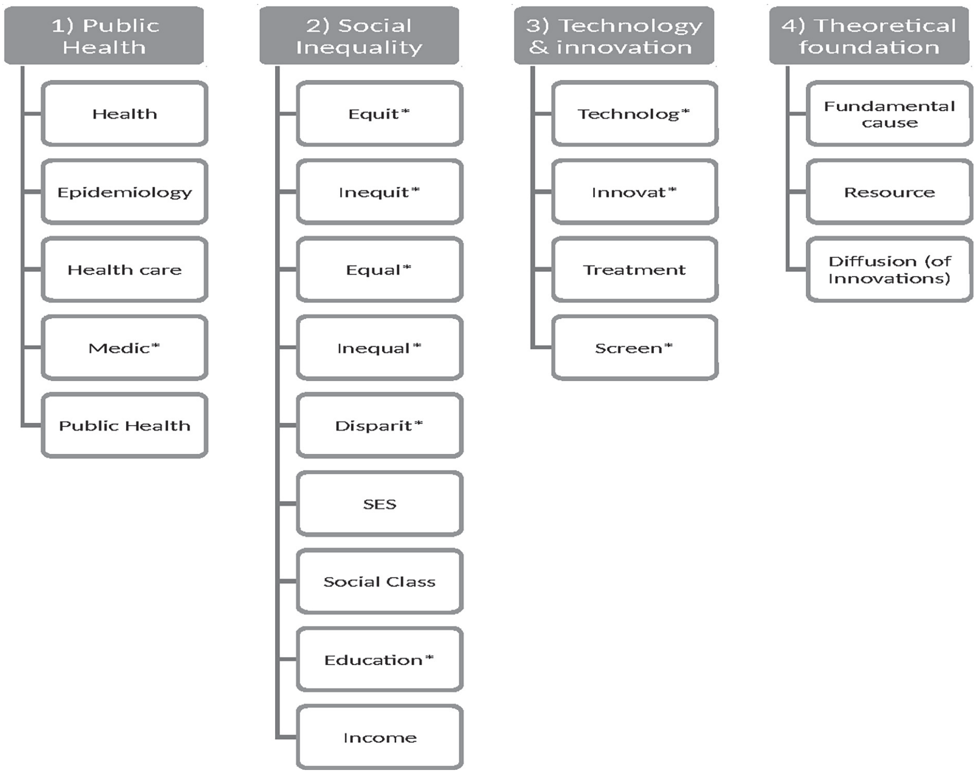

Fig 1. Search terms and their categorization into overarching themes.

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MEDLINE, Scopus, and ISI web of science. The search was updated on November 25, 2016. Scoping review methods were used for their ability to explore broad research questions and interpret large amounts of material from various forms of data and research, while providing an important first step in synthesizing a complex body of research that can be used to guide the direction of future research [26, 27].

Search terms were categorized into four categories ("public health," "social inequality," "technology and innovation," "theoretical foundation") in order to provide additional organization when combining terms during the search process (Fig 1). Only peer-reviewed studies based on original data analysis were included in this study, as interest was focused on collecting empirical analyses. A full overview of inclusion/exclusion criteria can be found in Table 1.

The initial search process was performed by two research librarians with expertise in the use of literature databases. Extensive testing of the search strings was performed before the search process. To reduce the number of irrelevant hits and increase accuracy of the searches, a proximity operator was used as well as custom search strings for each database. Rationale and search strings for each individual database can be found in Table 2.

The initial search resulted in a total of 4139 studies, after cleaning of the original data file. After sorting the dataset alphabetically by study title, the entire dataset was divided into four equal subsets. Each subset was then sorted independently by two individual researchers.

Table 1. Inclusion/Exclusion criteria.

Inclusion Criteria	Exclusion Criteria
English Language	Before 1996
Peer-reviewed original study or review, based on an original data analysis	Focus on health services or health care without specific focus on technology and inequalities
Addresses inequalities in health outcomes (also called health disparities, inequalities in health, health inequity, equity in health, etc.)	Innovations without a technological component or technologies with only a "software" component (such as new knowledge or cultural ideas)
Comparison of social groups/classes (i.e. low-income vs high income; rural vs urban; low educated vs high educated; white vs. Hispanic; etc.) or specific focus on a disadvantaged population.	Editorial, commentary, letters to the editor, columns, opinions, viewpoints, or similar
Specifically addresses technology (must include a "hardware" component, such as a tool or instrument)	
Explicit and identifiable application of *innovative* technology (new technology, or old technology used in a new way)	

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Studies deemed relevant by both researchers automatically advanced to secondary sorting. A third researcher, who had not previously worked with the respective subset, then sorted those studies deemed relevant by only one of the two original researchers. Studies deemed relevant by the third researcher also advanced to secondary screening. All relevant studies from the initial screening process were then combined into a single dataset (465 studies) for use during the secondary screening process. During the secondary screening process, three individual researchers independently sorted all studies deemed relevant from the initial sorting process using abstracts (if abstracts were not present, results and conclusion sections were used to

Table 2. Database rational and search strings.

Database	Rationale	Search string
Medline	As Medline is predominantly medically focused, a more permissive search string was used in order to open for a greater inclusion of medical studies focused on technology.	(health* OR epidemiology OR "health care" OR medic* OR "public health") adj5 (equit* OR inequit* OR equal* OR inequal* OR disparit* OR SES OR "social class" OR education* OR income) adj5 (technolog* OR innovat* OR treatment OR screen) adj5 ("fundamental cause*" OR resource OR diffusion OR innovation*)
Scopus	A stricter proximity search was used with Scopus. This was done to force the search to consider relevant words together.	(health OR epidemiology OR "health care" OR medic* OR "public health") W/5 (equit* OR inequit* OR equal* OR inequal* OR disparit* OR ses OR "social clas*" OR education* OR income) AND (technolog* OR innovat* OR treatment OR screen*) AND ("fundamental cause" OR resource OR diffusion W/1 innovation*)
ISI Web of Science	Same as Scopus	(health OR epidemiology OR "health care" OR medic* OR "public health") near/5 (equit* OR inequit* OR equal* OR inequal* OR disparit* OR ses OR "social clas*" OR education* OR income) AND (technolog* OR innovat* OR treatment OR screen) AND ("fundamental cause" OR resource OR diffusion near/1 innovation*)

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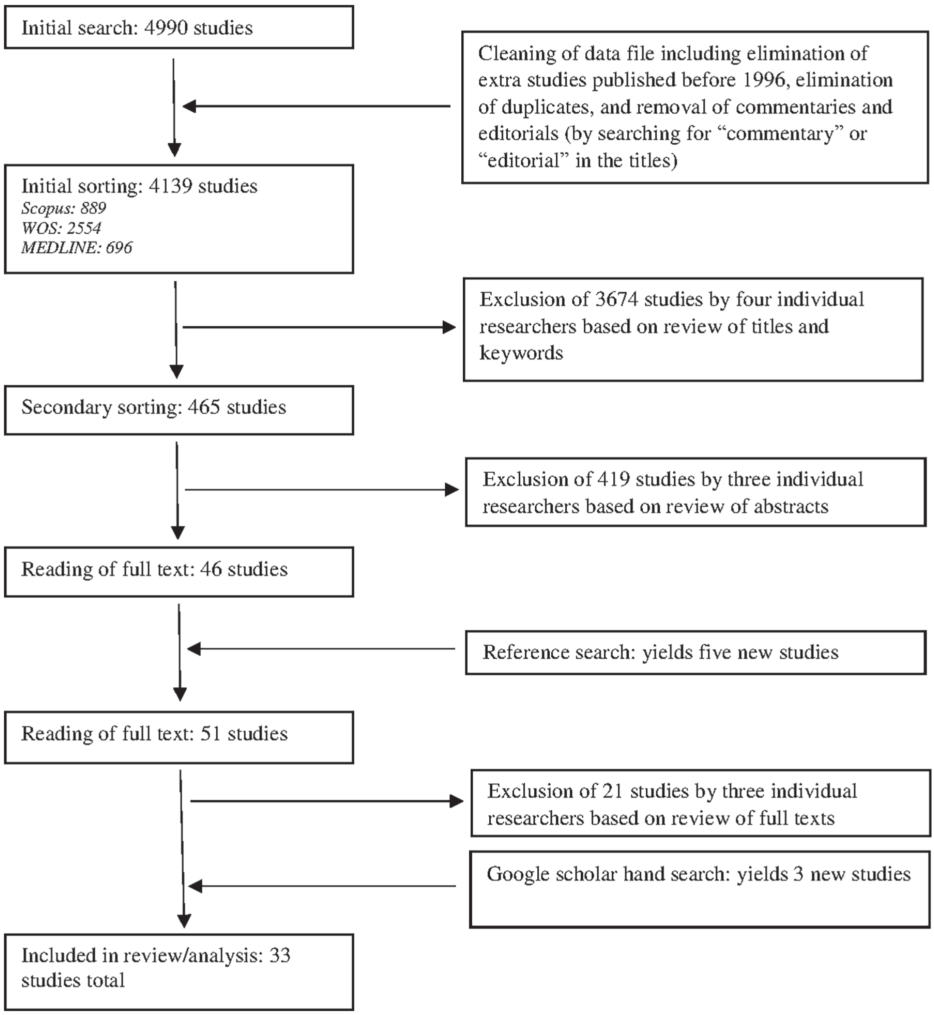

Fig 2. The sorting process.

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determine relevance). Only studies deemed relevant by all three researchers advanced to the final sorting process. In the final sorting process, three individual researchers independently read full texts of all included studies. Studies deemed relevant by all three researchers automatically advanced to the data extraction process, while studies deemed irrelevant by all three researchers were automatically excluded. Studies with inconsistent evaluations were discussed by all three researchers until agreement for inclusion or exclusion was met. The resultant studies from this multi-stage systematic sorting process were included in the data extraction process and presented in our results section (Fig 2). The inclusion/exclusion criteria was strictly applied at each stage of the sorting process and articles were excluded if deemed by multiple researchers to meet exclusion criteria based on title and keywords (stage 1), abstracts (stage 2), or full text (stage 3).

Data extraction was facilitated by the use of a data extraction form designed using procedures outlined by Armstrong et al. [25]. A data extraction form was used to systematically extract information relevant to the aims of this study as well as standard descriptive information. Along with standard title, author and year of publication information, categories included: study location; geographical level (local, regional, national or international); study population; methods used; specific illness addressed; technological innovation addressed/measured; method of implementation for the addressed technology; definition/measurement of social class/inequality; theoretical perspectives; main outcome measures (including health outcomes); overview of main results and conclusions. All full texts were read and analyzed by three individual researchers and individual data extraction forms were then merged into a single, unifying document used for the interpretation and presentation of results. Following typical scoping review methods, methodological quality of the included articles was not assessed systematically, however only peer-reviewed articles were included in our review process [24, 25, 28]. The lack of a systematic analysis of methodological quality is both a weakness and a strength of scoping review techniques. Although it is difficult for a scoping review to draw conclusions based on the quality of the included studies, the strength of a scoping review is in its ability to condense large amounts of material and guide the direction of future research including more comprehensive analyses of the quality of relevant methods [27, 28]. Assurance of methodological quality throughout the search, sorting and extraction processes in the current study however was protected using a systematic design based on a dynamic, reflexive examination process whereby multiple researchers, working at each stage of the process independently, regularly compared results and met to discuss, and reach agreement on, discrepancies [24, 27].

Results and discussion

Overview of included studies

An overview of included studies is offered in Table 3. An overview of excerpts from selected studies representing the formation of the narrative presented in the results and discussion section can be found as a table in supporting information (S1 Table. Forming the narrative–representative excerpts from selected studies). Data from the studies included in our results was most often collected using purely quantitative methods (N = 28), with some articles choosing to use mixed methods (N = 2) or qualitative methods (N = 3). Data collection varied widely between studies, with some studies addressing national populations, while others collected data at the hospital level or individual level. Of the studies addressing a specific illness (N = 18), approximately half of these addressed either HIV or blood/heart related illnesses. Of the technologies addressed by included studies, information/communication technologies (electronic health records and internet portals, e-health, internet-based social networks) and medical services technologies (prescription drugs, medical imaging, and diagnostic and treatment tools) dominated. Measurements of social position and inequality were relatively consistent with commonly used socio-economic variables, varying between income (or GDP in country comparisons), education, and employment status, in addition to geographical location, age, gender, and race/ethnicity. Outcome measures varied widely, however most studies were interested in investigating factors influencing the access, distribution, and/or use of specific technologies by various social groups (for example individual behaviors, facilitators and/or barriers). Some studies, however, addressed consequences associated with poor or limited access to these technologies, including related morbidity and/or mortality.

Table 3. Overview of included studies.

Authors	Country	Study population	Technological innovation measured or addressed	Social class/inequality variable	Main outcome measure(s)
Baum, Newman, & Biedrzycki (2014)	Australia	55 individuals located in areas with low SES	Information and communication technologies (ICT)	Race/ethnicity and socioeconomic status	Access and use of ICT
Bekelis, Missios & Labropoulos (2014)	United States	Patients undergoing any neurosurgical procedure 2005–2010	Cerebral aneurysm coiling	State/region, median income based on zip code	Average risk adjusted intensity of neurosurgical care and average coiling rate per state per year
Butler, Harootunian, & Johnson (2013)	United States	Physicians serving Medicaid and non-Medicaid patients in Arizona.	Electronic health records (EHR)	Insurance status	EHR access and use by general practitioners
Chang & Lauderdale (2009)	United States	Adults aged 20 and over from NHANES II, III, and continuous surveys.	Statin (HMG-CoA reductase inhibitors)	Socio-economic status by income	Income gradients for cholesterol levels over time
Cheng et al. (2012)	United States	Veterans hospitalized with ischemic stroke	Carotid artery imaging	Race/ethnicity	Receipt of carotid artery imaging; race of the patient and minority-serving status of the hospital
Choi & DiNitto (2013)	United States	Low-income homebound adults	Internet based information technology	Age and income	Internet use, eHealth literacy, attitudes toward computer/ internet use
Eddens et al. (2009)	United States	Cancer survivors	Internet/e-Health	Race/ethnicity	Characteristics of cancer survivors, cancer type, form of communication, website characteristics
Ferris et al. (2006)	United States	Adults (under 60) and children with asthma.	Meter dose inhaler	Race/ethnicity and age	Use of meter dose inhalers Insurance status Physician visits and reason for visit
Glied & Lleras-Muney (2008)	United States	Persons diagnosed with cancer	Drug approvals by number of active ingredients approved by FDA	Education	Mortality and drug approvals
Goel et al. (2011)	United States	Patients from an urban, academic primary care practice	Patient health portals	Race/ethnicity, age, gender, education, income	Enrollment in the patient portal, Solicitation of provider advice among enrollees, Requests for medication refills among enrollees.
Goldman & Lakdawalla (2005)	United States	HIV positive, aged 18+ who made at least one visit to clinic in 1996; Men and women aged 28–59 in 1948 residing in Framingham, Mass.	Highly Active Antiretroviral Therapy; beta-blockers	Education	Exposure to drug and health status before and after introduction of technology
Gonzales, Ems, & Suri (2016)	United States	Adults from low-income groups and staff of health care organizations	Cell phones/m-Health	Income	Experiences and challenges to using cell phones and disconnection, as well as related challenges to access healthcare and other social services.
Groeneveld, Laufer, & Garber (2005)	United States	Elderly (over 65) Medicare beneficiaries	Various "emerging" technologies: aortic valve replacement, internal mammary artery coronary bypass grafting, dual-chamber pacemaker implant, vena cava interruption, and lumbar/lumbosacral spinal fusion	Race/ethnicity	Procedure rates using emerging technologies by race
Han, et al. (2010)	Australia	General population with at least one diagnosed chronic medical condition	Information and communication technologies	Socio-economic status	Internet accessibility, socio-economic status by geographical area, prevalence of chronic disease

(*Continued*)

Table 3. (Continued)

Authors	Country	Study population	Technological innovation measured or addressed	Social class/inequality variable	Main outcome measure(s)
He, Yu, & Chen (2013)	China	Random sample of 71 hospitals from four sites	CT and MRI scanners	GDP at a regional level	Gini coefficient (equity), distribution of CT and MRI, characteristics of CT and MRI machines
Hing & Burt (2009)	United States	Non-federal office-based primary care physicians or providers (PCP)	Electronic health records (EHR)	Payment source; race/ethnicity; median household income	Likelihood of PCPs using EHR
Horvitz-Lennon, Alegría, & Normand (2012)	United States	Medicaid beneficiaries with schizophrenia who had filled at least 1 antipsychotic prescription during the study period	Long-acting injectable formulation of the atypical antipsychotic risperidone (LAIR)	Race/ethnicity and geographic location	Use of LAIR
Kontos, Emmons, Puleo, & Viswanath (2010)	United States	Representative sample of US adults	Internet: social networking sites (SNS)	Race/ethnicity and socioeconomic position	Internet access and SNS use
Korda, Clements, & Dixon (2011)	Australia	Patients (≥35 years of age) with a principal or co-diagnosis of acute myocardial infarction (AMI), and with no previous admissions for AMI, between 1989 & 2003.	Coronary procedures: angiography, angioplasty and coronary artery bypass surgery	Socio-economic status by SIEFA index of disadvantage	Receipt of a coronary procedure
Lang & Mertes (2011)	Europe	24 EU member states	E-health	Economic variables (GDP per capita, ICT market value, Broadband access in enterprises)	Effect of various economic, healthcare, and political variables on the implementation of e-health applications
Loureiro et al. (2007)	Brazil	Brazilian states	MRI, computerized tomography, and dialysis machines	Regional socio-economic status by GDP per capita	Distribution of access; number (surplus/deficit) of machines; public vs. private sector differences
Newhouse et al. (2015)	Many	Citizens 16–74 years of age who had used the internet in previous 3 months	Internet based information technology/e-mail	Geographical; education; gender; employment status	Frequency of sending emails to health personnel
Newman, Biedrzycki, & Baum (2012)	Australia	Residents from lower income and disadvantaged backgrounds in South Australia	Information and communication technologies (ICT)	Socioeconomic status	Access, usage and perceived facilitators and barriers to ICT
Ohl et al. (2013)	United States	Veterans in care for HIV infection	Combination antiretroviral therapy (cART)/raltegravir	Geographic (urban/rural); race/ethnicity; age/gender	Raltegravir adoption
Ohlsson, Chaix, & Merlo (2009)	Sweden	Individuals in Skåne region who were issued at least one prescription for statins between July and December 2005	Rosuvastatin (prescription statin)	Socio-economic status	Factors related to outpatient health care practice; physicians' propensity to prescribe rosuvastatin
Perez et al. (2016)	United States	Participants 21 to 35 years of age, had searched the Internet for health information within the past 12 months, and reported at least one barrier to health care services access.	Internet based IT	Education; recruitment from sites offering/not offering social services	Internet search behavior, strategies and processes
Polonijo & Carpiano (2013)	United States	Adolescent girls (age 13–17) and their parents/guardians	HPV vaccine (cervarix/gardasil)	Socio-economic status; race/ethnicity	Parental knowledge of the vaccine; health professional's recommendation of HPV vaccination; actual uptake, and finishing, of the vaccine
Rubin, Colen, & Link (2010)	United States	HIV positive black and white men and women between the age of 15 to 64	Highly active antiretroviral therapy	Socio-economic status; race/ethnicity	HIV/AIDS mortality before and after the introduction of highly active antiretroviral therapy

(*Continued*)

Table 3. (Continued)

Authors	Country	Study population	Technological innovation measured or addressed	Social class/inequality variable	Main outcome measure(s)
Slade & Anderson (2001)	Many	OECD countries between 1975–1995	MRI machines, CT scanners, kidney transplants, liver transplants, and hemodialysis patients	GDP per capita	Availability and utilization of technology
Stanley, DeLia, & Cantor (2007)	United States	Individuals at risk for sudden cardiac death (SCD)	Implantable cardioverter defibrillator	Race/ethnicity	ICD use and utilization
Wang et al. (2010)	Taiwan	Osteoarthritis patients ($\geq$60 years of age) who had undertaken at least one outpatient visit for osteoarthritis	NSAIDs	Income	Treatment incidence
Woolf et al. (2007)	United States	General population (adults 18–64 years of age)	General technological innovations	Education	Age-adjusted mortality
Zibrik et al. (2015)	Canada	Participants from Chinese and Punjabi public health education events	E-health: online tools for health education, communication and self-management	Ethnicity/immigrant status, age, gender, income, and education	e-health literacy

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Addressing classification and measurement challenges: Towards a more precise terminology

Social inequality. All variables used in included studies to address, define and measure social position acknowledge that these variables represent various social groups, or classes, that live in relative advantage/disadvantage to one another. These variables can be divided into three distinct approaches. The first approach is characterized by a distinction between selected social groups based on fixed (or ascriptive) factors. These studies use age, gender and/or race/ethnicity to define and measure differences between social groups. The second approach is characterized by social position determining an individual's control of various flexible resources that are to a relative degree amendable [15]. These studies generally stratify social position based on socio-economic variables such as education, income, and insurance or employment status. Unlike the two aforementioned approaches, the third approach is distinguished by the characteristics of place [29]. These studies use geographic location as a measure of social stratification, often defined as (but not limited to) a distinction between rural and urban settings.

These distinct approaches are similarly used to investigate social inequalities, however it is possible to question whether these distinct approaches can be used interchangeably to understand variations in the distribution of population health and innovative health technologies. Although SES may, for example, include various measures such as education, income, and occupational status, used alone or in combinations, one could question whether the mechanisms connecting education to health and technology are the same as the mechanisms connecting occupation or insurance status to health and technology. In relevant literature, such reflections are by and large missing, and very different measures of social position are often treated and interpreted similarly, which may affect the applicability and usability of results [30]. The implications of choosing one approach over another may have consequences on both theoretical and practical understandings of the specific social factors that influence access and use of innovative health technologies. In the studies included in our analysis, it is possible to observe variations in measured inequality based on chosen variables. The variation in results from these studies illustrate that whether or not inequalities in access and use of innovative health technologies are observable are dependent on the approach used to measure these inequalities and that common measures of social inequality in health cannot be used uncritically.

Our findings, however, may suggest that variations in measurement techniques are, in part, rooted in cultural or scientific traditions. It is interesting to note, for example, that although many of the studies from North America and Australia used a variety of approaches to measuring social inequality, race/ethnicity was often included. Race/ethnicity was, however, never included as a variable in collected studies originating from European, Asian, or South American countries, which instead favored the use of various measures of socio-economic status, such as income or education. Our results do not provide a clear explanation to this finding, but one may question whether this is due purely to availability of data or to cultural and historical factors, where race and ethnicity are more strongly associated with social stratification and class positions in North America and Australia [31, 32]. Regardless, the previous findings raise important questions regarding the extent to which social inequalities in access and use of innovative health technologies are dependent on the approach used to measure and define social groups, which must be critically addressed in future research.

Innovative health technologies. Although it is possible to broadly categorize technologies in included studies by type, a potentially more informative method of categorizing these technologies from a social inequalities in health context is by variations in access and use. Using an approach similar to those presented by Cotterman and Kumar [33], and a focus on level of perceived end-user control, it is possible to propose a division of technologies into three main categories (see Fig 3): technologies accessed and used directly by the end user (type 1 or *direct end-user technologies*), technologies used by the end user but accessed through someone other than the end user (type 2, or *direct-use gatekeeper technologies*), and technologies accessed and

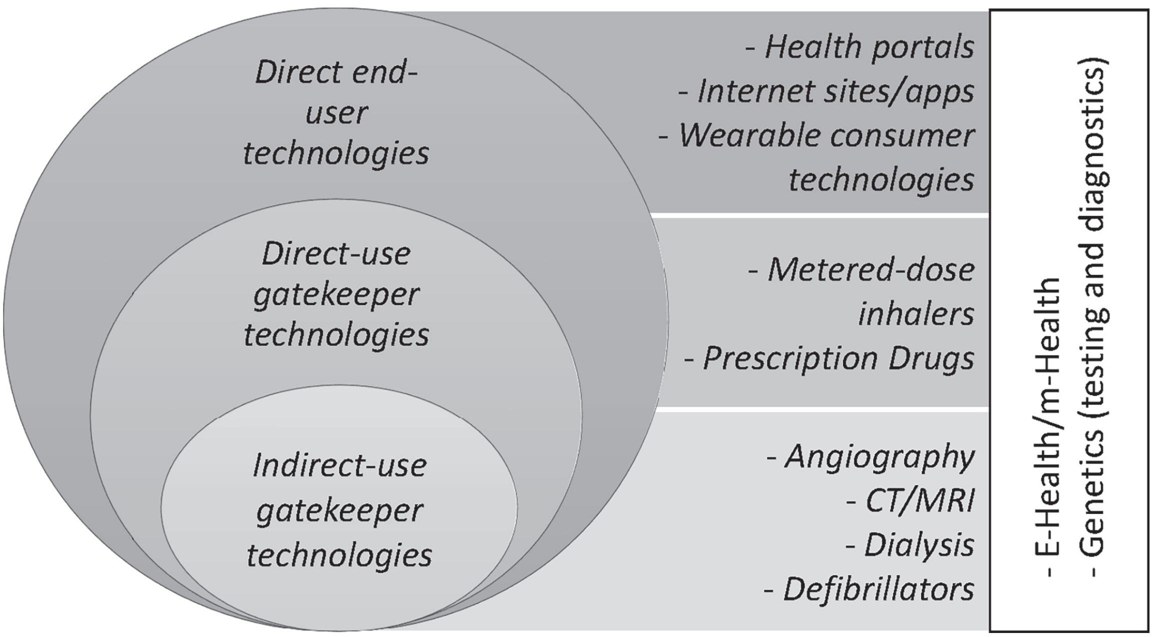

Fig 3. Classification of technologies.

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used by someone other than the end user (type 3, or *indirect-use gatekeeper technologies*). In this case "end user" is defined as the individual, or group of individuals, for which the technology is developed. End users generally do not include individuals who develop, operate, or distribute these technologies, unless these individuals are also end users (the operator of a direct end-user technology, for example, is also the end user). As the name implies, "gatekeepers," in this case, are individuals that guard access and eventual use of technologies by end users [13].

In the case of indirect-use gatekeeper technologies (type 3) and direct-use gatekeeper technologies (type 2), end-users are dependent on gatekeepers in order to gain access to these technologies. Korda et al. [20], for example, investigated the use of a number of coronary procedure technologies dependent on the expertise of health care personnel in which end users have very little direct control over the use and administration of these types of technologies [20, 34]. The technology examined by Rubin et al. [35] (highly-active antiretroviral therapy) differed in that, although access is dependent on a physician, use of the technology is significantly dependent on behavior by the end-user. Results by both Korda et al. [20] and Rubin et al. [35] demonstrate that, after the initial adoption of these technologies, social inequalities in health grew, regardless of whether the use of these technologies was dependent on end user behavior and, furthermore, regardless of the fact that these technologies must be accessed by way of trained health personnel. Results by Korda et al. [20] however also suggest that these inequalities may decline over time, as the adoption by lower SES groups increases.

> "The SES inequalities in diffusion observed for angiography and CABG are consistent with the lag in diffusion/inverse inequality hypothesis–for both these procedures, rates peaked earlier in the higher SES patients than the lower SES patients resulting in inequalities, which then disappeared over time. . ."[20, 36]

Similar findings are corroborated by He et al. [37], Ohl et al. [38], and Stanley et al. [39]. Moreover, results by Goldman and Lakdawalla [40] demonstrate that complicated treatment regimens increase social inequalities in health while simplifying treatment regimens reduce inequalities, illustrating the dynamic complexity of the relationship between access and use of innovative technologies and variations in social inequalities in health.

> "Simply by improving the productivity of healthcare, new technologies can widen disparities across socioeconomic groups. However, new treatments that simplify the production of health and reduce the importance of patient effort work in the opposite direction. . .complex new treatments for HIV appear to have increased disparities among HIV+ individuals, while pharmaceutical breakthroughs in the treatment of hypertension made self-management less important and coincided with a contraction in disparities. . ."[40]

Nevertheless, the results highlighted above suggest that SES influences variations in the use of innovative technologies by end users even when access is dependent on a "gatekeeper".

Direct end-user technologies (type 1), contrary to direct-use gatekeeper (type 2) and indirect-use gatekeeper technologies (type 3), are directly accessed and used by end users. The access and use of these technologies is assumed largely dependent on individual agency, or in other words, the assumption that individuals are equally able to consciously make decisions to access or use these technologies for purposes of influencing health. However, the studies included in our results consistently demonstrated that access and use of these technologies was far from equal. Baum et al. [41], for example, demonstrated that low socio-economic groups have restricted access and use of digital information and communication technologies that, in turn, affect access to a range of social determinants of health, creating a vicious cycle of disadvantage and poorer health.

> "The educational opportunities to acquire fundamental literacy also shape health literacy, which therefore in turn affects people's ability to improve their health status and health outcomes. This disadvantage is compounded because digital literacy is increasingly a pre-requisite for health service delivery and access to health information."[41]

Gonzales et al. [42] indicate that access to technologies for disadvantaged groups is unstable, and can be regularly disrupted, suggesting that simply measuring access to technology adoption across socioeconomic groups ignores the possibility that unstable access–or unequal use–can have large consequences on social inequalities in health. Perez et al. [43] support these results, further demonstrating that purely having access to a particular technology does not guarantee equal use. In fact, an increase in social inequalities in health after the implementation of health technologies is often demonstrated by studies included in our results. Importantly, regardless of findings suggesting that these inequalities will decrease as access to these resources becomes more universal, results from included studies illustrate that access to resources does not necessarily eliminate the (re)production of social inequalities in health.

Unfortunately, our results do not clearly illustrate whether any one of the categories of technologies highlighted in included studies has the potential to influence social inequalities in health to a greater degree than another. Our findings do, however, illustrate a complex relationship, suggesting that the pathways and mechanisms through which inequalities increase or decrease over time vary depending on the factors that influence *both* access and use, as well as type, of these technologies. Furthermore, it was rare for studies included in our results to explicitly measure health outcomes related to the access or use of these technologies. Therefore, studies rarely addressed or investigated specific mechanisms or pathways linking health technology access and/or use to unique explanations of variations in health. Consequently, it is clear that more research is needed to further understand these complex mechanisms.

It is also clear that some important technologies are missing from the literature. The technologies addressed by studies included in our results focus predominantly on technologies designed and used in health care services. Included in this collection of technologies is a growing focus on the internet and internet-based tools, as the use of these technologies also become an integrated resource in health care services [3, 4, 42, 44–46]. However, as various researchers have highlighted in recent years, technologies that have the potential to greatly influence health and social inequalities in health are not limited to those found in health care services [3, 6, 7, 11]. These technologies include innovations used to monitor and control individual health, such as genome sequencing and lifestyle technologies (wearable devices and personal, digital applications, for example). It is, therefore, clear that future research investigate the potential implications of these types of innovative technologies on social inequalities in health.

Discussing potential pathways: Conceptualizing access and use

The studies included in this article exhibit varying approaches for conceptualizing the relationship between innovative health technologies and social inequalities in health. Studies discussing a perspective grounded in individual access and adoption of these technologies [18, 20, 39, 47–49] often refer to the diffusion of innovations theory, which categorizes adopters of innovations based on individual characteristics related to social positioning [13]. These studies use this theory to establish that lower SES groups are slowest to adopt, and therefore benefit less from, innovative health technologies. However, as access to these technologies "diffuses" throughout the population, and lower SES groups begin to adopt, these inequalities begin to diminish and may potentially disappear [18, 20, 37–40, 47].

> "Income gradients were positive in an era prior to statins, but became negative in the period subsequent to the advent and dissemination of statins. While the more advantaged were once more likely to have high levels of cholesterol and LDL, they are now definitively less likely. Additionally, exploratory analyses suggest that income is positively associated with statin use accounting for clinical need. . . While resources affect access to technologies, some technologies can also affect resources, lessening the productivity of various health inputs."[18]

Although this perspective assumes that the unequal adoption of these technologies is relatively unavoidable, they argue that the extent to which these innovations influence social inequalities in health is subject to the rate at which these technologies diffuse.

Building on this explanation, a number of studies [18, 19, 35, 47, 50] draw attention to the fundamental cause theory, which suggests that individuals "deploy" flexible resources, "such as money, knowledge, power, prestige, and beneficial social connections. . .to avoid risks and adopt protective strategies" [15]. These studies use this theory to illustrate that innovative health technologies are accessed to a greater degree by individuals of higher social position.

> "The SES–HIV/AIDS mortality association, although present in the pre HAART period, was greater in the peri-HAART period and greater still in the post HAART period, even when race and other factors were controlled. . .These findings are consistent with fundamental cause theory, which holds that when innovations render a disease more treatable, the benefits of such developments are not evenly distributed."[35]

Explanations referring to the fundamental cause theory and the diffusion of innovations, however, often assume that as innovative health technologies become more evenly distributed–or adopted–across social strata, so too will their benefits.

The above perspectives are contrasted by studies presenting social inequalities more specifically as a consequence of variations in use of innovative health technologies. These discussions often refer to explanations grounded in theories related to health literacy [43, 44, 51, 52] or digital divide [41, 42, 46, 53–55]. While health literacy refers to an individual's ability to assess, understand, and use information critical to using health services and making decisions regarding health [52], digital divide refers to variations in the use of digital technologies between social strata [54]. These studies suggest that, regardless of access, inequalities exist due to the characteristics of social position determining an individual's proficiency in using innovative health technologies to benefit health. Perez et al. [43], for example, demonstrate that, regardless of access to internet-based tools, health information searching and processing strategies vary by SES, benefitting higher educated individuals.

> "When confronted with a specific set of symptoms, higher-SES participants tended to use search strategies that branch out—the exploration of conditions they expect contribute to the symptoms and systematically exploring offshoots of that condition, such as related conditions or symptoms. Lower-SES participants used heuristics to prune the scope of their Internet search—i.e., heuristics to ignore or remove search topics believed to be superfluous to the condition."[43]

Results by Zibrik et al. [52] and Newman et al. [55] illustrate the significance of socioeconomic and cultural factors influencing variations in the quality of use of innovative health technologies, favoring individuals of higher social position. These studies emphasize the experiences of individuals with innovative health technologies, demonstrating that variations in user experience as a result of social positioning has the potential to undermine the benefits assumed by universal access.

The above theories, however, seem to suggest that these inequalities are driven by the potential of social positioning to provide individuals with the ability to make conscious choices and "consume" these resources [56], assuming that these choices are made consciously and with motivated intent to improve health [23]. However, numerous studies included in our results highlight the importance of mechanisms at the institutional and political levels that may significantly influence the distribution, in access and use, of innovative health technologies across social strata [14, 34, 37, 45, 57–64]. Many of these studies demonstrate that patterns of adoption and use of innovative health technologies at the level of the health care institution may significantly influence the potential of these innovations to benefit the health of end users regardless of individual choice or intent.

> "Patients admitted to non-minority-serving hospitals were more likely to receive carotid artery imaging than patients admitted to minority-serving hospitals. . .the predicted probabilities of receiving carotid artery imaging were similar between white patients and black patients at non-minority-serving hospitals. . .However, the predicted probabilities among white patients and black patients at minority-serving hospitals were both significantly lower than white patients at non-minority-serving hospitals."[34]

Furthermore, a study by Lang and Mertes [62] demonstrated that the prevailing orientation of dominating political parties can influence how innovative health technologies are accessed and used at the State level, resulting in variations in the distribution of these resources. In a similar discussion, Han et al. [60] refer explicitly to the social determinants of health theory, which describes the unequal distribution of health as a result of socioeconomic conditions that are largely constructed by social policy [65], to stress the significance of a geographical patterning of health influencing variations in access and use of innovative health technologies.

Due to a focus on single technologies, however, many of the perspectives discussed above fail to address the potential influence that the rapid, uninterrupted development of new technologies may have on the reduction or (re)production of social inequalities in health. It could be suggested that the cumulative effects of multiple technologies adopted over time is itself a mechanism for (re)producing health disparities. In this case, potential mechanisms could be related to windfall benefits [13], which are benefits afforded by early adopters (high SES individuals) that accumulate over time, or Bourdieu's theories of capital and symbolic violence [66], where the development and implementation of innovative technologies by high SES groups may reinforce social stratification. Baum et al. [41] demonstrate that Bourdieu's social theories are a relevant addition to a discussion of innovative health technologies and social inequalities in health, drawing attention to the ways that innovative health technologies potentially influence the interaction of social, cultural, and economic capital to reproduce inequalities in health. They conclude that "some people are being caught in a vicious cycle whereby the inability to make beneficial use [of innovative health technologies] reinforces and amplifies existing disadvantage" [41].

The results of this study, therefore, seem to suggest that understanding the pathways through which various innovative health technologies reduce or (re)produce social inequalities in health is context dependent. Theories focused on the dependency of individual resources, such as fundamental cause theory, may therefore be most appropriate for understanding socially stratified variations in the access and use of direct end-user (type 1) technologies. Interestingly enough however, studies referring to these theories generally address direct and indirect-use gatekeeper (types 2 and 3) technologies, allowing one to question the merit of these explanations. Conversely, mechanisms at the institutional and political levels would thus seem most appropriate in explaining direct and indirect-use gatekeeper (types 2 and 3) technologies, where the advantages of these technologies are often poorly recognized by individuals of lower social status or where access is limited by gatekeepers (for example, political or institutional agents). In order to better understand social inequalities in health, these contextual variations draw attention to the need for critical distinctions between technologies based on how, and in what context, these various technologies are accessed and used. This may include a stronger focus on understanding the role of institutions and accompanying theories that explain complex mechanisms influencing the distribution of population health [1].

Limitations

Some limitations not addressed earlier in this study are worth discussing. First, although the choice of search terms was purposefully broad and systematically identified using relevant literature, it is possible that the ability to collect relevant literature from a larger breadth of research fields and traditions could have been limited. This is due to the possibility that the researchers' previous relation to the fields of sociology and health limit the familiarity, and therefore inclusion, of relevant terms or language used in the fields of technology and innovation. Second, the decision to exclude grey literature, including books, reports, etc., may have led to the exclusion of relevant literature, which could have possibly been used to widen or further support perspectives presented in the results. However, this choice was made with consideration for a purposeful selection of empirical, peer-reviewed studies using original data analyses. The goal here was to increase the probabilities of including relatively high quality research and excluding the possibility of grey material that is lower in quality and neither peer-reviewed nor includes original analyses. Furthermore, as grey literature includes reports and documents often drafted by order of political or special interest organizations, it is more difficult to assess underlying biases that would negatively bias our results. Third, the decision to exclude studies focused on treatment techniques within health services may have excluded some relevant literature. Very often, treatment techniques are dependent on the use of a specific technology. However, had the current study included literature focused on treatment techniques, without a specific focus on the technology used in this treatment, it would have been up to the authors to investigate whether or not each treatment technique included the use of an innovative technology, introducing bias as well as a very problematic assessment process. Furthermore, the inclusion of such studies would have shifted the focus of the current study from that of one focused on novel perspectives related to technology and public health to one focused on the relatively well established field of social inequalities in treatment and health services. The authors, therefore, felt that the inclusion of such studies was out of the scope of the current study and would have fundamentally transformed the current study's aims and contribution to the scientific literature.

Conclusions

This review was interested in systematically investigating existing literature that explores the influence of innovative technologies on social inequalities in health. The results of this study offer interesting perspectives worth consideration, with implications for further investigation of the influence of innovative health technologies on social inequalities in health. This study questions established scientific measures of social inequality, where various measurements (such as race/ethnicity, income, education, geography, etc.) are often used interchangeably to investigate variations in access and use of innovative health technologies. Results illustrate that the choice of measurement has the potential to bias findings and, therefore, significantly influence the understanding of complex relationships between innovative health technologies and social inequalities in health. Furthermore, this study proposes that a social inequalities perspective may benefit from an understanding, and differentiation, of technologies based on how these technologies are accessed and used by end users. Factors and mechanisms that influence access, for example, may differ from factors and mechanisms that influence use. It is clear that it is not enough to solely focus on the factors and mechanisms that influence unequal access and therefore ignore how variations in use importantly shape social inequalities in health. It is, moreover, not enough to focus attention solely on health care services technologies but, importantly, to investigate emerging technologies in lifestyle health, genomics, and the increased use of personalized devices in health. Furthermore, a deeper understanding of social inequalities in health and innovative health technologies is dependent on distinguishing between a perspective focused on individual resource use, which often draws a questionable causal relationships between SES, technology access/use, and health outcomes, and a perspective focused on mechanisms that are more dependent on social and institutional structure than on individual agency. Although the studies included in our results generally suggest that the implementation and adoption of new technologies (re)produce SES and class-based social inequalities in health, some results indicate that these technologies can, in fact, reduce inequalities over time. Additional research, based on the findings discussed in this study, are needed, however, to reliably establish these conclusions. As much of the current research is dominated by the use of quantitative methods of social epidemiology, additional research may benefit from an increased use of qualitative, sociological methods in order to further investigate mechanisms and pathways leading to the (re)production of social inequalities in health as a result of innovative technologies [8, 30]. It is, nevertheless, becoming increasingly important to investigate the social implications and consequences of a society increasingly influenced by technological innovations, including the ways in which these technologies may influence the unequal distribution of health as a human right.

Supporting information

S1 Table. Forming the narrative–representative excerpts from selected studies.
(DOCX)

S1 File. Original data file.
(TXT)

S1 PRISMA Checklist.
(DOC)

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Paper II:
Educational Inequalities in high- vs. low-preventable health conditions:
Exploring the Fundamental Cause Theory

Abstract

Aim: To explore variations in educational gradients or gaps between high- and low-preventable health conditions. *Background*: This is one of the first European studies to test whether the association between socioeconomic status and morbidity is stronger for 10 high- than for three low-preventable health conditions, by gender across 20 countries. *Data and methods*: The 2014/15 European Social Survey included questions on 11 health conditions experienced over the last 12 months, cancer at any age, and symptoms of depression during the last week. We include respondents from 20 countries (N_{men} = 12,073; N_{women} = 13,488) aged 25 to 69. We estimated age-adjusted educational gradients on 13 conditions using logistic or OLS-regression stratified by country and gender, and high- and low-preventable pooled conditions variables on pooled country samples. *Results*: Both among men and women the proportion of educational gaps were larger for the high-preventable than the low-preventable conditions in most countries, supporting the Fundamental Cause theory (FCT) hypothesis. However, there was large variations in the number of significant associations across countries and between genders. In the pooled conditions and countries analysis, no associations were significant among the low-preventable conditions. For the high-preventable conditions there was a weak significant educational gap among men, and a weak but nevertheless more distinctive and complete educational gradient among women. *Conclusion*: In a first explorative comparative European analysis we found support for the FCT hypothesis. Thus, the FCT can be used on morbidity data classified as low- versus high-preventable. We recommend extending this framework with institutional theories to explain within- and between-country health inequalities.

1. Introduction

Since the 1980s social inequalities in health have been well documented both within and between countries in Europe and North-America. Despite changes to social structures and disease patterns, expansion of health care and welfare services, and general improvements in standards of living and quality of life, these inequalities have persisted and, in some countries, even widened. A range of theories has sought to explain what has often been labeled a paradox – that such inequalities continue to exist despite the developments listed above (Mackenbach, 2012).

In a 1995 paper, Link and Phelan (1995) proposed a general theory to explain these persisting disparities, labelled the theory of fundamental causes (FCT). The FCT suggests that social inequality is the fundamental cause of disease and mortality, with multiple time- and context-variant mechanisms affecting multiple proximate risk factors, generating multiple health outcomes. One way of testing this theory has been to compare mortality by preventability, with the assumption that with higher preventability follows larger health inequalities.

Using data from the 'Social determinants of health' module of the 2014/15 European Social Survey (ESS; European Social Survey Round 7 Data, 2014) that included 10 high- and three low-preventable health conditions, this article aims, as a novel empirical contribution to the FCT literature, to explore variations in educational gradients or gaps between health conditions classified as high- or low-preventable by gender across countries, as well as conducting a pooled countries analysis of pooled low- and high-preventable conditions in relation to education and gender. We consider this an explorative, first European analysis, which can be followed up in various directions in future research using the same or similar data.

1.1 Background

Attempts to explain social inequalities in health have included a materialist theory, with an emphasis on inequalities generated by structure; a psychosocial theory, that emphasizes relative deprivation, and a behavioral-cultural theory, focusing on individual health agency and inequalities generated by consumption patterns (Elstad, 2000). These explanations all relate to the theoretical perspective of health determinants, defined by Elstad (2000, p. 29) as "factors or conditions which are presumed to have a general influence on people's health, their longevity, and their level of ill health", and the determinants' uneven distribution along the social structure. Another explanation utilizes a life course perspective, where biological and social experiences from an early age and throughout the life course causes health inequalities among adults (Mackenbach, 2012). The physical environment, social structures, and individual behavior could further mediate these experiences, and the ways socio-economic status (SES)affects health over the life course can be through latent, cumulative, or more complex pathways (Quesnel-Vallée & Jenkins, 2009).

Link and Phelan (1995) considered contemporary research on health inequalities as moving from merely describing social patterns of disease towards attempting to understand the mechanisms that link social conditions to health. Consequently, they argued for a move away from disease-proximate risk factors and towards contextualizing health risk: "investigators must (1) use an interpretive framework to understand why people come to be exposed to risk or protective factors and (2) determine the social conditions under which individual risk factors are related to disease" (Link & Phelan, 1995, pp. 83-84). Money, knowledge, power, prestige and social connections were proposed as key, flexible resources – associated with variables such as SES, social networks, stigmatization, ethnicity, and gender – that could help individuals avoid multiple health risks and promote good health. Inequalities in possessing these resources were considered to be a fundamental cause of inequalities in multiple disease outcomes across time and space – putting people at risk of risks, irrespective of the aforementioned societal changes (Link & Phelan, 1995). With that, they implied that these measures of social position – SES, gender, ethnicity, and social capital – thus had an independent, causal link to inequalities in health outcomes rather than merely being a "confounding variable" or "placeholder" for yet undiscovered proximate factors (Lutfey & Freese, 2005; Phelan, Link, Diez-Roux, Kawachi, & Levin, 2004).

Critiques and further developments of the FCT

Freese and Lutfey (2011; 2005) have demonstrated how the FCT assumes individual "health-directed human agency"; if inequalities in flexible resources is to be manifested as inequalities in health outcomes, the theory assumes that agents purposely apply these resources to "garner health advantage" (Link & Phelan, 2002, p. 732). Freese and Lutfey (2011, p. 72) claimed that an agency-centered theory "does not provide a satisfactory explanation of how the fundamental relationship between SES and health is preserved", and suggested spillovers within social groups, habitus, and institutions' contribution to health inequalities as potential directions for future research. This description of the FCT as a general theory with little potential for specific explanations was echoed by Mackenbach (2012), whereas Beckfield, Olafsdottir, and Sosnaud

(2013) have argued that there is an unexploited potential of institutional features in comparative health inequality research. Empirical research investigating the association between health inequalities and country-level characteristics such as welfare state regimes, overall social expenditure, and other indicators of welfare institutions and social policy have supported their claim (cf. Álvarez-Gálvez & Jaime-Castillo, 2018; Dahl & van der Wel, 2013; Eikemo, Bambra, Joyce, & Dahl, 2008; Eikemo, Huisman, Bambra, & Kunst, 2008; van der Wel, Dahl, & Thielen, 2011). Consequently, Beckfield and colleagues (2015, p. 230ff) have proposed a theoretical framework aiming to explain how "the same individual- or household-level causes vary in their effects across institutional settings". This framework is made up by the processes of redistribution (channeling resources), compression (setting lower and upper bounds for the social determinants of health), mediation (intervening on the social determinants), and imbrication (reinforcing or cross-cutting policies).

An implication of the FCT is that the benefits from our increasing ability to control disease and death have been distributed according to the mentioned vital, flexible resources (Phelan & Link, 2005). Social inequalities in health should therefore be more prominent in cases where these resources actually matter, i.e. for diseases and causes of death where there is a possibility of prevention and cure, e.g. through health behavior or accessing relevant health care services or technologies (Link & Phelan, 2010). The next sections present examples of research investigating how social inequalities in health may vary with preventability, including studies of both mortality and morbidity.

Health inequalities, preventability, and mortality

In 2004, Phelan et al. tested the FCT by comparing educational gradients in mortality rates across causes of death associated with high or low degree of preventability. Their results supported the FCT; the educational gradients were stronger for preventable than for non-preventable causes of death. Similar results supporting the FCT have been reported by Phelan and Link (2005), Masters et al. (2012; 2015), Hummer and Lariscy (2011), Meara (2008), and Mackenbach et al. (2015). Mackenbach and colleagues (2017) provided a more comprehensive study of several aspects of the FCT. Using harmonized mortality data, covering most of 20 national or regional populations from 1980 to 2010, they found that mortality declined faster among the highly educated, in particular for preventable causes of death. However, some findings contradicted their expectations: when mortality increased, it did in general not increase less for the higher educated, and multilevel analyses showed that the degree of income inequality had no significant effect on mortality differences.

Socioeconomic gradients in preventable mortality have also been documented in Spanish (Zapata Moya, Buffel, Navarro Yáñez, & Bracke, 2015), Australian (Piers, Carson, Brown, & Ansari, 2007), Korean (Song & Byeon, 2000), and Swedish (Westerling, Gullberg, & Rosén, 1996) populations. Some contradictory findings have also been reported: Hem et al. (2009) found approximately the same patterns of educational differences for both preventable and non-preventable causes of death in Norway, and Mustard et al. (2010) found similar mortality differences between occupational groups for causes of death both amenable and not amenable to medical care in Canada. Gadeyne and colleagues (2017) studied educational gaps in breast cancer among women in 18 European countries. They detected a negative association between education and breast cancer mortality among young women, and a positive association among older women. The FCT proposes that when more knowledge, medical insight, and treatments of a health condition becomes available, a negative association between SES and the condition emerges; in this case meaning that higher educated women in recent decades have made better use of developments in breast cancer detection, prevention, and treatment.

Health inequalities, preventability, and morbidity

Mackenbach (2012) has described the FCT as a general theory to explain health inequalities in mortality as well as morbidity. One study that investigated preventable disease rather than mortality is Bränström et al. (2016). Swedish survey data containing information on sexual orientation was linked with registry data on inpatient and outpatient health care use from 2001 to 2011, which was classified as high- and low-preventable using ICD-codes from Phelan and colleagues' (2004) rating. Their results indicated support for the FCT, showing that sexual minorities had a higher risk of experiencing high-preventable diseases. Comparisons with alternative classifications showed some convergence for the male population, but differences in the approach to classification made direct comparisons difficult (Bränström et al., 2016).

Chang and Lauderdale (2009) examined the relationship between income and cholesterol level after a new and expensive treatment had been implemented. They found that an initially positive association was reversed when new medication became available. When health-related conditions changed, high-SES individuals gained a health advantage, and the conditions in question became more predictable and manageable.

A rare comparative study on the association between SES and high- versus low-preventable health conditions found support for the FCT for the USA but not the Canadian population, which also supports the hypothesis that national policies and social inequality in general affects the association between SES and health conditions (Willson, 2009). However, the study included only two health conditions – cardiovascular disease and cancer, with the latter classified as a relatively less preventable disease compared to the former. Moreover, SES was measured as income quintiles, and men and women were pooled together.

To sum up, previous research studying the associations between health inequalities and preventability that suggests support for the FCT has mostly focused on SES and mortality, i.e. measures such as income and education and high- and low-preventable causes of death. Similar research using morbidity data has been inconclusive. However, it is unclear whether the lack of strong support for the FCT is due to the health conditions being studied, how SES has been operationalized, or what country populations that have been studied. Consequently, there is a need for studies that include a range of health conditions across countries that differ institutionally and utilizing harmonized measurements and data collection methodology across countries. Furthermore, as FCT also refers to fundamental social structures such as gender and ethnicity, connected mechanisms should also be theorized and studied empirically within a cross-country institutional framework (see e.g. Beckfield et al., 2015). Nevertheless, before embarking on such a theoretical and empirical task, a first explorative analysis should be undertaken as to reveal to what extent there actually are any systematic within and between cross-country variations in the association between core fundamental causes, such as socioeconomic status and gender, and a range of low- and high-preventable conditions.

1.3 Research question and novelties

Our main hypothesis is that educational gradients or gaps are more likely to appear among health conditions classified as high-preventable. Furthermore, we want to explore whether there are patterns of educational gradients or gaps for clusters of countries and by gender. In an analysis using pooled conditions variables and pooled country samples, we will further test whether an educational gap or gradient is different for men than for women, i.e. an interaction.

Our study adds several novelties to the existing literature: It is a first explorative and comparative European analysis using educational attainment as a harmonized measurement of SES; it includes three low-preventable and 10 high-preventable measures of morbidity rather than cause of mortality; the analysis includes 20 countries, has an explicit focus on gender, and the results are visualized to reveal not only the size of any gaps or gradients, but also the level and variation of prevalence across countries. We also do an analysis on pooled countries and high-preventable conditions to study how gender may interact with SES. Any positive results suggesting support for the FCT more generally, or patterns suggesting cross-country institutional similarities or gender differences, could be continued in a follow-up study using the same or similar data.

2. Data and methods

2.1 Data

We defined our population as men and women aged 25 to 69 years of age by the time of interview, assuming that most respondents had completed secondary or tertiary education by the age of 25. We included Israel and 19 European countries that took part in the European Social Survey Round 7 (ESS) collected in 2014/15. Country specific weights adjusted for both the probability of survey participation and sample skewness. (For more information about the survey methodology and the health module see ESS (2014) and Eikemo, Bambra, Huijts, and Fitzgerald (2016).

2.2 Dependent variables

Morbidity was measured as 13 self-reported health conditions. The prevalence of these conditions based on the ESS 2014/15 health module has been reported in previous research, also in relation to region, education and occupational class (McNamara, Balaj, Thomson, Eikemo, & Bambra, 2017; McNamara, Balaj, Thomson, Eikemo, Solheim, et al., 2017; McNamara, Toch-Marquardt, et al., 2017; Thomson et al., 2017). What the present article adds to these analyses is a comparison between more and less high- and low-preventable conditions, a visualization of the prevalence and educational gradients, and a discussion integrating theories on social inequalities in health.

In the questionnaire, the respondents were asked: "Which of the health problems on this card have you had or experienced the last 12 months?" Listed on the card were heart or circulation problems; high blood pressure; breathing problems such as asthma attacks, wheezing, or whistling breathing; allergies; back or neck pain; muscular or joint pain in hand and arm; muscular or joint pain in foot or leg; problems related to your stomach or digestion; problems related to a skin condition; severe headaches; diabetes. For each condition, a variable was coded as "yes" equal to 1 and "no" equal to 0.

In another question the respondents were asked whether they ever had cancer affecting any part of the body; leukaemia; malignant tumour; malignant lymphoma; melanoma, carcinoma, or other skin cancer, where the same coding was applied. Because of a questionnaire error, this variable was not included for the Czech Republic.

A battery consisting of eight questions was used to construct a version of the Center for Epidemiologic Studies Depression Scale (CES-D8), which measures symptoms of depressions. Initially, the respondents were asked how much during the last week they had felt depressed; felt everything they did was an effort; slept restlessly; were happy; felt lonely; enjoyed life; felt sad; felt they could not get going. They could answer "None or almost none of the time", "Some of the time", "Most of the time", "All or almost all of the time" or "Don't know". The fourth and sixth items had reversed scales and were used to identify zero-variance respondents, that is, anyone who answered the same response alternative to all eight items despite the two reversed items. Zero-variance respondents were coded as item-missing. A mean score ranging from 1 to 4 was rescaled to cover the range 0 to 1 and calculated for those who had answered at least six items and were not zero-variance respondents.

We classified the self-reported conditions as ten high- and three low-preventable conditions, a terminology adopted from Bränström et al. (2016). Our classification of conditions is based on Phelan and colleagues (2004), where two MDs independently rated the preventability of 96 causes of death, coded according to the ninth edition of the International Classification of Diseases (ICD9). First, the MDs rated the degree to which the causes were amenable to medical prevention, thereafter to which degree the incidents were preventable, and finally an overall rating from 1 ("virtually impossible to prevent death") to 5 ("virtually all deaths preventable") was assigned (Phelan et al., 2004). We compared this rating to the chronic conditions listed in the questionnaire and made a similar 1-5 rating of the conditions. Preventability of death was replaced with whether it is possible to prevent these health problems from ever occurring. Where we could not find direct equivalents between the ICD9 causes of death and the 13 conditions, we searched medical literature for empirical tests of the conditions' preventability. Consequently, the relationship between causes of death and chronic health problems are not 1:1; Phelan and colleagues' (2004) classification is more fine-grained than what is possible to do with the self-reported conditions in our data, but we believe that this transparent approach adds reliability to our analysis. The full ranking, with ICD equivalents and literature references, is included in the appendix (Table A.1).

These equivalents enabled us to divide the 13 conditions into 10 high-preventable (back or neck pain, breathing problems, cancer, depression, diabetes, heart or circulation problem, high blood pressure, muscular or joint pain in foot or leg, muscular or joint pain in hand or arm, stomach or digestion related) and three low-preventable conditions (allergies, severe headaches, skin condition related).

2.3 Independent variables

Age is measured as a continuous variable ranging from 25 to 69 years. National responses to educational qualifications were coded by the ESS-team following the ISCED2011 criteria, increasing the harmonization of educational levels across countries. We recoded this variable into a set of dummy variables: no education or primary education completed; completed secondary level degree; completed a tertiary level degree or higher (reference category).

2.4 Analysis

To estimate our models, we used binary logistic regression for all dichotomous dependent variables and OLS-regression for the continuous depression scale. After estimating the regression parameters, we calculated predicted probabilities for each of the three educational level categories with 95% confidence intervals, for men and women in each country respectively. Age was set ‘as observed’ in the calculations. The predicted probabilities and confidence level scores were used to plot figures summarizing the results. Because the prevalence of each condition can vary much across countries the Y-axis range is not identical across all countries. We therefore allowed the range to vary between countries while keeping it similar for men and women within countries. While the sample size was the same across regressions for each respective male or female country sample (given the item-missing of either age or educational level), the analytical samples used in each respective regression varied given each dependent variable’s item-missing. For simplicity, we present only the descriptive statistics for each variable by gender and country and not for every analytical sample (see table A.2).

For a pooled country-samples and pooled conditions analysis we create two new dependent variables that measure whether the person has one or more low-preventable conditions (1) or not (0), or one or more of ten high-preventable conditions (1) or not (0), and we extended our model with age and education to also include 19 country dummies. For ‘depression’ to be included among the high-preventable conditions, we made a cut-off at >0.33 on the depression scale.

The statistical software STATA 14.2 with the add-on package *SPost* 13 was used in all analyses (STATA; Long & Freese, 2014). The command *mgen* was used to save analytically calculated predicted probabilities with upper and lower bounds for the confidence intervals.

The figures presenting the saved estimates were created using IBM SPSS version 24 and the program Paintbrush.

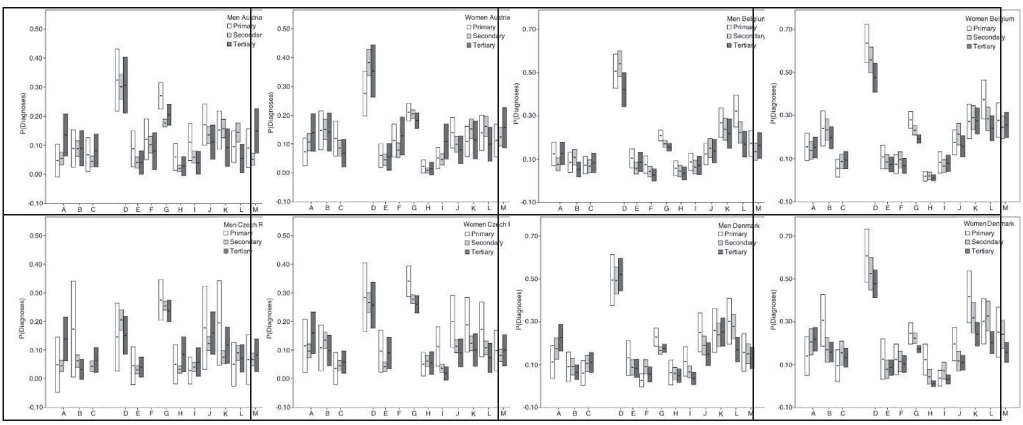
3. Results

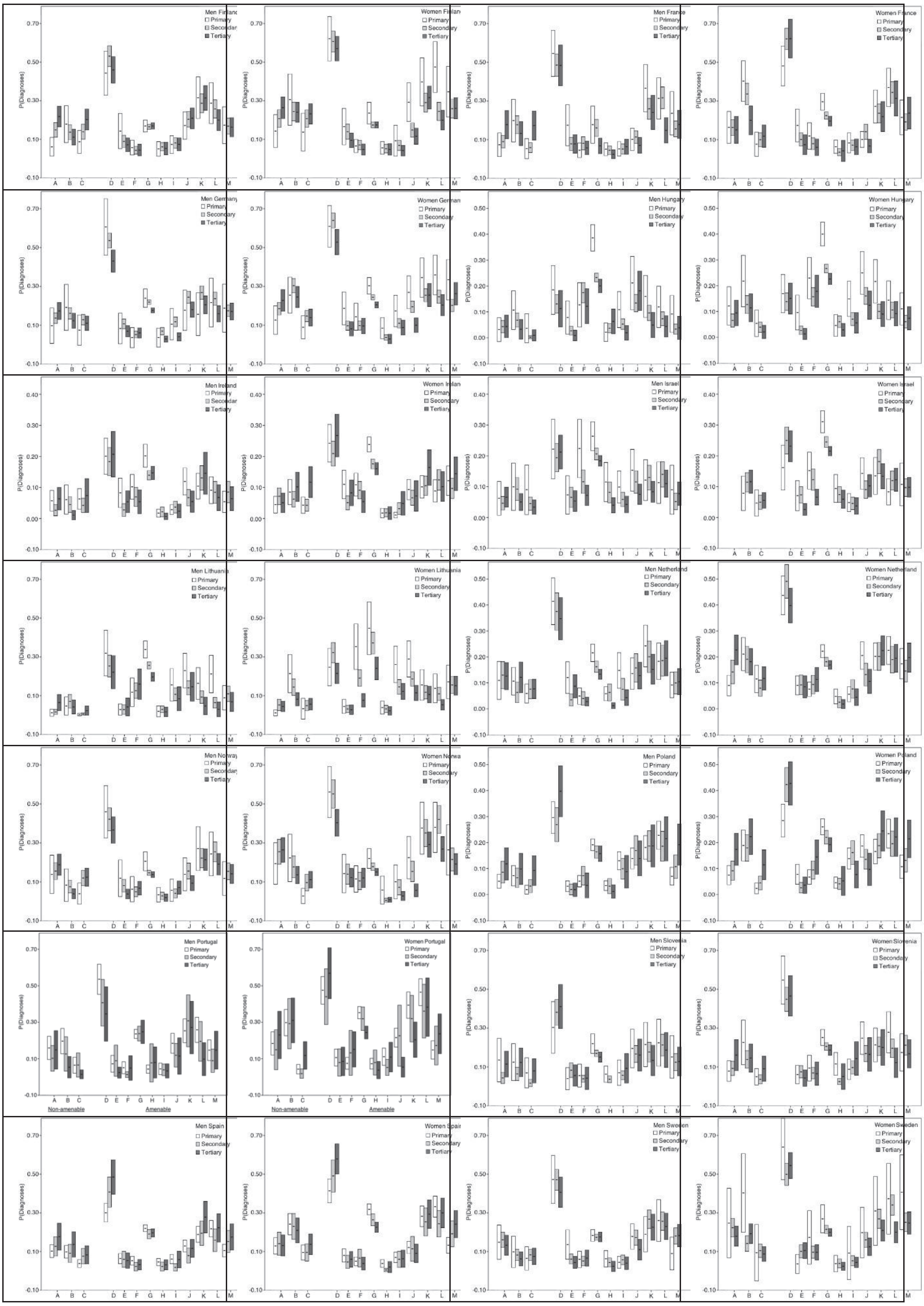
The unadjusted prevalence of each condition varied between countries (see tables A.3 and A.4). For example, 39% of the total sample reported back or neck pain, ranging from 15% among Hungarian men to 50% among German women. Diabetes was the condition with the overall lowest prevalence: ranging from 1% of Norwegian women to 8% of Israeli men (5% in the total sample). On average, 22% of male respondents and 32% of female respondents had experienced one or several of the low-preventable conditions, while the respective figures were 58% and 61% for the high-preventable conditions. This could indicate a stronger presence of comorbidity among the high- preventable conditions. Although an interesting finding, we will not follow it up in this article.

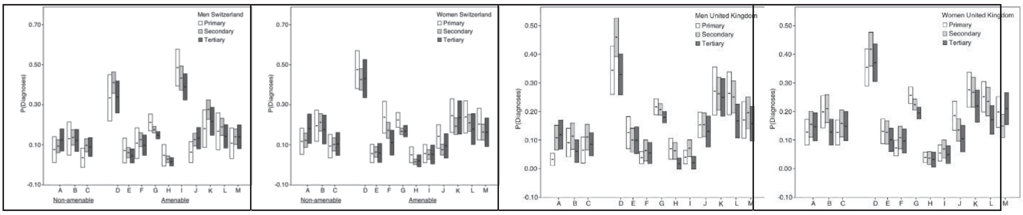
3.1 Stratified conditions and country samples

Results from the 518 regressions are displayed graphically in figure 1 as 13 conditions listed as low- or high-preventable by country and gender. The prevalence levels of the different conditions are indicated by their predicted probability, “P(Diagnosis)”.

Figure 1: Age-adjusted predicted probabilities by educational level among men and women for all countries and conditions




Men Finland
Women Finland
Men France
Women France
Men Germany
Women Germany
Men Hungary
Women Hungary
Men Ireland
Women Ireland
Men Israel
Women Israel
Men Lithuania
Women Lithuania
Men Netherland
Women Netherland
Men Norway
Women Norway
Men Poland
Women Poland
Men Portugal
Women Portugal
Men Slovenia
Women Slovenia
Men Spain
Women Spain
Men Sweden
Women Sweden
Primary
Secondary
Tertiary
P(Diagnoses)
Non-amenable
Amenable



Note: A – Allergies, B – Headaches, C – Skin condition, D – Back or neck pain, E – Breathing problems, F – Cancer, G – Depression, H – Diabetes, I – Heart or circulation problem, J – High blood pressure, K – Muscular or joint pain in foot or leg, L – Muscular or joint pain in hand or arm, M – Stomach or digestion problems. A-C = low-preventable conditions, D-M = high-preventable conditions. Bars indicate 95% confidence intervals.

As the boxes depicting confidence intervals show, few conditions had a significant tripartite monotonous social gradient, i.e. significant differences between primary, secondary, and tertiary education for each condition that goes in one direction. However, results become clearer if we instead focus on educational gaps rather than gradients, i.e. between the primary and tertiary educational level. Appendix tables A.5 and A.6 give an overview of significant educational gaps by country and condition for men and women respectively.

Among men, we found significant gaps in the positive direction for 8 of the 60 regression analyses of low-preventable conditions (13%) and for 47 of the 199 regression analyses of high-preventable conditions (24%). For the full male sample, 9/10 high-preventable conditions had significant gaps. Among women, the corresponding numbers were 6/60 (10%), 64/199 (32%), and 8/10 conditions for the full sample. There were positive significant educational gaps for the same conditions among both men and women in the same country in 27/199 analyses of high-preventable conditions, and both genders-same country negative gaps in 2/60 analyses of low-predictable conditions. In addition, we observe that for men and women respectively there were eight and nine significant gaps in the negative direction among the 60 low-preventable regressions, but only three and six significant gaps respectively in the negative direction among the 199 high-preventable regressions. However, it should also be noticed that in the majority of high-preventable regressions, the null-hypothesis of no significant educational gap in the positive direction could not be rejected.

Depression stood out as the condition with the most significant educational gaps, evident in 16 and 19 countries for men and women respectively. Apart from depression, heart or circulation problems among men and high blood pressure among women were conditions with frequent gaps, along with muscular or joint pain in hand or arm for both genders. Back or neck pain and stomach or digestion related problems were the high-preventable conditions showing the least educational gaps.

When adding up the number of significant educational gaps in each country, Hungary has the highest occurrence of significant educational gaps in high-preventable conditions among men, with 5. Denmark and Germany stood out among women with significant gaps among 6 of the 10 high-preventable conditions. When comparing the proportion of significant high- vs. low-preventable educational gaps within countries, i.e. dividing the number of significant gaps in the positive direction on the total number of high- and low-preventable conditions respectively within each country, we found that for men, 14 of 20 countries had a higher proportion of significant educational gaps among high-preventable conditions. Belgium, Czech Republic, Israel, Norway, Poland, and United Kingdom showed a higher proportion of significant educational gaps among the low-preventable conditions. For women, the corresponding figure was 17/20 countries, with France, Sweden, and the United Kingdom having an inverted relationship between the condition categories. Moreover, when summarizing how often there was an educational gap in the positive direction for any given diagnosis for both men and women within the same country, we find that except for depression, few statistically significant gaps in the positive direction are common to both men and women within the 20 countries.

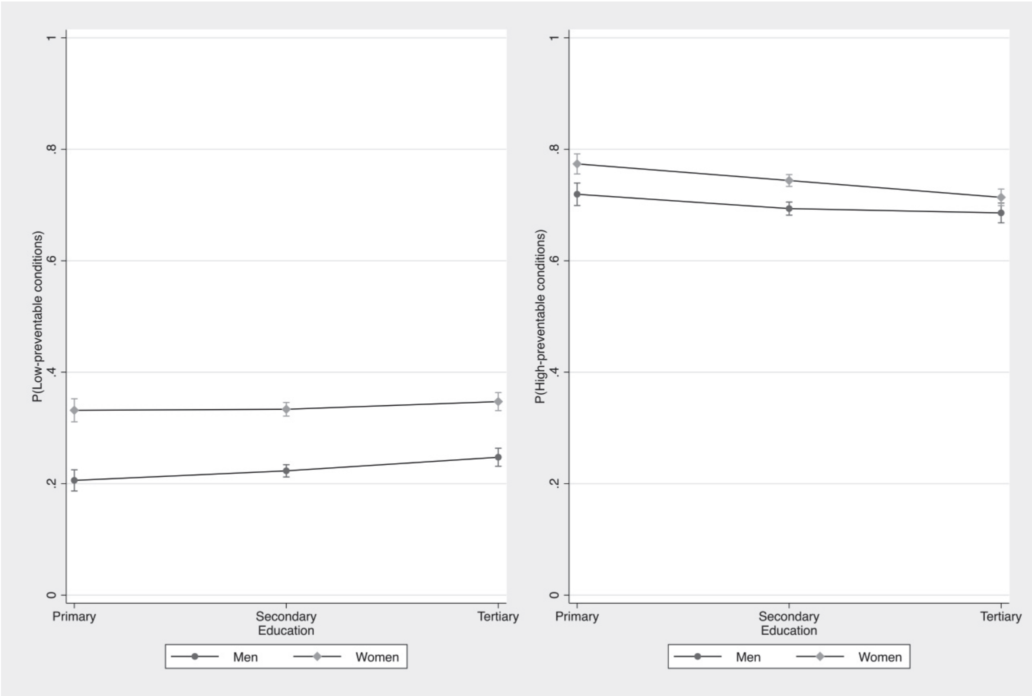
3.2 Pooled conditions and pooled country samples

To further examine the FCT in a more simplified way, we pooled the chronic condition variables into two categories, low- (conditions A-C) and high- (conditions D-M) preventable conditions, creating two new variables that we regressed on education and age. This allows us to study the association between education and the low- and high-preventable conditions in a way that is easier to interpret, including whether we may trace any similarities across countries and to test the interaction between gender and education in a pooled countries analysis.

On average 22% of men and 33% of women had experienced at least one of three low-preventable conditions, ranging from 8% of Lithuanian men to 45% of Finnish women. Corresponding average numbers for the high-preventable conditions were 58% and 62%, ranging from 34% of Hungarian men to 77% of French women. First, we did gender- and country-specific regressions with these pooled conditions dependent variables, and in general there were more educational gaps for high-preventable conditions, again supporting the FCT hypothesis (Table A.7).

Some countries' results contribute to reinforce the patterns we observed when first adding up the significant results in tables A.5 and A.6: Hungary showed strong, significant educational gaps for the high-preventable conditions for both men (OR = 3.55, $p < 0.05$) and women (OR = 3.81, $p < 0.001$), while Germany showed strong, significant positive associations for women only (OR = 2.97, $p < 0.05$). For other countries, the results from this analysis diverged from the stratified one. For example, Denmark did not have any significant associations for neither men nor women. Other notable findings were the significant educational gaps found for the high-preventable conditions among Norwegian (OR = 3.86, $p < 0.05$) and Finnish women (OR = 2.65, $p < 0.10$), and Lithuanian men (OR = 3.89, $p < 0.05$) and women (OR = 5.20, $p < 0.001$).

Figure 2: Age-adjusted predicted probabilities for pooled condition and country variables with education-gender interaction



Next, we pooled all countries together into one sample and extended the model containing age and education with a set of country dummy variables, gender, and the interaction term between gender and education. This analysis allows us to test whether fundamental cause of socioeconomic inequality is different for men and women in relation to high- and low-preventable conditions.

In both regressions the interaction term was statistically non-significant ($p > 0.20$). However, when we present the results as predicted probabilities in Figure 2 (keeping the age and country dummy variables 'as observed'), the visualization reveals a weak interaction between gender and education for the high-preventable conditions.

For the low-preventable conditions we see a weak increase by educational level among men but not women, with the predicted outcomes for men and women running almost parallel and women being significantly more likely than men to have a low-preventable condition at all educational levels. This result supports the expectation that there is no positive significant association between education and low-preventable conditions. For the high-preventable conditions women had a somewhat higher prevalence than men among those with primary or secondary education, but not tertiary education. Furthermore, the probability difference between primary and tertiary education is men is significant, but very small – less than one percentage point. Among women, we observe a significant probability drop of approximately three percentage points between the primary and tertiary educated, leading to the levelling of gender differences in high-preventable conditions at the highest educational level.

4. Discussion

Our main hypothesis was supported for both men and women by our empirical analysis in our first overall assessment of the statistically significant educational gaps shown in Figure 1. High-preventable conditions had more educational gaps than low-preventable conditions, and this gap was also significant in analyses of pooled conditions variables and pooled country samples, indicating that for conditions where our ability to prevent is comparatively high, resources associated with education can be beneficial.

When summarizing regression results across countries and conditions, we found a larger proportion of statistically significant educational gaps in the positive direction among the high-preventable conditions, and a larger proportion of 'negative' educational gaps among the low-preventable conditions, which both lend support to the FCT hypothesis. However, we also observe that in the majority of high-preventable regressions the null-hypothesis of no significant educational gap in the positive direction could not be rejected. Further, despite an overall aggregate support for the FCT hypothesis when summarizing the proportion of significant educational gaps for all countries and conditions, there are nine countries where the hypothesis is not supported for either men or women. These two findings call into question the strength of SES as a fundamental cause across a wide range of high-preventable conditions. Moreover, this summary shows that at the country level there is stronger support for the hypothesis among the female than among the male country populations. Hence, this summary suggests that SES as a fundamental cause does not create similar health inequalities for men and women within countries. This point will be revisited in section 4.2.

Pooling all conditions and placing them in one of two categories provided an overview, at the potential cost of nuance. Though we have a pattern where educational gaps were more frequent among the high-preventable conditions, few gaps are significant for all countries and conditions, and the strength of the association between education and preventable morbidity vary between countries and genders.

In the discussion chapter, we take an exploratory approach and interpret specific findings more in depth. Relevant condition-, country-, and gender-specific findings will be compared to previous research. Lastly, we will discuss methodological limitations.

4.1 Health conditions

In studies stratifying by specific conditions or causes of death, inequalities have been particularly pronounced for cardiovascular disease and related risk factors (cf. Hummer and Lariscy (2011); Masters et al. (2012); Meara et al. (2008); Zapata Moya et al. (2015)), classified by Mackenbach et al. (2015) as amenable to behavior change. This is to some degree reflected in our stratified analyses, with six countries showing significant educational gaps for heart or circulation problems among both genders and eleven countries showing high blood pressure among women. Depression is the condition where most countries show significant educational gradients; 16 countries among men and 19 among women. Here, it is worth noting a methodological point: the overall mean score on the depression scale is relatively low, meaning there is little 'depression' in the sample. Thus, we here rather study variation and educational gaps in relatively good 'well-being' across all populations. Educational inequalities were also found in Zapata-Moya and colleagues' (2015) study using a (self-reported) dichotomous depression variable, with pronounced gender differences in women's disfavor among the lower educated.

4.2 Gender

Analyses were stratified by gender. Prevalence figures (Table A.3 and A.4) showed that more female than male respondents had experienced one or more health problems, which was as expected based on previous findings (cf. McNamara, Balaj, Thomson, Eikemo, Solheim, et al. (2017)). Regression results indicated similar patterns across genders when looking at the health problems separately, with a higher number of significant associations across countries, while the educational gap for the pooled high-preventable conditions variable was larger for women than for men (Table A.7). For the low-preventable conditions, results were similar across genders, except for an inverted gap among men when pooling condition and country samples.

As both our initial analyses and previous research had indicated gender differences in the association between high-preventable mortality/morbidity and SES (cf. Meara et al. (2008); Piers et al. (2007); Zapata Moya et al. (2015)), we wanted to test whether the effect of education was significantly different for women than for men. Our models including an interaction term between education and gender, showed that for low-preventable conditions, men and women did not benefit differently from education. However, results from the high-preventable conditions indicated that gender differences were levelled among the higher educated, indicating stronger support to the FCT hypothesis among women than among men. One interpretation could be that the resources associated with higher education were of greater benefit for women than for men, another that lacking these resources were more detrimental to women than to men, or, that men and women with equal socioeconomic positions nevertheless do not possess similar resources or opportunities to make use of their resources, such as obtaining equally good jobs despite similar qualifications within a gender segregated labor market. What specific resources and mechanisms could be of relevance here? Some of the explanations proposed in previous research have emphasized gender differences in the adoption of lifestyle traits, such as Meara et al. (2008) suggesting that a differential decline in smoking habits in the US, with sharper divergences among women, could explain the gender differences in their results. A similar trail of thought can be found in Mackenbach's (2017) discussion of the persisting small inequalities in all-cause mortality in Southern Europe; he highlights how the smoking patterns common in parts of Western Europe – gradually becoming a habit associated with low SES – has yet to reach Southern European countries like Italy and Spain.

4.3 Countries

Following standard social determinants of health explanations, like the 'rainbow' model of Dahlgren and Whitehead (1991), the social distributions of these conditions could be influenced by both human agency, living and working conditions, and institutional arrangements. While Willson's (2009) comparative study suggested an effect of national policies, more specifically the universal health care system and encompassing social policies in Canada, on preventable health inequalities, results from Mackenback et al. (2015; 2017) were more ambiguous. Though inequalities were at lower levels in Northern, Southern, and continental than in Central-Eastern European countries, a measure of country-level inequality showed no significant effects. Expectations from these studies were partly supported by our results from analyses of stratified and pooled conditions, as Central-Eastern countries Hungary and Lithuania showed consistently large inequalities among men and women, compared to continental countries such as Austria and France. However, these estimates also displayed gender differences within countries. For example, in the Northern and continental countries Norway, Denmark, and Germany, there were large educational gaps among women and non-significant gaps among men.

The ambiguity of these results suggests complex mechanisms linking national policies to preventable health inequalities, with variations across conditions, countries, and gender. The FCT postulates that health-beneficial resources associated with SES, gender, ethnicity, and social capital may work through various mechanisms, and thus have changing impacts, in different contexts. An example from our findings is the variation between genders in educational inequalities for high- and low-preventable conditions. In an attempt to analyze this variation, we suggest that future research integrate an institutional perspective, e.g. the framework by Beckfield and colleagues (2015), with the fundamental cause perspective. A starting point could be to build our current model into a multilevel model with indicators of redistribution, compression, mediation, and imbrication as country-level variables, and explore their associations with the different health conditions – both independently and interacting with education and gender.

4.4 Methodological limitations

Some reported conditions, such as cancer, included a range of diagnoses, making it difficult to determine its overall preventability. Preventability and amenability have for decades been issues in the epidemiological literature, with debates over definitions and boundaries between avoidable, preventable, and amenable disease; over the contribution of individual behavioral factors, primary and secondary health care, and medical technology and knowledge; and over whether certain diseases and causes of death are avoidable at all (Nolte & McKee, 2004). In a review of literature on amenable mortality, Nolte and McKee (2004, p. 52) suggested that findings using these classifications should be treated as indicators of concern and for future research rather than as confirmatory evidence. Within the health inequalities field, the Phelan et al. (2004) classification appears to have set precedent for preventability comparisons, as it has modelled several similar studies in the following years (cf. Bränström et al., 2016; Mackenbach et al., 2015; Mackenbach et al., 2017) . In this article, the potential limitation of ambiguous classification is approached by maintaining an exploratory scope, not seeking to provide clear-cut answers about high- and low-preventable conditions, but to explore the data by condition, country, and gender, as a first step before undertaking more rigorous analyses. The high-preventable conditions differ greatly in potential causes and consequences but has in common that some degree of lifestyle adjustment or individual health agency may reduce the probability of experiencing the condition.

The link between educational attainment and health outcomes has been thoroughly established (Montez & Friedman, 2015). Educational status may be related to material health-beneficial resources such as fulfilling jobs and economic security (Montez & Friedman, 2015), or to more education-specific resources such as knowledge or ability to process information. An argument for measuring SES by education, as opposed to other indicators, is because "It is a useful indicator if for no other reason than it is generally available for both sexes, excludes few members of the population, and is less subject to negative adult health selection" (Lynch & Kaplan, 2000, p. 22). The last part implies that one's level of educational attainment usually is unaffected by health outcomes measured at adult age (Mackenbach et al., 2015). In addition, educational attainment may indicate a more long-term location in the social structure, as opposed to potential shifts in occupational status and current income (Elstad, 2000). In addition to having an independent association with health outcomes, education may therefore be a precise proxy for SES, intercepting the effect of other SES measures on health.

The universality of education as an SES variable enables us to compare social gradients across countries and conditions, but when it comes to explaining the disease-specific mechanisms, the approach of treating education as merely a SES proxy may not be the most adequate strategy. Braveman and colleagues (2005) argue that "One size does not fit all"; meaning that researchers too often use different measures of SES interchangeably and with similar assumed associations with health outcomes. Education may work through different mechanisms and trigger different flexible resources when affecting social inequality in psychiatric, cardiovascular-related, or muscular conditions.

Furthermore, as most Western countries have experienced an expansion of educational systems in recent decades, education may mean different things for different generations, generating different pathways to health (Hayward, Hummer, & Sasson, 2015). Educational attainment may thus not be a uniform measure of social stratification across age groups, countries or genders. However, to really study the age-cohort-period effect, longitudinal data would be necessary.

An important limitation of our study concerns the classification of health problems as high-or low-preventable. This exploration of the social gradient in high- and low-preventable self-reported morbidity is to our knowledge the first of its kind, and we argue that it exhibits a novel way of testing the theory – the mechanisms connecting social position to respectively morbidity and mortality may differ substantially. Health inequality research using survey data have been dominated by the use of global measures such as self-rated health. The utilization and classification of specific health problems in our analyses may represent an attempt to improve the validity of such analyses. The conditions listed in the ESS health module are not perfectly matching neither overall health nor strict medical classification measures such as the

ICD. They may nevertheless give an accurate expression of a respondent's health status, as they can be seen as constituting a fusion of medical categories, individual feelings, and social conventions – corresponding to the health concepts of disease, illness, and sickness (cf. Hofmann, 2016).

Piers et al. (2007, p. 5) defined amenable conditions as "those [conditions] from which it is reasonable to expect death to be averted even after the condition has developed", while preventable conditions "typically include those for which there are effective means of preventing the condition from occurring", including e.g. lifestyle adjustments and legal measures. Following this argument, we found "preventable" to best describe the nature of the conditions in this paper. We wish to highlight the subjective aspect of this classification; one condition in the survey may contain a cluster of different diagnoses with different degrees of preventability.

The preventability rating and classification of each independent health condition can most likely be debated. In order to communicate with the findings of Phelan et al. (2004) and subsequent studies, we found it vital that the two classifications were to some degree equivalent. However, some self-reported conditions were described as 'pain', which may be symptoms of several diseases. In those cases, we took a 'catch-all approach' and aimed to find medical diagnoses with numerous causes and symptoms, such as arthritis and migraine. Though this procedure may not be accurate for all self-reported pains, we argue that it provides a reliable measure of preventability.

By breaking the analyses down by gender, country, and conditions, some samples were small, weakening the power of statistical hypothesis testing. Nevertheless, using both the pooled and stratified data fits with this first study's exploratory scope, allowing us to discuss both general and specific explanations concerning high- and low-preventable conditions in European countries.

Another limitation concerns the nature of survey data; self-reported conditions may be suspected to diverge from clinical measurements. Dalstra et al. (2005) reviewed comparisons of self-reported health and clinical diagnoses. They found a high degree of accuracy; the few incidents of divergence were less educated people underreporting certain conditions, potentially causing an underestimation of the socioeconomic inequalities (Dalstra et al., 2005).

Prevalence and compositional effects also represent potential limitations: The proportion of respondents who had experienced the different health conditions or obtained primary, secondary and tertiary education varied between countries, which potentially could affect the regression analyses and estimations. Including weights in our models aimed at countering these effects.

A last limitation concerns representability, a general limitation regarding health survey data. The prevalence of conditions in our study population may be an imperfect representation of actual population prevalence, since response rates differed between countries, and only non-institutionalized respondents were included. We met the latter limitation in our analyses by limiting the upper age inclusion criteria to 69 years; with that aiming to exclude non-institutionalized elderly, whose health may not be representative for their respective populations. For further information on ESS strengths and limitations, see Eikemo et al. (2016).

5. Conclusion

This explorative analysis of educational inequalities for high- and low-preventable conditions supported the FCT hypothesis that social inequalities in health increase with our ability to detect, prevent, and cure disease. In our analyses we found more significant gaps among the high- than the low-preventable conditions. Our analyses using pooled conditions variables yielded similar results, while also indicating that the health-beneficial resources associated with education are differently distributed between women and men.

Though most high-preventable conditions showed the expected educational gaps, our exploration of the country- and condition-stratified analyses detected substantial variation between conditions, countries, and genders. Previous findings highlighting specific conditions and country patterns – such as cardiovascular disease and Eastern-Central European countries – were to a certain degree reflected in our results. Variation across countries and conditions indicates that the SES-health associations are context-dependent, with a need for more context-specific explanations. The integration of an institutional perspective may therefore enhance future comparative research.

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Appendix

Table A.1: Overview of ESS7 conditions, their ICD equivalents, and preventability ranking

Condition in ESS7	**Most similar cause of death in Phelan et al. (2004)**	**Most similar other condition and literature on preventability**	**Rating based on Phelan et al. (2004)**
Allergies		Gore & Custovic (2004)	1
Back or neck pain		Arthritis: Powell et al. (2005) Källberg et al 2011	5
Breathing problems	Chronic obstructive pulmonary disease		5
Cancer	Highest-mortality neoplasms		4
Depression	Suicide and self-inflicted poisoning Suicide and self-inflicted injury by hanging	Tanaka et al. (2011) Melnyk et al. (2006)	4
Diabetes	Diabetes mellitus		4
Heart or circulation problem	Congestive heart failure Ischemic heart disease		4
High blood pressure	Hypertensive heart disease		4.5
Muscular or joint pain in foot or leg		Arthritis: Powell et al. (2005) Källberg et al 2011	5
Muscular or joint pain in hand or arm		Arthritis: Powell et al. (2005) Källberg et al (2011)	5
Severe headaches		Migraine and Cluster headache: Rasmussen (1993) Mitsikostas & Rapoport (2015)	2

		Schürks et al. (2006)	
Skin condition related	Similar to allergies	Gore & Custovic (2004)	1
Stomach or digestion related	Peptic ulcer		5

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Table A.2: Descriptive statistics, independent variables

		Age		Education (%)			
		Mean	SD	Primary	Secondary	Tertiary	n
Austria (AT)	Men	47.1	12.6	12.89	73.14	13.98	644
	Women	46.4	12.3	18.39	65.11	16.50	685
Belgium (BE)	Men	47.7	12.5	27.61	47.19	25.20	623
	Women	47.5	12.4	20.06	44.30	35.63	623
Czech Republic (CZ)	Men	47.6	12.2	4.27	80.20	15.53	702
	Women	47.3	12.5	6.29	79.51	14.20	859
Denmark (DK)	Men	47.5	13.1	14.45	51.78	33.77	533
	Women	48.2	12.1	12.87	38.25	48.88	536
Finland (FI)	Men	49.8	13.0	15.97	54.50	29.53	745
	Women	49.7	13.1	11.91	52.36	35.73	764
France (FR)	Men	47.9	12.3	14.81	61.48	23.70	675
	Women	48.1	12.9	20.08	56.79	23.13	722
Germany (DE)	Men	48.8	12.2	4.28	66.49	29.23	1122
	Women	48.1	12.3	8.48	65.49	26.02	1049
Hungary (HU)	Men	48.3	12.4	10.38	74.34	15.28	530
	Women	48.3	12.8	15.21	62.63	22.16	677
Ireland (IE)	Men	47.9	13.1	36.24	41.87	21.90	781
	Women	46.7	12.6	28.95	49.16	21.89	950
Israel (IL)	Men	45.6	13.8	13.93	51.82	34.24	768
	Women	46.4	13.3	11.79	51.69	36.51	975
Lithuania (LT)	Men	48.4	12.0	14.75	62.30	22.95	610
	Women	49.2	12.8	10.72	55.36	33.92	961
Netherlands (NL)	Men	49.7	12.9	29.11	36.84	34.05	608
	Women	48.1	12.4	31.13	36.75	32.13	800
Norway (NO)	Men	48.0	12.3	10.16	51.72	38.11	551
	Women	47.8	12.6	11.88	41.04	47.08	480
Poland (PL)	Men	46.4	13.0	45.54	34.57	19.89	538
	Women	47.8	13.0	34.41	40.84	24.76	622
Portugal (PT)	Men	48.2	13.0	55.93	27.58	16.49	388
	Women	49.2	12.5	58.86	18.38	22.76	457
Sweden (SE)	Men	47.6	13.3	14.17	59.19	26.64	593
	Women	47.4	12.9	6.87	55.97	37.15	611
Slovenia (SI)	Men	48.4	13.0	13.28	66.67	20.05	399
	Women	48.1	12.7	17.89	60.34	21.77	464
Spain (ES)	Men	46.4	12.0	53.31	26.10	20.58	724
	Women	46.5	12.1	44.31	26.65	29.04	668
Switzerland (CH)	Men	48.0	12.7	12.13	62.05	25.37	544
	Women	47.4	12.5	19.57	61.23	19.20	552
United Kingdom (UK)	Men	48.3	12.6	27.40	41.89	30.70	697
	Women	47.9	12.6	31.84	38.90	29.26	892

Table A.3: Country and total population prevalence of conditions (percentage of male sample)

	Low-preventable			High-preventable										Pooled	
	A	B	C	D	E	F	G	H	I	J	K	L	M	LP	HP
AT	6.2	9.0	5.7	31.5	5.0	10.3	0.19	3.4	7.4	15.5	16.4	13.2	7.4	17.8	45.7
BE	11.1	9.0	7.4	49.6	8.5	5.1	0.18	4.7	7.2	13.5	24.6	23.4	16.1	23.2	67.4
CZ	5.4	6.4	5.0	20.7	4.2	N/A	0.26	5.5	5.4	15.7	9.8	9.1	7.5	14.5	46.1
DK	17.0	7.7	9.9	49.9	9.2	7.7	0.18	6.2	7.3	19.8	24.3	24.7	13.5	29.3	72.4
FI	15.0	11.4	14.0	48.1	8.9	5.7	0.17	7.5	9.8	23.1	30.7	25.1	16.1	32.1	71.8
FR	11.4	14.8	8.7	46.7	8.3	6.8	0.19	5.0	6.7	12.6	25.5	28.4	19.0	29.3	65.9
DE	13.9	14.2	11.6	49.4	8.6	5.9	0.21	6.3	9.7	24.7	24.0	20.8	16.6	31.2	70.6
HU	4.4	7.1	1.0	14.8	4.2	19.2	0.26	6.1	8.2	19.7	11.7	9.8	4.6	11.6	34.8
IE	4.9	3.4	5.2	19.6	5.4	9.1	0.16	2.5	4.9	11.5	12.6	8.8	7.0	12.7	37.5
IL	5.9	7.3	4.7	19.7	5.5	11.9	0.21	7.9	8.0	11.6	11.7	12.3	6.7	15.0	37.2
LT	3.3	5.3	1.2	25.5	2.8	15.2	0.27	3.5	13.0	16.8	11.7	10.2	10.0	8.4	48.7
NL	10.2	8.4	9.1	37.2	9.2	6.3	0.17	7.6	10.0	17.3	20.2	19.7	10.9	24.0	61.9
NO	16.3	6.0	11.4	40.5	6.9	6.0	0.15	2.7	6.2	14.0	23.4	23.2	14.3	27.2	63.9
PL	8.1	7.6	4.3	31.2	3.1	7.1	0.19	3.9	14.6	17.6	20.5	22.6	11.1	17.6	55.2
PT	12.4	13.9	5.2	43.6	7.0	5.2	0.24	7.0	6.7	19.3	26.3	22.4	15.0	27.0	64.7
SE	15.2	7.6	7.8	43.7	6.9	5.6	0.18	4.4	5.2	16.2	24.1	24.5	16.5	27.5	63.9
SI	6.8	8.0	3.3	38.7	7.0	6.1	0.18	5.8	9.3	21.1	18.8	21.1	13.1	15.7	61.9
ES	11.2	9.1	5.7	35.0	5.8	4.7	0.20	4.6	5.5	13.3	20.2	20.8	13.0	23.0	55.9
CH	9.4	12.3	8.7	37.9	6.1	12.2	0.17	3.0	5.2	13.3	25.1	17.3	12.9	25.9	57.2
UK	9.2	8.5	9.4	38.7	11.5	6.0	0.21	6.9	6.6	18.4	26.8	23.0	17.4	23.2	62.1
Total	9.9	9.0	7.3	36.2	6.8	8.1	0.20	5.3	7.8	16.8	20.4	18.9	12.5	22.1	58.0

Note: A – Allergies, B – Headaches, C – Skin condition, D – Back or neck pain, E – Breathing problems, F – Cancer, G – Depression (mean score), H – Diabetes, I – Heart or circulation problem, J – High blood pressure, K – Muscular or joint pain in foot or leg, L – Muscular or joint pain in hand or arm, M – Stomach or digestion problems, LP – Low-preventable conditions, HP – High-preventable conditions

Table A.4: Country and total population prevalence of conditions (percentage of female sample)

	Low-preventable			High-preventable										Pooled	
	A	B	C	D	E	F	G	H	I	J	K	L	M	LP	HP
AT	10.7	14.2	8.8	36.2	5.1	10.0	0.20	1.6	5.9	11.3	14.2	15.2	12.7	26.0	48.4
BE	15.1	22.8	8.0	54.6	9.0	7.9	0.23	1.8	7.5	18.8	28.4	28.6	25.4	37.5	73.2
CZ	10.7	13.1	4.9	28.7	5.7	N/A	0.29	7.0	4.7	14.2	13.1	11.7	9.2	24.9	51.7
DK	19.0	17.5	12.5	49.8	8.2	11.4	0.20	3.9	4.9	14.0	29.7	26.7	19.6	38.2	68.2
FI	21.3	22.1	20.2	57.6	12.6	7.6	0.24	5.9	7.3	18.1	33.6	26.6	26.4	45.4	76.2
FR	17.4	27.4	9.4	57.6	10.8	10.1	0.18	4.9	8.9	13.2	26.1	34.9	23.3	43.7	77.3
DE	17.8	27.3	14.2	60.2	10.2	10.3	0.25	4.3	11.6	19.3	27.2	24.8	22.9	44.3	75.4
HU	8.7	13.3	4.0	16.6	4.0	19.9	0.29	6.6	10.0	20.5	14.5	12.9	7.9	21.3	37.0
IE	6.1	7.6	5.9	24.6	7.9	9.9	0.19	1.9	3.1	8.8	12.7	11.8	11.4	16.4	39.6
IL	6.6	11.1	4.9	23.2	5.2	11.1	0.25	7.9	4.8	11.1	15.5	12.6	10.5	18.9	37.2
LT	4.4	12.8	4.2	28.3	3.7	20.2	0.29	3.4	17.9	21.8	13.0	10.9	16.5	18.5	53.3
NL	16.0	19.0	10.2	44.7	10.1	10.4	0.20	4.5	6.5	15.6	22.4	22.1	17.6	37.3	64.1
NO	24.8	16.5	10.0	47.7	12.5	10.6	0.17	1.3	5.0	12.1	31.3	32.9	21.3	41.1	67.2
PL	11.3	18.7	5.5	39.6	5.3	10.6	0.24	5.8	16.2	18.9	21.8	24.2	14.5	29.7	61.6
PT	16.6	30.2	7.4	49.7	9.2	10.3	0.33	7.4	10.7	21.0	36.5	41.1	18.8	42.1	71.5
SE	19.9	16.5	9.3	51.1	10.0	11.2	0.21	3.1	5.1	15.5	24.4	28.4	25.8	37.5	70.8
SI	10.5	14.4	5.0	46.7	7.1	8.1	0.21	6.2	11.0	21.1	21.7	20.4	19.6	26.0	68.0
ES	12.3	23.1	10.8	48.2	6.5	5.3	0.28	2.6	6.3	11.3	28.2	30.5	17.0	38.3	64.9
CH	13.1	19.4	10.0	43.2	6.0	18.0	0.18	2.4	5.1	9.6	20.9	20.9	17.1	34.7	59.9
UK	14.1	17.5	14.0	40.0	13.9	10.2	0.24	4.5	6.1	15.0	27.6	24.5	19.7	36.0	62.2
Total	13.3	17.9	9.0	41.4	8.1	11.3	0.23	4.4	8.0	15.5	22.3	22.0	17.5	32.1	60.9

Note: A – Allergies, B – Headaches, C – Skin condition, D – Back or neck pain, E – Breathing problems, F – Cancer, G – Depression (mean score), H – Diabetes, I – Heart or circulation problem, J – High blood pressure, K – Muscular or joint pain in foot or leg, L – Muscular or joint pain in hand or arm, M – Stomach or digestion problems, LP – Low-preventable conditions, HP – High-preventable conditions

Table A.5: Logistic regression (A-F & H-M) or OLS-regression (G) of primary vs. tertiary education on thirteen diagnoses, men aged 25-69

	Low-preventable			High-preventable									
	A	B	C	D	E	F	G	H	I	J	K	L	M
Austria (AT)							+**		+*				
Belgium (BE)						+*	+**					+**	
Czech Republic (CZ)		+*				N/A				+**			
Denmark (DK)	+*						+**		+**			+**	
Finland (FI)	-**												
France (FR)	-*		-**				+**					+**	
Germany (DE)			-**	+**	+*		+**		+**				
Hungary (HU)		+*					+***		+**	+**	+**	+*	
Ireland (IE)		+*			+*		+**			+**			
Israel (IL)						+***	+**		+**				
Lithuania (LT)	-**		+*				+***	+*			+**	+**	
Netherlands (NL)							+***		+**		+*		
Norway (NO)							+**	+**					
Poland (PL)	+**	+*			+**		+**						
Portugal (PT)		+*		+**	+**			+**				+**	
Sweden (SE)													
Slovenia (SI)					+**		+**						
Spain (ES)	-**			-***			+*				- **		
Switzerland (CH)			-*				+**						- **
United Kingdom (UK)	-**						+**					+**	
Full sample	-***	+***	-***	+**	+**	+*	+***	+***	+***	+**	+**	+***	

Notes: + indicates positive association between condition and primary education, - indicates negative.

A Allergies; B Severe headaches; C Skin condition related; D Back or neck pain; E Breathing problems; F Ever had cancer; G Depression; H Diabetes; I Heart or circulation problem; J High blood pressure; K Muscular or joint pain in foot or leg; L Muscular or joint pain in hand or arm; M Stomach or digestion related; * p < 0.10; ** p < 0.05; *** p < 0.001; No diagnose F for the Czech Republic

Table A.6: Logistic regression (A-F & H-M) or OLS-regression (G) of primary vs. tertiary education on thirteen diagnoses, women aged 25-69

	Low-preventable			High-preventable									
	A	B	C	D	E	F	G	H	I	J	K	L	M
Austria (AT)									-*				
Belgium (BE)				+**			+***					+**	
Czech Republic (CZ)						N/A	+**		+**	+**		+*	
Denmark (DK)		+**		+*			+**	+***		+**	+**	+*	
Finland (FI)	-*						+*			+***		+***	
France (FR)		+**		-*	+*		+***						
Germany (DE)	-*				+**		+***	+**	+**	+***		+**	
Hungary (HU)		+*			+**		+***		+**	+**	+**		
Ireland (IE)			-**			+*	+***		-**		-*		
Israel (IL)					+*	+**	+***						
Lithuania (LT)	-*	+**				+***	+***		+**	+***		+**	
Netherlands (NL)	-***						+**			+**			
Norway (NO)			-*	+**			+**	+*	+**	+**			
Poland (PL)	-*				+**		+**		+*	+*		+**	
Portugal (PT)			-**			-*	+***			+**	+**		
Sweden (SE)		+**					+*					+**	
Slovenia (SI)	-*						+**					+**	
Spain (ES)				-**			+***						-**
Switzerland (CH)						+**	+**						
United Kingdom (UK)		+*					+**			+**		+**	
Full sample	-***	+***	-***		+***	+**	+***	+***	+***	+***	+**	+***	

Notes: + indicates positive association between condition and primary education, - indicates negative.

A Allergies; B Severe headaches; C Skin condition related; D Back or neck pain; E Breathing problems; F Ever had cancer; G Depression; H Diabetes; I Heart or circulation problem; J High blood pressure; K Muscular or joint pain in foot or leg; L Muscular or joint pain in hand or arm; M Stomach or digestion related; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.001$; No diagnose F for the Czech Republic

Paper III: Monitoring the social gradient: Inequalities in use of blood pressure monitors in the HUNT Study

Abstract

Aim: To investigate the cross-sectional and longitudinal social gradient in use of blood pressure monitors, an innovative health technology. *Background*: this is one of the first studies of social inequalities in the utilization of an end-user health technology in a universal health care context. The diffusion of innovation (DoI) and fundamental cause (FCT) theories predicts a widening of inequalities with the introduction of a new technology. *Data and methods*: Two waves (N>18,000) of the Nord-Trøndelag Health Study (HUNT), conducted in 1997 and 2008. Dependent variables were three indicators of blood pressure monitor use. Independent variables were educational attainment and income quartiles. Control variables were gender, age, and blood pressure. *Results*: For the blood pressure monitor variable from 1997, there was evidence of an educational gradient. No social inequalities were found for the 2008 monitor variable. When interacting SES with a survey wave dummy, results showed a social gradient from 1997 becoming smaller or non-significant in 2008. These results are supportive of the DoI and FCT, suggesting that the use of technology may initially generate health inequalities, which becomes lesser as the technology is diffused across all social strata.

1. Introduction

Innovation within health technologies have been extensive over the last decades and has been proposed as a remedy to many of the central challenges facing modern health care, related to public health as well as biomedical or economic issues (World Health Organization, 1997). Research have also demonstrated a positive association between technological development and health outcomes, such as Dutta, Gupta, and Sengupta's (2019) study of ICT and infant mortality in selected Asian countries.

However, several pitfalls have been suggested, for instance the technologies' "impact upon healthcare costs, the creation of difficult ethical dilemmas, issues of personal privacy, and threats to the professional relationships between patients, families, and physicians" (Shine, 2004). Inequalities in outcome is also a recognized consequence of the diffusion of innovations (Rogers, 2003). In much of the health inequalities literature, the diffusion of medical innovations has proved to have an initial inequality-generating function; when new technologies or information is introduced, it tends to be disproportionally utilized by the higher social strata (cf. Gadeyne et al., 2017; Link, Northridge, Phelan, & Ganz, 1998; Polonijo & Carpiano, 2013; Wang, Clouston, Rubin, Colen, & Link, 2012). This is in line with a seminal theory in the field, the fundamental cause theory (FCT), which proposes that time- and context-dependent mechanisms will connect social positions with health outcomes. Different flexible resources associated with socioeconomic status, such as money, knowledge, power, prestige, and social networks, may be employed in different contexts to protect against health risks (Link & Phelan, 1995). In countries with high living standards and advanced welfare and health care systems, the introduction of medical innovations may be a particularly relevant mechanism generating health inequalities (Link et al., 1998; Mackenbach, 2012).

This article examines how the use of blood pressure monitoring technology is distributed across socioeconomic positions. This is done through using two survey waves of the Norwegian Nord-Trøndelag Health Study (HUNT) from 1997 and 2008, linked with register data on income and education. The CVD modules in the two waves include questions on experiences with blood pressure monitoring technologies. To my knowledge, this is the first investigation of social inequalities in use of an innovative, end-user health technology in a universal health care context.

Over the last decades, Norway have seen a drop in cardiovascular disease (CVD) and related mortality, while the social inequalities for this cause of death persist (Strand et al., 2014). High blood pressure is an important risk factor and determinant in this aspect, with studies showing that social inequalities in CVD mortality is reduced by up to 24% when controlling for hypertension (Strand & Tverdal, 2004). While population blood pressure has seen a similar decrease in this time period, it remains unclear whether medical innovations such as blood pressure monitoring technology have been significantly contributing to this dual development of overall decrease and persisting inequalities.

2. Background

Throughout the 20th century, growing real income was paired with increased life expectancy in most high-income countries; among the proposed explanations for this decline were better nutrition, public health improvements, vaccination, and innovations in medical treatments (D. Cutler, A. Deaton, & A. Lleras-Muney, 2006). Nevertheless, one's position in the social structure, however measured, has been and continues to be a significant predictor of health outcomes (Deaton, 2002; Mackenbach et al., 2017). A range of theories attempts to explain this so-called paradox, both general social theories and theories with attention to the distribution of specific health-relevant resources (Mackenbach, 2012).

The fundamental cause theory (FCT) have gained foothold in recent years. It was formulated by Link and Phelan (1995) as a reaction to what they saw as a prevailing approach in health inequality research: to mainly investigate the social distribution of risk factors located proximate to the health outcome in the causal chain. Link and Phelan (1995: 85) argued for the importance of looking upstream at "the more fundamental factors that put people at risk of risks". Within this line of reasoning, social conditions are the fundamental causes of health inequality; if the unequal distribution of vital, flexible resources persist, so will inequalities in health outcomes. One consequence for empirical research is an intensified focus on the mechanisms connecting social position with health and how these may change over time and across institutional contexts (Freese & Lutfey, 2011; Lutfey & Freese, 2005). Housing conditions may in most industrial countries be a less relevant mechanism for health inequalities in 2019 than in 1850; but if resources still are unevenly distributed, this mechanism may be replaced by another, e.g. the utilization of medical technology, and health inequalities will endure.

2.1 Technology and health inequalities

The diffusion and utilization of innovative health technologies represent a good case for testing the FCT: they are likely to improve population health; one can determine a point in time where these innovations did not exist, i.e. where they did not mediate social inequalities in health; and they are human inventions rather than acts of nature, thus illustrating the social shaping of health (Link et al., 1998, pp. 378-379). Investigating innovations' effect on health inequalities resonates well with studies of the diffusion of innovations (Rogers, 2003). This theory proposes a hierarchical diffusion of innovations, where people of higher social positions are early adopters of new behavior (Rogers, 2003; Victora, Vaughan, Barros, Silva, & Tomasi, 2000). Cutler, Deaton, and Lleras-Muney (2006) writes of how the emergence of a health gradient has followed transitions in knowledge, science, and technology, mentioning the Enlightenment, the germ theory of disease, and knowledge of the health consequences of smoking. The following section reviews selected research on social inequalities within use of and access to innovative medical technology; many of them with a fundamental cause theory (FCT) or diffusion of innovations (DoI) perspective. The literature review is structured by Weiss and colleagues' (2018) categories of innovative health technologies.

Some studies have focused on what Weiss et al. (2018) termed *indirect-use gatekeeper technologies*, where end-users of the technology are dependent on gatekeepers (usually medical professionals) for access and utilization. Relevant examples are screenings and surgery procedures. Link et al. (1998) focused on the social gradient in the use of two medical innovations: pap smears and mammography. Both innovations showed social inequalities over the study years (1988-1995). The use of pap smears was stable, while the use of mammography showed a rapid increase, meaning that all groups benefited from the innovation, but the top socioeconomic groups benefited more (Link et al., 1998). Gadeyne et al. (2017) found that breast cancer mortality went a positive to a negative association with education from the 1990s to the 2000s; authors interpret that this is in line with the FCT - increased information and availability of mammography screening have contributed to the inversion of the gradient. Explicitly testing the FCT and its link with the DoI, Zapata-Moya, Willems, and Bracke (2019) found that the influence of SES on preventive practices varied with the practices' diffusion stages; PSA tests in an early majority stage showed the largest inequalities, blood pressure checks in a late majority/laggard stage showed the smallest. Willems and Bracke (2018a, 2018c) investigated the social determinants of cancer screening across European countries, and found substantial educational inequalities in cancer screening, with organized screening programs and physician initiatives partially levelling these disparities. In a longitudinal analysis of cancer screening across Belgian regions, Willems and Bracke (2018b) found greater fluctuation for screening of breast cancer than for cervical cancer, with a reduction of inequalities in a region where official screening programs were initiated. Korda, Clemens and Dixon (2011) investigated social inequalities in coronary surgery, a technology with strong features of gatekeeping. They found a diffusion lag – people of high SES had an earlier peak in the uptake of coronary surgery.

Another strand of research has concentrated on *direct-use gatekeeper technologies*, where the people affected by the innovation are responsible for using it, but still depend on gatekeepers for access (Weiss et al., 2018). Many of these studies have utilized longitudinal data on different types of prescription drugs. Goldman and Lakdawalla (2005) found that the introduction of simplifying hypertension drugs contributed to a contraction of health inequalities, while a new, somewhat complicated HIV treatment regimen (HAART) was disproportionally utilized by the better educated. Rubin, Colen, and Link (2009, p. 1056) analyzed the same phenomenon, reaching supporting findings: "SES–HIV/AIDS mortality association became stronger following the introduction of the innovative treatment HAART". Similar conclusions were drawn by Chang and Lauderdale (2009), finding that the introduction and diffusion of the statin drug over the years 1976-2004 correlated with a widening of disparities in cholesterol. Finally, Glied and Lleras-Muney (2008, p. 756) used state mortality changes and approved drug ingredients as general and specific measures of health-related progress and innovation, finding "support for the hypothesis that the education gradient is steepest for those diseases that have seen the most health-related innovation".

Direct end-user technologies are "technologies accessed and used directly by the end user"; these technologies depend to a larger degree on individual user agency (Weiss et al., 2018). Digital health literacy or so-called eHealth devices were the study objects in several of the studies included in Weiss and colleagues' (2018) review. Two studies using Australian focus groups showed that a number of determinants hindered disadvantaged groups in utilizing digital technology to gain health benefits, including financial strains, lacking English or technological literacy, unstable housing and employment situations, poor health, and lacking social networks (Baum, Newman, & Biedrzycki, 2012; Newman, Biedrzycki, & Baum, 2012). Socioeconomic inequalities were also present in Perez and colleagues' (2016) investigation of digital health information processing strategies, where low-SES participants showed a tendency for intuitive – "unconscious, rapid, automatic, and high capacity thin" – strategies. Individual level utilization of direct end-user technology can also be affected by structural factors such as cell phone disconnection, as shown in Gonzales, Ems, and Suri's (2016) results from interviews at two free health clinics in the US.

Finally, health-beneficial information may also follow the same hierarchical pattern of diffusion. A well-known example is the development of the quitting 'epidemic' in smoking across Europe: As the negative effects of tobacco smoking became known, people of higher social positions were the first to adjust their behavior, with an inversion and a widening of smoking-related health inequalities to follow (Mackenbach, 2012). Using cross-sectional survey data on US teenagers and the HPV vaccine, Polonijo and Carpiano (2013) found that there was a significant social gradient with regards to knowledge, recommendation by physician, and finally uptake of the vaccine. These inequalities were significant when using mother's education and household income as SES measures, as well as for race/ethnicity, leading the authors to conclude that disparities were present in all stages of innovation diffusion, from first knowledge to actual uptake (Polonijo & Carpiano, 2013, p. 123). Looking at actual health outcomes of information disparities, Wang and colleagues (2012) found that an interaction between SES and a measure of informational diffusion was significantly associated with colorectal cancer mortality, indicating that high information diffusion rates may reduce the impact of SES on mortality.

2.2 Study context

In this study, blood pressure monitors serve as a case for investigating technology's role in generating and/or mediating health inequalities. The traditional mercury sphygmomanometer has over the last decades been phased out as the standard blood pressure measuring equipment, and new types of measurement tools have become available to both health professionals and patients, such as aneroid and oscillometric technology (Moe, Getz, Dahl, & Hetlevik, 2010). In a survey conducted among 173 GPs in 45 medical centers in central Norway, only 7% of the GPs reported not having monitors available for patients to loan 24-hour automatic blood pressure monitors (Moe et al., 2010). Blood pressure monitors have also become increasingly available for personal purchase in stores. Prevalence figures from the HUNT study (Table 1) suggest an increase in the use of blood pressure monitors. In HUNT2, 4.7 % of respondents report having a blood pressure monitor at home; in HUNT3, 27.4 % reports having used a 24-hour blood pressure monitor. As for the question repeated in HUNT2 and HUNT3, a total of 14.6 % of respondents report having measured blood pressure at home; stratifying the two surveys return a 9.8 % prevalence in HUNT2 and a 17.6 % prevalence in HUNT3. Although not completely comparable, these figures combined indicate an increased adaption of personal blood pressure monitoring equipment from the years 1997 to 2008. All in all, this can be interpreted as an indication of blood pressure monitors being widely diffused in early 21st century Norway. As the Norwegian health care system in characterized by a high degree of universality, measures for treatment and prevention should be equally distributed across the social strata. Nevertheless, research on different medical services in Norway have proved substantial social inequalities in access and utilization (Brekke, Holmås, Monstad, & Straume, 2018; Elstad, 2018; Fiva, Hægeland, Rønning, & Syse, 2014; Nilssen et al., 2016; Sulo et al., 2016).

Social inequalities in CVD have persisted over the last decades, through what can be characterized as a rapid medical and technological development, thus increasing the ability both health systems and individuals to prevent, detect, and treat disease (D. Cutler et al., 2006; Strand et al., 2014). Simultaneously, the absolute overall prevalence of CVD risk factors like hypertension have decreased, as the overall use of remedies like blood pressure medication and measuring devices have increased (Holmen et al., 2016). Have these developments benefited all social strata equally – or could unequal use of blood pressure monitors be an indicator of the opposite? The reviewed research has indicated that while introducing innovative technology or new information to the health field may have beneficial effects on average, they may also generate and widen social inequalities in health. Social inequalities in health have continued to persist in the Nordic welfare states, despite their universalistic principles and advanced health care systems (Mackenbach et al., 2017). Could inequality structures in technology use contribute to explain these trends? Masters, Link, and Phelan (2015) have described a shortcoming of the FCT: it does not explain how the same resources and health outcomes show different associations across different contexts. Stages in the diffusion process could represent these contexts and contribute to explain how resources may have varying effects. Zapata-Moya and colleagues (2019, p. 189) highlight how “the conjunction with DOI theory adds a contextual and temporal dimension to FCT”, and this study is an attempt to further follow up this joining of theories with empirical research covering several time points.

3. Data and Methods

The Nord-Trøndelag Health Study (HUNT) is a population-based panel study carried out in 1984–86 (HUNT1), 1995–97 (HUNT2), and 2006–08 (HUNT3) in Nord-Trøndelag County in Norway. The two latter waves will be utilized in this study. This county is to a large degree representative of the Norwegian population regarding demography, economy, morbidity, and mortality, and with approximately 120,000 respondents in total and 28,000 respondents participating in all three waves, the HUNT study provides representative, reliable, and valid measurements of the Norwegian population’s health during the last decades (Holmen et al., 2003; Krokstad et al., 2012). All respondents above the age of 20 in Nord-Trøndelag county were invited, response rates were 69% and 54% for HUNT2 and HUNT3 respectively. The questions on blood pressure monitors were included in a cardiovascular questionnaire module given to respondents who either reported use of hypertension medication (HUNT2) or showed indications of cardiovascular or renal disease in the baseline screening (HUNT3). The research project was given approval by the Regional Committee for Medical and Health Research Ethics in Central Norway (REK-Mid).

3.1 Variables

The analyses utilized three dependent variables indicating use of blood pressure measurement equipment, all dichotomous with “Yes” and “No” as question choices. A question included in both HUNT2 and HUNT3 was worded “Have you ever measured your blood pressure yourself at home?” (*Self-measure* in tables). Further were analyses preformed with variables worded “Do you have a blood pressure monitor at home?” (HUNT2, *Home-measure* in tables) and “Have you used a 24-hour blood pressure monitor?” (HUNT3, *Auto-measure* in tables) as dependent variables.

Two explanatory variables measuring SES were included: education measured as completed primary, secondary or tertiary education (following the ISCED classification) and yearly individual income measured in quartiles. These variables are register data collected by Statistics Norway and linked to HUNT respondents through their personal identification number. The two SES variables measures are meant to capture health-relevant resources associated with social position, for instance money, knowledge, power, prestige, and social networks; they are added to the models separately and combined. Systolic and diastolic blood pressure (SBP and DBP), clinically measured by health professionals, were included as independent control variables, as patients with high measured blood pressure typically is advised by their GP to also have their blood pressure measured out of office (Kleinert et al., 1984; Lindbaek, Sandvik, Liodden, Mjell, & Ravnsborg-Gjertsen, 2003).

Age was measured in years and also included as a squared term to control for potential curve-linearity. Gender was treated as a binary variable with women as the reference. A survey wave dummy was added to the model in order to control for structural, unmeasured changes occurring between the first and second study wave. This dummy was used to construct two multiplicative interaction terms between survey wave and 1) income quartile and 2) educational attainment in order to investigate whether SES had a different impact on technology use at the two time points. Table 1 displays descriptive statistics for dependent and independent variables.

3.2 Methods

Since the dependent variable only allowed data collection from one or two time points, panel data methods such as fixed effects regression were unsuitable. In the analyses using the question included in both HUNT2 and HUNT3, data from the two waves were pooled, and logistic regression were performed with robust standard errors adjusting for individual respondent clustering. For the two other dependent variables, cross-sectional logistic regression analyses were performed. Models were first run with income and education entered separately, then together in the same model. Lastly, in the analyses using data from both HUNT2 and HUNT3, models including interactions between the survey wave dummy and the SES variables were run. Marginal predicted probabilities were calculated and are displayed graphically in figures 1-3. Table 2 displays the final regression models for all three dependent variables. In an online appendix are the partial regression modelling for all dependent tables displayed in tables A.1-A.3. Analyses were performed using software STATA 15.

Table 1: Descriptive statistics – distribution and mean

	HUNT2+3	HUNT2	HUNT3
Variable	**Distribution/Mean (SD, Min-Max)**	**Distribution/Mean (SD, Min-Max)**	**Distribution/Mean (SD, Min-Max)**
Primary education	37.8 %	49.7 %	30.2 %
Secondary education	48.8 %	41.8 %	53.4 %
Tertiary education	13.3 %	8.5 %	16.5 %
Income quartile group 1	54.9 %	62.2 %	50.1 %
Income quartile group 2	8.5 %	9.7 %	7.7 %
Income quartile group 3	21.3 %	15.4 %	25.1 %
Income quartile group 4	15.4 %	12.7 %	17.2 %
Age	65.3 (12.2, 19.5-99.3)	65.4 (12.0, 20.8-99.3)	65.2 (12.3, 19.5-96.9)
Systolic BP	145.4 (22.7, 67-260)	157.0 (22.7, 81-239)	138.3 (19.5, 67-260)
Diastolic BP	80.5 (13.6, 36-156)	88.6 (12.8, 44-156)	75.6 (11.5, 36-137)
Gender (Man)	46.4 %	43.3 %	48.5 %
Self-measure	14.6 %		
Home-measure		4.7 %	
Auto-measure			27.4 %
N	18,153 (15,705)*	6,910	11,133

*Observations (individual respondents)

4. Results

First looking at the control variables, we find that age had significantly positive associations with having a 24-hour blood pressure monitor in HUNT3 and and having ever measured blood pressure at home in HUNT2 and HUNT3. A weak, but significant negative estimate for the squared variable indicates a diminishing effect of age on the probability of utilizing blood pressure monitoring equipment. Systolic and diastolic blood pressure showed mostly positive, significant associations with equipment use; an exception being diastolic blood pressure in HUNT2, which were not statistically significant. Being male was positively associated with having a blood pressure monitor at home in 1997 (HUNT2), negatively associated with using a 24-hour blood pressure monitor in 2008 (HUNT3) and showed no significant association with ever having measured blood pressure at home (HUNT2 and HUNT3). Finally, the survey dummy estimate was positive in the models including both HUNT waves, meaning that the probability of measuring one's blood pressure at home increased from 1997 to 2008.

Table 2: Final regression models, all dependent variables

	Model 1 Home-measure (HUNT2)	Model 2 Auto-measure (HUNT3)	Model 3 Self-measure (HUNT2+3)	Model 4 Self-measure (HUNT2+3)	Model 5 Self-measure (HUNT2+3)
Age	1.084 [0.999,1.177]	1.175*** [1.139,1.213]	1.064*** [1.035,1.093]	1.066*** [1.038,1.096]	1.068*** [1.039,1.097]
Age (squared)	0.999* [0.998,1.000]	0.999*** [0.998,0.999]	0.999*** [0.999,1.000]	0.999*** [0.999,1.000]	0.999*** [0.999,1.000]
Systolic blood pressure	1.008* [1.001,1.016]	1.011*** [1.008,1.014]	1.009*** [1.006,1.012]	1.009*** [1.006,1.012]	1.010*** [1.007,1.012]
Diastolic blood pressure	1.012 [0.999,1.024]	1.013*** [1.008,1.018]	1.008** [1.003,1.013]	1.008*** [1.004,1.013]	1.008*** [1.003,1.013]
Gender (man)	1.853*** [1.447,2.373]	0.773*** [0.705,0.847]	1.035 [0.941,1.139]	1.023 [0.929,1.126]	1.018 [0.925,1.120]
Income quartile group 2	0.969 [0.640,1.468]	1.042 [0.881,1.233]	1.203* [1.020,1.420]	1.195* [1.013,1.411]	1.335 [0.998,1.786]
Income quartile group 3	0.942 [0.632,1.405]	1.060 [0.932,1.205]	1.182* [1.031,1.355]	1.171* [1.022,1.342]	1.807*** [1.433,2.278]
Income quartile group 4	1.085 [0.719,1.638]	1.093 [0.934,1.279]	1.430*** [1.220,1.676]	1.418*** [1.211,1.662]	2.664*** [2.098,3.383]
Secondary education	1.622*** [1.242,2.119]	1.063 [0.961,1.176]	1.277*** [1.145,1.425]	1.840*** [1.530,2.213]	1.247*** [1.118,1.391]
Tertiary education	3.034*** [2.115,4.354]	1.090 [0.950,1.251]	1.816*** [1.572,2.097]	3.575*** [2.773,4.610]	1.798*** [1.559,2.074]
HUNT wave 3			2.330*** [2.097,2.589]	3.615*** [3.036,4.305]	3.316*** [2.841,3.871]
Income quartile 2 * HUNT wave 3				0.877 [0.625,1.230]	
Income quartile 3 * HUNT wave 3				0.565*** [0.444,0.719]	
Income quartile 4 * HUNT wave 3				0.428*** [0.337,0.542]	
Secondary edu. * HUNT wave 3					0.579*** [0.471,0.711]
Tertiary edu. *					0.395***

HUNT wave 3					[0.300,0.519]
Pseudo-R^2	0.0577	0.0376	0.0553	0.0583	0.0589
N	6910	11133	18153	18153	18153

Odds ratios; 95% confidence intervals in brackets

* p < 0.05, ** p < 0.01, *** p < 0.001

Moving on to the explanatory SES variables, the analyses showed that in HUNT2, income quartile groups was not significantly associated with having a blood pressure monitor at home. Educational attainment however, showed a positive, significant association with the same dependent variable. Having secondary or tertiary compared to primary education was associated with respectively 2 and 6 percentage points higher probability of having a blood pressure monitor at home. There were indications of a full educational gradient, with the tertiary educated having higher probability of technology use than the secondary educated, who showed higher probability than the primary educated. These educational effects were present also when the income variable was included. In the models with the 24-hour blood pressure monitor as a dependent variable (HUNT3), neither income quartile group nor educational attainment showed significant associations.

Lastly, the probability of ever having measured one's blood pressure at home was approximately 2 percentage points higher for respondents belonging to the second or third compared to the first income quartile group (P = 15.2% vs. P = 14.9% vs. P = 13.0%); belonging to the fourth income quartile group increased the probability by 4.4 percentage points (17.4%). Educational attainment was also significantly associated with this dependent variable, with approximately 2.7 and 7.5 percentage points higher probability for the secondary and tertiary educated compared to the primary educated (12.0% vs. 14.7% vs. 19.5%). In these models, the interaction terms showed that the effect of both income and education significantly decreased from 1997 to 2008. Figure 1 illustrate how the social gradient in 1997 for using both income and education is reduced in 2008. For the lowest income quartile group, the probability of ever having measured one's blood pressure at home increased from 6.4% (95% CI: 5.5-7.2) to 18.0% (95% CI: 16.7-19.3), while for the highest income quartile group, this probability increased from 15.1% (95% CI: 12.9-17.3) to 19.9% (95% CI: 18.0-21.9). In 1997, there were substantial differences between income quartile groups, with the fourth group having significantly higher probabilities than all other groups of ever having measured blood pressure at home; in 2008, differences between income quartile groups were non-significant. The pattern was similar when looking at educational attainment; from 5.7% to 17.5% for the primary educated, from 9.9% to 18.4% the secondary educated, and from 17.3% to 22.8% for the tertiary educated. A tripart educational gradient in 1997 became a two-part gap in 2008, with the difference between the primary and secondary educated category being non-significant in 2008. In sensitivity analyses, income and education were added separately to the model, with results being similar.

Using the pseudo-R^2 estimates to briefly assess the models, the education variable appeared to improve model fit the more than the income quartile group variable, but differences were small; the pseudo-R^2 estimates vary between 3.7% and 5.9%.

Figure 1: Predicted probabilities of Home-measure (HUNT2)

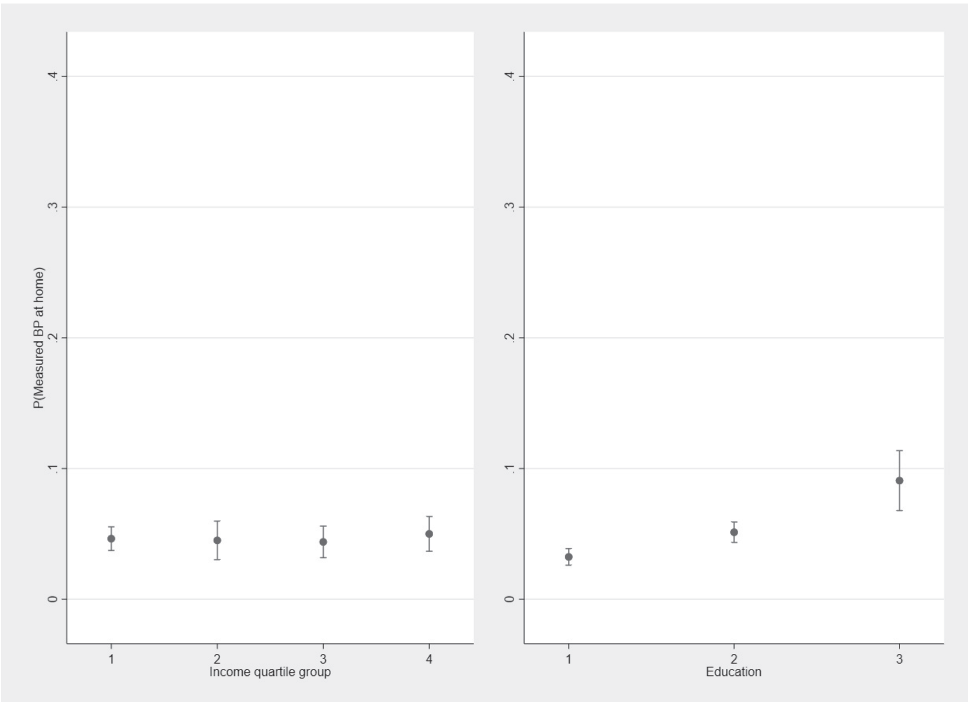


Figure 2: Predicted probabilities of Auto-measure (HUNT3)

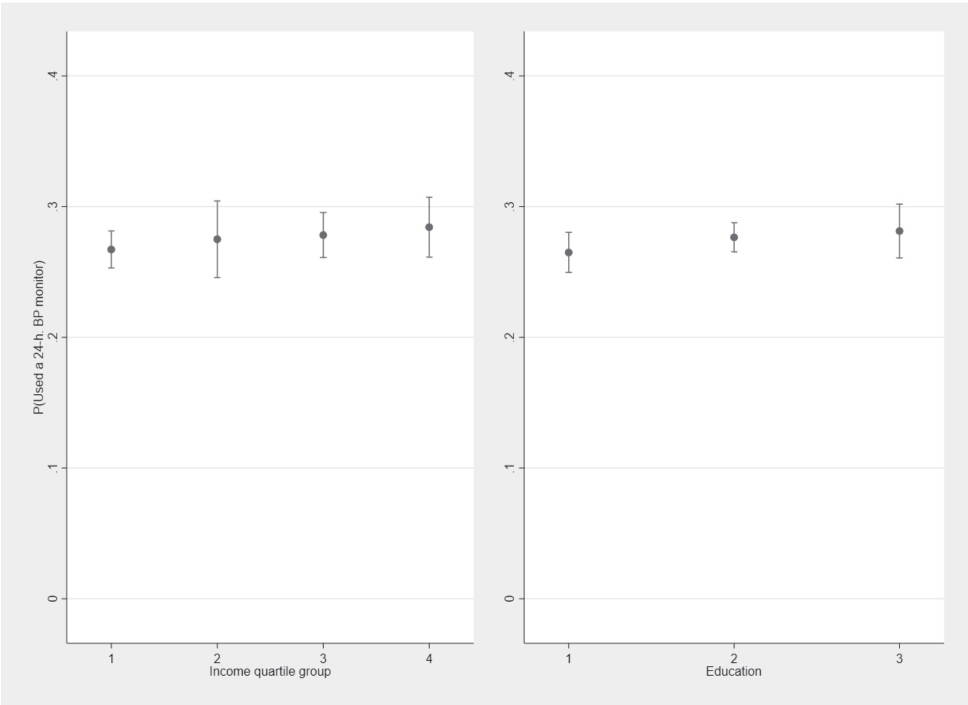
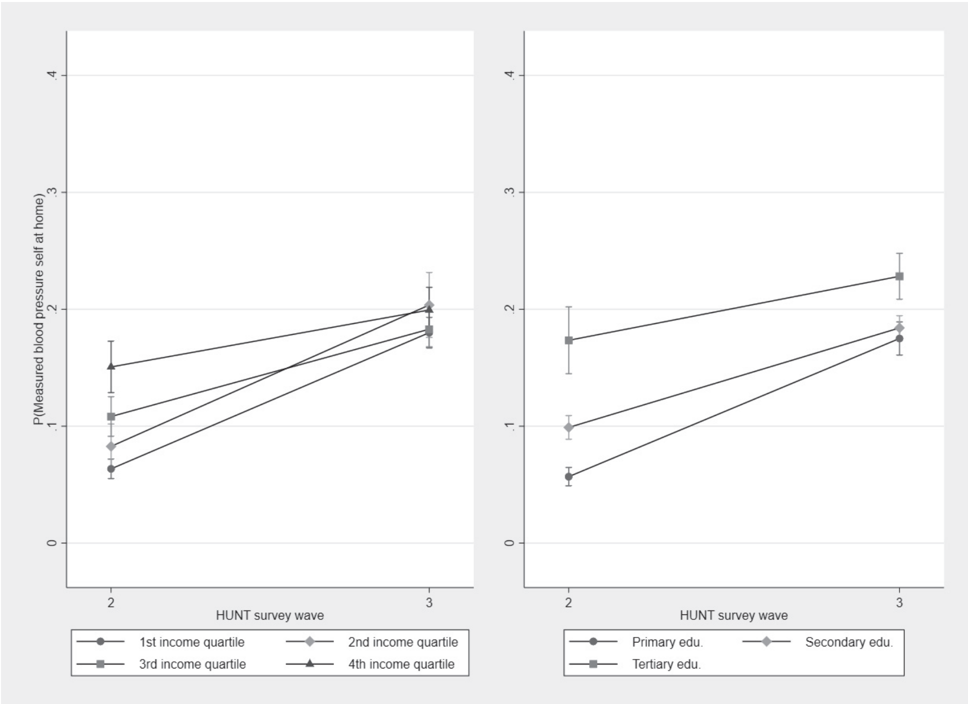


Figure 3: Predicted probabilities of Self-measure (HUNT2+3)



5. Discussion

Results from analyses of three variables measuring of personal blood pressure monitor use suggested that a social gradient was more present at earlier time points, both when comparing estimates across survey waves, and when including an interaction term with a survey wave dummy. Educational attainment showed overall stronger and more robust associations with technology use than personal income.

The DoI theory predicts that innovations are diffused in an S-shaped pattern, first reaching groups of early adopters with characteristics such as higher educational attainment, greater wealth, and higher placement on other measures of social status (Rogers, 2003). The cross-sectional and longitudinal analyses of this article indicate support for these predictions; the effect of income and education on blood pressure monitor use diminish at later time points, possibly due to the innovation being at a later stage in the diffusion process and therefore utilized across all social strata. Results can also be interpreted as support for the FCT; at the early adoption stages of a health technology, the resources available to the rich and higher educated enable them to adopt such innovations before the poorer and less educated, with widening health inequalities a plausible consequence.

Returning to the typology of innovative health technologies, blood pressure monitors can be classified as both a direct-use gatekeeper technology, where use follows from a GP-patient consultation, and a direct end-user technology, as it increasingly has become available at the private market for individuals to buy and use at their own initiative. If access to the technology is dependent on a health professional gatekeeper, inequalities in use may reflect that GPs, with or without intent, prioritize rich and well-educated patients in a technology's early phase. It could also indicate that rich and well-educated patients possess resources, such as networks, knowledge or communication skills, that could influence, convince or pressure physicians to include innovative technologies in their treatment, also in a universal health care system like the Norwegian (Elstad, 2018; Nilssen et al., 2016). Brekke et al. (2018) demonstrated how patients with low education and income get shorter consultations with their GP, supporting the notion that the leeway in the GP-patient consultation is of most advantage to high SES-patients.

If blood pressure monitors are viewed as direct end-user technologies, other mechanisms may be relevant. Since this class of technology is more sensitive to individual agency, income and education may be directly associated with individual and structural adoption barriers such as pricing and lacking knowledge. Further has previous research shown that low SES can be associated with more intuitive strategies when navigating the health technology field (Gonzales, Ems, & Suri 2016). With regards to blood pressure monitors, *why* and *how to* use such equipment at home may be questions without intuitive answers. Though blood pressure is an important risk factor for cardiovascular mortality, it may be more related to the concept of *disease* than to *illness* or *sickness*, i.e. the condition may be discovered by medical professionals before it is experienced as a lack of well-being by a patient (illness) or recognized as hampering one's function in society (sickness) (Hofmann, 2016). With this in mind, there may also be differences in individual motivations for choosing to use innovative health technologies. For a poor and low educated person's present and prospective life situation, the relative improvement of using the latest blood pressure monitoring technology may be low; Pepper and Nettle (2017) have called such behavior an 'appropriate response' to limitations in one's life chances.

The statistical models in this article included two measures of social stratification: income quartile group and educational attainment. These are commonly used indicators when investigating socioeconomic inequality – but may be connected to health-related outcomes through very different pathways (Braveman et al., 2005). Income may be a more direct measure of material resources but is sensitive to changes over the life course, while education is a more stable measure of social stratification, changing little over most parts of a respondents' life, and a substantial predictor of social status (Elo, 2009; Schneider, 2010). In analyses of social inequalities in health, education may serve as a direct measure of cognitive function; knowledge may be a flexible resource possible to deploy in different contexts (Link, 2008). Education may further give access to other health-beneficial material and immaterial resources such as social networks and safe jobs with economic and personal rewards (Montez & Friedman, 2015).

Results in this article indicate that educational attainment is a stronger predictor of technology use than income quartile group, possibly suggesting that resources affiliated with education is more closely related to technology use in this study context. The FCT suggest that social position and health outcomes are connected through time- and context-sensitive pathways (Phelan, Link, & Tehranifar, 2010). The Norwegian health care system builds on universalistic principles; every citizen has the same formal rights to treatment. Could immaterial resources in this context lead to informal advantages? The size of your wallet may not directly affect the treatment you receive, but your knowledge, motivation, and networks may be of influence. If the use of technology is to serve as an intervening mechanism reproducing health inequalities in a Norwegian context, the immaterial resources connected to education may be the most relevant to study.

5.1 Limitations

These analyses have some limitations. The first ones concern the dependent variables. All three are indicators of technology utilization, asking about the use of blood pressure monitors. They do however differ in formulation: One asks whether respondents have a blood pressure monitor at home, implying ownership. Another question asks whether respondents ever have used specific measuring equipment, a 24-hour blood pressure monitor, where gatekeeping and access may differ from other measurement equipment. A third question asks whether respondents ever have measured their blood pressure themselves at home, not indicating ownership nor the use of a specific technology. Though the implications from these questions may be a source of error making comparisons across models difficult, I will argue that they all measure an underlying phenomenon, the inclination to health technology use. The discussion of results has also drawn few causal conclusions based on comparisons across models. Secondly, it is assumed that blood pressure monitors have undergone a diffusion process from 1997 to 2008, while there is no direct measure of this development. However, the assumption of diffusion is supported by research literature and descriptive statistics from the HUNT surveys. Lastly, there are unmeasured uncertainties related to the process of adopting and utilizing the blood pressure monitors. The involvement of the GP and the actual benefits from using a blood pressure monitor may vary between cases. This article is cautious in drawing conclusions about the direct health benefits of inequalities in technology use. More of interest is the demonstration of general patterns in a novel setting – which again can become the basis for later studies.

The income variable is based on that year's reported taxable income. Many respondents have a reported income of zero, which may include no actual income, or public or private benefits exempted from taxation; this group of respondents may therefore be heterogenous. Initial bivariate analyses indicated a high prevalence of low-educated, young, and old people in this group. Further, sensitivity analyses where zero-income respondents were excluded showed similar results as the analyses included in the article: The effects of income quartile groups on technology utilization were in the same 'direction', but at a lower level of statistical significance. It can therefore be argued that the zero-income group is a relevant measure of low socioeconomic status.

There may be differing, unmeasurable needs for blood pressure monitors which possibly may affect results. Respondents answering the relevant questionnaire were selected based on symptoms of cardiovascular disease. Further were systolic and diastolic blood pressure variables added as controls. These two factors should adjust for some variation in need, but the professional autonomy and negotiations in the actual interaction between GP and patient may still influence the decision to use a blood pressure monitor. Previous research has shown social inequalities in the utilization of health care services, and that the degree of complexity in treatment regimens was associated with social inequalities in health outcomes, i.e. that well-educated patients benefitted disproportionally from complex treatments (Goldman & Lakdawalla, 2005; Vikum, Bjørngaard, Westin, & Krokstad, 2013).

6. Conclusions

In this novel investigation of end-user technology in a universal health care setting, results suggest that the social gradient in use of blood pressure monitors was reduced as the technology was diffused from 1997 to 2008. This temporal trend is evident among several measures of technology utilization, but conclusions should be made with caution, as data was not perfectly comparable across survey waves. Education appears to be a more reliant predictor of technology use than income, which may suggest a relatively higher importance of immaterial resources in the Norwegian universal health care setting. The study adds contexts to the fundamental cause theory, displaying how resources represented by educational attainment can have different effect on technology utilization depending on the innovation's diffusion status. These unequal effects may manifest themselves as inequalities in disease and mortality.

Innovative health technologies are in this context produced by private companies for the international market and given a monetary value based on supply and demand. Lupton (2012) has described how a medical condition like blood pressure is surrounded by a network of actors, e.g. medical professionals, patients, and pharmaceutical and advertising companies, – all affecting the everyday use of technologies such as blood pressure medication and monitors. In Norway, the use of these technologies is predominantly not dependent on market logics but may nevertheless be subject to constraints based on budget control and efficiency. This article has demonstrated general patterns of social inequalities in technology use, but there are still uncertainties associated with the actual decision to adopt; I therefore support the request from Korda and colleagues (2011) to investigate closer the intermediate role of medical professionals when health inequalities are reproduced through technology.

7. References

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Appendix

Table A.1: Home-measure, full regression models (HUNT2)

	Model 1	Model 2	Model 3
Age	1.080	1.082	1.084
	[0.995,1.171]	[0.998,1.174]	[0.999,1.177]
Age (squared)	0.999*	0.999*	0.999*
	[0.998,1.000]	[0.998,1.000]	[0.998,1.000]
Systolic blood pressure	1.007	1.008*	1.008*
	[1.000,1.014]	[1.001,1.016]	[1.001,1.016]
Diastolic blood pressure	1.011	1.012	1.012
	[0.999,1.024]	[1.000,1.024]	[0.999,1.024]
Gender (man)	1.912***	1.892***	1.853***
	[1.495,2.445]	[1.490,2.403]	[1.447,2.373]
Income quartile group 2	1.047		0.969
	[0.693,1.582]		[0.640,1.468]
Income quartile group 3	1.072		0.942
	[0.722,1.592]		[0.632,1.405]
Income quartile group 4	1.479		1.085
	[0.993,2.202]		[0.719,1.638]
Secondary education		1.625***	1.622***
		[1.247,2.118]	[1.242,2.119]
Tertiary education		3.113***	3.034***
		[2.198,4.410]	[2.115,4.354]
Pseudo-R^2	0.0437	0.0575	0.0577
N	6933	6910	6910

Table A.2: Auto-measure, full regression models (HUNT3)

	Model 1	Model 2	Model 3
Age	1.177***	1.175***	1.175***
	[1.141,1.214]	[1.140,1.212]	[1.139,1.213]
Age (squared)	0.999***	0.999***	0.999***
	[0.998,0.999]	[0.998,0.999]	[0.998,0.999]
Systolic blood pressure	1.011***	1.011***	1.011***
	[1.008,1.014]	[1.008,1.014]	[1.008,1.014]
Diastolic blood pressure	1.014***	1.013***	1.013***
	[1.008,1.019]	[1.008,1.019]	[1.008,1.018]
Gender (man)	0.772***	0.780***	0.773***
	[0.705,0.846]	[0.713,0.853]	[0.705,0.847]
Income quartile group 2	1.043		1.042
	[0.882,1.234]		[0.881,1.233]
Income quartile group 3	1.063		1.060
	[0.936,1.208]		[0.932,1.205]
Income quartile group 4	1.113		1.093
	[0.956,1.297]		[0.934,1.279]
Secondary education		1.070	1.063
		[0.967,1.183]	[0.961,1.176]
Tertiary education		1.108	1.090
		[0.969,1.267]	[0.950,1.251]
Pseudo-R^2	0.0374	0.0375	0.0376
N	11174	11133	11133

Odds ratios; 95% confidence intervals in brackets
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.3: Self-measure, full regression models (HUNT2+3)

	Model 1	Model 2	Model 3	Model 4	Model 5
Age	1.060***	1.069***	1.064***	1.066***	1.068***
	[1.032,1.089]	[1.040,1.098]	[1.035,1.093]	[1.038,1.096]	[1.039,1.097]
Age (squared)	0.999***	0.999***	0.999***	0.999***	0.999***
	[0.999,1.000]	[0.999,0.999]	[0.999,1.000]	[0.999,1.000]	[0.999,1.000]
Systolic blood pressure	1.008***	1.009***	1.009***	1.009***	1.010***
	[1.005,1.011]	[1.006,1.012]	[1.006,1.012]	[1.006,1.012]	[1.007,1.012]
Diastolic blood pressure	1.009***	1.009***	1.008**	1.008***	1.008***
	[1.004,1.014]	[1.004,1.014]	[1.003,1.013]	[1.004,1.013]	[1.003,1.013]
Gender (man)	1.036	1.084	1.035	1.023	1.018
	[0.942,1.140]	[0.988,1.189]	[0.941,1.139]	[0.929,1.126]	[0.925,1.120]
Income quartile group 2	1.248**		1.203*	1.195*	1.335
	[1.059,1.471]		[1.020,1.420]	[1.013,1.411]	[0.998,1.786]
Income quartile group 3	1.234**		1.182*	1.171*	1.807***
	[1.078,1.412]		[1.031,1.355]	[1.022,1.342]	[1.433,2.278]
Income quartile group 4	1.666***		1.430***	1.418***	2.664***
	[1.428,1.944]		[1.220,1.676]	[1.211,1.662]	[2.098,3.383]
Secondary education		1.309***	1.277***	1.840***	1.247***
		[1.174,1.459]	[1.145,1.425]	[1.530,2.213]	[1.118,1.391]
Tertiary education		1.956***	1.816***	3.575***	1.798***
		[1.703,2.247]	[1.572,2.097]	[2.773,4.610]	[1.559,2.074]
HUNT wave 3	2.463***	2.375***	2.330***	3.615***	3.316***
	[2.221,2.732]	[2.140,2.636]	[2.097,2.589]	[3.036,4.305]	[2.841,3.871]
Income quartile 2 * HUNT wave 3				0.877	
				[0.625,1.230]	
Income quartile 3 * HUNT wave 3				0.565***	
				[0.444,0.719]	
Income quartile 4 * HUNT wave 3				0.428***	
				[0.337,0.542]	
Secondary edu. * HUNT wave 3					0.579***
					[0.471,0.711]
Tertiary edu. * HUNT wave 3					0.395***
					[0.300,0.519]
Pseudo-R^2	0.0502	0.0538	0.0553	0.0583	0.0589
N	18217	18153	18153	18153	18153

Odds ratios; 95% confidence intervals in brackets
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Paper IV:
Medical innovations can reduce social inequalities in health:
An analysis of blood pressure and medication in the HUNT Study

Abstract

This paper examines whether the use of blood pressure medication has a mediating association with social inequalities in blood pressure levels. In Norway, cardiovascular disease has for decades been both the overall leading cause of death and the cause with the highest social inequalities. High blood pressure is an important risk factor in this aspect, and prescription drugs have been established as a standard treatment of hypertension. We have seen population blood pressure levels fall, blood pressure inequality levels remaining stabile, and medication use increase. The paper uses panel data from the Nord-Trøndelag Health Study linked with registry data on education and income. Results from fixed effects regression analyses indicate that blood pressure medication overall has a levelling effect. The traditional social gradient is mainly found among non-users of medication. With blood pressure medication being plausibly at a late stage of its diffusion, these findings give some support to the hierarchical diffusion model, while they also imply the need for equal access to sufficient blood pressure treatment.

1. Introduction

Health problems are disproportionally distributed between the more and less affluent in society. These patterns, often referred to as social inequalities in health, have been widely reported in all Western countries, including egalitarian Norway, during the last decades (Mackenbach, 2017). Innovative technologies have been proposed as means to reduce health inequalities, as well as other challenges facing European welfare states; be that increasing costs, decreasing tax revenues, or multi-morbidities associated with ageing populations (World Health Organization, 1997; Juma & Yee-Cheong, 2005; Piot, 2012). However, it is unclear how such technologies affect population health, and whether they contribute to or if they buffer against the health gap between vulnerable and resourceful groups in society. A much-cited example is McKeown's (1980) thesis of how increases in population and improved quality of life are not results of advances within medicine, but rather within broader social and economic conditions. A seminal theory in the health inequality field, the fundamental cause theory, also focus on social conditions as the basic causes of health, and further suggests that technological innovations could be one of the mechanisms that generate health inequalities (Link & Phelan, 2002). Subsequently, a model of hierarchical diffusion, proposing that innovative technology and new knowledge is diffused unequally across the social strata, has also been supported by empirical findings (Link, Northridge, Phelan, & Ganz, 1998). If these assumptions are correct, an important health barrier among technologically advanced societies would be identified.

Estimates from the Global Burden of Disease study show that cardiovascular disease (CVD) is the leading cause of death in Norway in the years 1990-2016, while also having the highest absolute educational inequalities in mortality through all decades since the 1970s (Institute for Health Metrics and Evaluation, 2018; Strand et al., 2014). Hypertension have been the leading risk factor of CVD and a pivotal component in these inequalities (Institute for Health Metrics and Evaluation, 2018; Strand & Tverdal, 2004).

While the generally positive effect of drug treatment on hypertension has been demonstrated over the last decades, consequences for inequalities remains unclear (Holmen et al., 2016). This article therefore asks whether the reported social inequalities in CVD are affected by medical innovations, specifically how the diffusion of blood pressure (BP) medication affects BP inequalities. More specifically, I seek to 1) examine social inequalities in BP levels; 2) analyse whether BP medication has a significant impact on these inequalities, and the direction of this contribution; and subsequently 3) discuss the mechanisms connecting medication use with health inequalities. With basis in the fundamental cause and diffusion of innovation theories, I hypothesise that BP medication will have a significant, mediating effect on social inequalities in BP, but that the size and direction of the gradient is contingent on several potential confounders (see end of section 2). In the following, I will present relevant concepts and research on the role of technology in social health inequalities, before presenting some selected research on social inequalities in BP. In the results section, regression analyses of panel data indicate that medication may have a levelling effect on BP, contributing to a reduction in social inequalities. This, I argue, suggests that BP medication has reached a late stage of its diffusion process.

2. Background

In 1995, Link and Phelan introduced the theory of the fundamental causes of social inequalities in health (FCT). Here, they introduce two vital concepts: "contextualizing risk factors" and "fundamental causes" (Link & Phelan, 1995: 84). The latter are the general forces of social inequality in a society, located upstream in the causal chain leading to health inequalities, while the former is the process of analysing the social mechanisms connecting more proximate risk factors to disease (Link & Phelan, 1995). Examples of proximate risk factors could be working and living conditions; diet, exercise and other health behaviors; access to and utilization of health services; or the diffusion and adoption of technological innovations (Phelan, Link, Diez-Roux, Kawachi, & Levin, 2004; Phelan, Link & Tehranifar, 2010). When social inequalities persist and our ability to control disease increase, health disparities grow – and these disparities will be greater for health problems where potential preventability is high (Phelan et al., 2004; Phelan & Link, 2005).

One way to operationalise the FCT in empirical research, has been to examine the association between SES and health innovations proven to effectively reduce mortality. Examples are preventive practices like Pap smears and mammography, where Link and colleagues' (1998) study showed that after the implementation, education and income were consistently over time positively associated with the two screens. A later study using European mortality data on breast cancer showed how these trends have manifested themselves in mortality figures: while higher educated women previously had a higher risk of dying from breast cancer, this association had been inverted during the latter decades. The increasing availability of mammography screening was proposed as an explanation (Gadeyne et al., 2017). Additionally have Goldman and Lakdawalla (2005) showed how a new, but complicated treatment for HIV was disproportionally adopted by the better educated, contributing to a widening of health inequalities; Glied and Lleras-Muney (2008) found that individuals living in counties with more years of compulsory schooling had a higher survival rate from diseases associated with high degrees of innovation; Chang and Lauderdale (2009) demonstrated how cholesterol levels became significantly negatively associated with income only after the adoption of statins in glucose treatment; and findings from Wang and colleagues (2012) indicated that diffusion of information had a moderating effect on SES inequalities in colorectal cancer mortality.

Studies like these have indicated that innovative technology and new knowledge can function as inequality-generating mechanisms: reproducing patterns following the unequal distribution of flexible resources like money, knowledge, power, prestige, and social networks into social inequalities in health outcomes, independently of more proximate risk factors.

However, empirical research has also challenged the FCT, demonstrating that some flexible resources return greater health benefits in particular contexts. An example is how the effect of education on mortality have varied across gender and racial groupings, which is largely left unexplained by the FCT. A response could be to identify and test the associations between different contexts and the effects of different resources (Masters, Link, & Phelan, 2015). The diffusion of innovations theory offers such a contextual dimension, by focusing on the temporal development of health-beneficial innovations (Zapata-Moya, Willems, & Bracke, 2019). This approach assumes a hierarchical diffusion model, where innovative technology and new knowledge first reach the higher socioeconomic strata before being diffused across the population in an S-shaped pattern (Rogers, 2003). Here, the degrees of diffusion represent the different contexts, meaning that the effect of the same flexible resource will vary between different time points due to an innovation being differently diffused.

The assumption of hierarchical diffusion patterns has also been tested by empirical research. Victora and colleagues (2000; 2005; 2018) have found support a hypothesis of inverse equity: Individuals of higher SES are typically early adopters of new ideas and technologies, which leads to inequalities increasing before a threshold is reached. Then, as the innovation is utilised also by lower SES groups, inequality rates go down. The authors looked at a series of health indicators and public health innovations such as infant mortality, vaccines, vitamin supplementation, and skilled birth delivery in health facilities. Findings from Korda, Clemens, and Dixon (2011) also indicated support, results showing socioeconomic lags in several coronary surgical procedures, with earlier uptake peaks among higher SES patients. Lastly, Zapata-Moya, Willems, and Bracke (2019) demonstrated how the social gradient in the use of preventive measures varied with diffusion rate; inequalities were larger among practices in an early stage, such as PSA tests and Pap Smears, and smaller or non-significant among practices in a later stage, such as cholesterol readings and blood-pressure checks.

Norway is a technologically advanced country with a comprehensive and universal welfare state and health care system, which nevertheless have shown (Mackenbach et al., 1997), and continue to show (Strand & Madsen, 2018), a substantial health gradient across numerous measures. Researchers have proposed a wide array of explanations for this so-called paradox – among them are mathematical artefacts, social mobility, and new forms of social stratification and marginalization (Mackenbach, 2017; Huijts & Eikemo, 2009). Could the diffusion of innovative technology contribute to explaining this paradox? Smoking is a well-known example of how the logic of hierarchical diffusion has been applied to explain these inequality patterns, where knowledge of the health-damaging effects of smoking has been unequally diffused across European countries, making smoking a particularly marginalised low-status habit in the Nordic and Western European countries, contributing to inequalities in smoking-related mortality within these countries (Mackenbach, 2012; Huijts et al., 2017; Osler et al., 2000). With regards to BP innovations and inequality, Mills et al. (2016) found that high-income countries showed higher rates of hypertension awareness, treatment, and control than both low-income countries and the global average, and these disparities had increased over the period 2000-2010.

The diffusion of innovations model adds context to the fundamental cause theory. Combining these two frameworks implies that different adoption rates of innovative health technology can explain variation in health inequalities. This article utilises this approach on the case of blood pressure (BP) medication, an innovation presumably late in the diffusion process.

2.1 Study Context

Blood pressure has been a health outcome with a substantial social gradient. Meta-analyses and review studies have demonstrated this association across various contexts and measures, also in studies dating back to 1966 (Leng, Jin, Li, Chen, & Jin, 2015; Colhoun, Hemingway, & Poulter, 1998). Comparisons of self-reports and clinical measures have showed an underestimation of socioeconomic inequality when relying on the former (Johnston, Popper, & Shields, 2009; Mosca, Bhuachalla, & Kenny, 2013). In Norway, Strand & Tverdal (2006) found increasing educational inequalities in SBP among women and stabile inequalities among men over the years 1974-1988. Ernstsen and colleagues (2012) found that while the prevalence of hypertension (SBP ≥ 140 mmHg and DBP ≥ 90 mmHg) decreased from HUNT1 to HUNT3, and absolute educational inequalities decreased among women and remained stable among men, while relative inequalities in hypertension widened over time for both genders.

Both the international WHO MONICA study and the HUNT Study have shown overall declines in BP levels from the mid-1980s to the mid-2000, but only partly explained by increasing use and effect of BP medication (Tunstall-Pedoe Connaghan, Woodward, Tolonen, & Kuulasmaa, 2006; Holmen et al., 2016). Holmen and colleagues (2016) further found a substantial BP decline among respondents reporting never having used medication, and bivariate analyses showed this decline to be strongest among the lowest educated.

The use of antihypertensives in Norway has steadily increased since their introduction in the 1950s (Meland, 2009). Figures from the HUNT study show a increase of BP medication use from 12.9% of all respondents in 1984 to 20.6% in 2008, while figures from the Norwegian Institute of Public Health (2018) show an increase from 141 to 168 users per 1,000 inhabitants in the period 2004-2017. Diuretics became available as the first hypertension-combating agents in the 1950s, followed by beta-blockers in the late 1950s and early 1960s, and calcium channel blockers shortly after (Gavras, 2001). This diffusion varied between countries and markets; beta-blockers were introduced in Europe in 1965 but became available in the US as late as 1976 (Goldman & Lakdawalla, 2005). Gu and colleagues (2012) found that the use of antihypertensive medications among hypertensive patients in the US had increased from 63.5% to 77.3% over the years 2001-2010. The increased usage was associated with an increase in BP control rates from 45% to 60%. Overall, the observed developments suggest that BP medication is a medical innovation far along in a diffusion process, as different drugs have been active for over 30 years prior to the first HUNT study. Following the hierarchical diffusion model, this development suggests equal access and use of BP medication across the social strata. However, the contribution of BP medication to the stabile social gradient in BP remains unexplored.

The findings above indicate that different socioeconomic groups in the present study may benefit differently from using BP medication. For several reasons, the direction and strength of the social gradient in this study is difficult to intuitively predict. First, across all European countries, low SES is associated with risky health behaviour, such as smoking, binge drinking, physical inactivity, and a diet consisting of less fruit and vegetables (Huijts et al., 2017). This could contribute to social inequalities in BP prior to consulting and prospective medicine prescriptions. Second, as BP medication is in Norway prescribed by one's general practitioner (GP), a certain selection effect is therefore likely: Individuals with high BP may be more likely to have medicine prescribed. These two challenges are met with two methodological measures: including lifestyle and biomedical controls and using fixed effects regression.

Third, research has shown that high-SES groups traditionally have been more prone to consult health care professionals (Vikum, Bjørngaard, Westin, & Krokstad, 2013); meaning that high BP among high-SES groups have a higher probability of being treated. Lastly, BP medication may not be associated with the same degree of innovativeness as the studies referred above. It is likely that the diffusion process has reached a threshold, and that BP medication use has a weaker association with SES in the HUNT Study period. Clouston and colleagues (2016) have argued that most diseases reach a stage where social inequalities are reduced, potentially because of diffusion of innovations leading to a saturation among those of higher SES and/or increased uptake among those of lower SES. The development of social inequalities in polio and kidney infection mortality illustrated this development (Clouston, Rubin, Phelan, & Link, 2016; Phelan, Link, & Tehranifar, 2012). Though previous inequalities in BP have proved to be substantial, this disease may be reaching a point in the demographic and epidemiological transition stage where inequalities are starting to decline, possibly due to the increased utilization of BP medication.

3. Data and Methods

The Nord-Trøndelag Health Study (HUNT) is a population-based study performed in three waves: HUNT1 (1984–86), HUNT2 (1995–97), and HUNT3 (2006–08). The study contains information from approximately 120,000 individuals, and 27,605 individuals participated in all three surveys. Participation rates range from 59% to 88% of invited respondents. Nord-Trøndelag County is fairly representative of Norway as a whole, for example in terms of geography, economy, morbidity, and mortality (Holmen et al., 2003). Respondents completed two questionnaires at home before and after attending a clinical health exam. In this study, HUNT data is linked with the income and education databases from Statistics Norway (SSB) through a Norwegian personal identification number. The project was approved by the Regional Committee for Medical and Health Research Ethics in Central Norway (REC Central). Statistics software STATA 15 was used to analyse the data material.

3.1 Variables

Dependent variables were SBP and DBP, measured manually by professionally trained nurses in HUNT1 and assisted with automatic measures in HUNT2 and HUNT3. As is standard in medical literature, the average of the second and third readings (first and second readings in HUNT1) was used to minimise the risk of measurement error. Two variables for socioeconomic status (SES) were included. Education was measured in three levels – primary, secondary, and tertiary. Respondents' yearly income in 1986, 1997, and 2008 was divided into quartile groups. A large number of respondents was registered with 0 as yearly income. Potential consequences of this distribution are treated in the discussion chapter. By example of Holmen et al., (2016), indicators of a healthy lifestyle and biomedical variables proved to have an association with high BP were added as controls. Body mass index (BMI) was calculated as weight/height squared; height and weight were measured with light clothes and no shoes and rounded off to the nearest 1.0 cm and 0.5 kg. Smoking was dichotomised: former daily smoker, daily smoker, and occasional smoker (latter only in HUNT3) was given value 1; never smoked daily was given value 0. Exercise was also dichotomised, respondents in HUNT1 and HUNT3 who reported being physical active less than once a week, were given value 0. Respondents in HUNT2 reporting neither hard nor light physical activity once a week were given value 0. Age was measured in years, and an additional age squared variable was added to account for curveliearity. Two dichotomous variables were constructed for respondents who reported having or having had respectively diabetes and myocardial infarction. Heart rate was measured simultaneously with BP, using the same equipment. Glucose and cholesterol levels are also known predictors of BP, but these measurements were not comparable across all three HUNT surveys, and therefore not included in the models. A survey wave dummy was included in all models, in order to control for differing diffusion processes. Table 1 provides descriptive statistics of included variables.

Table 1: Descriptive statistics

	Male population				Female population			
Variable	**Mean or %**	**SD**	**Min**	**Max**	**Mean or %**	**SD**	**Min**	**Max**
Systolic BP[1]	137.7	18.9	60	278	132.3	22.7	68	295
Diastolic BP[1]	81.8	11.9	26	156	77.4	12.5	35	168
Primary education	29.6 %				34.3 %			
Secondary education	53.6 %				45.7 %			
Tertiary education	16.7 %				20.0 %			
BP medication	14.0 %				15.7 %			
Income q1	21.0 %				28.4 %			
Income q2	7.5 %				11.0 %			
Income q3	22.7 %				43.2 %			
Income q4	48.8 %				17.5 %			
Age[2]	49.8	16.4	19.1	99.3	49.3	16.6	19.1	99.6
BMI	26.3	3.6	14.2	53	25.9	4.6	12.1	55.9
Smoker	63.2 %				52.3 %			
Exercise > 1/week	63.7 %				68.3 %			
Diabetes	3.2 %				2.7 %			
Myocardial infarction	4.4 %				1.3 %			
Heart rate[3]	70.0	12.7	29	166	73.5	12.4	32	182
N (individual respondents)	77,134 (45,211)				83,078 (47,495)			

[1] mmHg, [2] Years, [3] Beats/minute

3.2 Methods

The HUNT data was analysed with fixed effects (FE) regression methods, using BP levels directly as dependent variables. FE regression is a method where it is possible to control for time-invariant unmeasured variables correlating with one or more of the independent variables (Petersen, 2004). A Hausman test showed covariance between the models' error term and independent variables, meaning that FE regression was appropriate. This approach analyses within-unit variation, and possible selection bias are reduced when only change over time for each respondent is used to estimate effects. Mummolo and Peterson (2018) have written of how several substantial consequences of FE regression often is overlooked, such as the loss of variance and unclear interpretations of estimates. This study adopts two of their proposed measures to avoid these pitfalls: clarifying the studied variance and adjusting the outcome scale to within-unit variation.

Regression models were stratified by gender, with SBP and DBP as dependent variables. SES explanatory variables and lifestyle and biomedical control variables were added separately to the model. Interaction terms, where the SES variables was multiplicated with the medication variable, were constructed. For readability, only SES and medication variables were displayed in the final models (Table 2); results are further displayed as figures of predicted BP levels.

Table 2: Regression models with SES interactions, SBP and DBP for male and female population

	Men				Women			
	Systolic		Diastolic		Systolic		Diastolic	
Primary education	1.086	0.560	0.491	0.273	1.828*	1.277	-0.116	-0.326
	(0.929)	(0.924)	(0.597)	(0.594)	(0.722)	(0.718)	(0.448)	(0.447)
Secondary	0.223	-0.279	0.167	-0.0574	0.994	0.520	0.142	-0.0508
education	(0.735)	(0.730)	(0.472)	(0.469)	(0.524)	(0.519)	(0.325)	(0.323)
Income quartile	1.014***	2.794***	-0.197	0.824***	0.877**	2.477***	-0.582**	0.148
group 1	(0.297)	(0.317)	(0.191)	(0.204)	(0.309)	(0.319)	(0.192)	(0.198)
Income quartile	2.371***	2.808***	0.335	0.673**	1.131***	1.315***	-0.0803	-0.0360
group 2	(0.314)	(0.347)	(0.202)	(0.223)	(0.311)	(0.324)	(0.193)	(0.202)
Income quartile	1.066***	1.232***	0.0117	0.184	0.577*	0.617**	-0.0870	-0.0502
group 3	(0.202)	(0.212)	(0.130)	(0.136)	(0.226)	(0.232)	(0.141)	(0.144)
BP medication	-2.569***	-2.186***	-3.046***	-1.803***	-4.158***	-2.479***	-3.830***	-2.506***
	(0.620)	(0.394)	(0.398)	(0.253)	(0.677)	(0.655)	(0.420)	(0.407)
BP med. x	-4.744***		-1.513**		-4.789***		-1.506**	
Primary ed.	(0.747)		(0.480)		(0.778)		(0.483)	
BP med. x	-3.460***		-1.314**		-3.330***		-1.343**	
Secondary ed.	(0.680)		(0.437)		(0.746)		(0.463)	
BP med. x Income		-8.014***		-4.826***		-9.616***		-4.607***
q1		(0.504)		(0.324)		(0.718)		(0.447)
BP med. x Income		-4.234***		-3.056***		-3.983***		-1.803**
q2		(0.725)		(0.466)		(0.889)		(0.553)
BP med. x Income		-2.572***		-2.257***		-1.558*		-1.084*
q3		(0.564)		(0.363)		(0.723)		(0.450)
Constant	141.8***	142.4***	46.88***	47.13***	124.1***	125.7***	48.69***	49.46***
	(5.329)	(5.311)	(3.424)	(3.413)	(5.111)	(5.089)	(3.172)	(3.164)
Within-R^2								
N	77143	77143	77135	77135	83083	83083	83078	83078

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Standard errors in parentheses.

Control variables not displayed in models: survey year, age, age squared, BMI, smoking status, physical exercise, self-reported diabetes, myocardial infarction, heart rate.

4. Results

Lifestyle and biomedical control variables are only briefly reported; these estimates change little across models and were not connected to any central hypotheses. BMI, exercise, and heart rate were positively associated with SBP and DBP; self-reported diabetes and myocardial infarction were negatively associated; smoking had no significant association with SBP nor DBP. SBP decreased and DBP increased with age, but the squared age variable show that these effects diminished as the respondents grow older.

Use of medication was significantly associated with lower BP. Positive changes in SES indicators were by and large associated with negative changes in BP. Advances in educational attainment was associated with lowered SBP; this association was weakened but still significant by the introduction of lifestyle and biomedical controls. Primary education was associated with lower DBP, but this association was not significant after adding controls. Low levels of income were significantly associated with higher levels of SBP among both men and women. The income estimates were statistically robust, but the actual effect on SBP was quite modest; changes between quartile groups predicted <3 mmHg change in blood pressure when controls were added. Low income was initially associated with low DBP, but the estimates were either very small or not significant after including controls.

The interaction variables were significantly negative for both men and women across both measures of SES and BP, before and after including control variables. This means that the negative effects of adopting medication on BP were stronger for people of lower SES. For instance, having low education and starting on medication predicted a 7.3 mmHg decrease in SBP among men, while the decrease for the high-educated was 2.6 mmHg. The corresponding estimates for low- and high-educated women were 9.0 and 4.2 mmHg. Low-income men starting on medication were estimated to have a 10.2 mmHg decrease in SBP, while for high-income men, the effect was a 2.2 mmHg decrease. Low- and high-income women were predicted to experience respectively a 12.1 and 2.5 mmHg decrease. This is depicted in figures 2 and 3 with marginal prediction plots based on regression models in table 3, other variables were kept as observed.

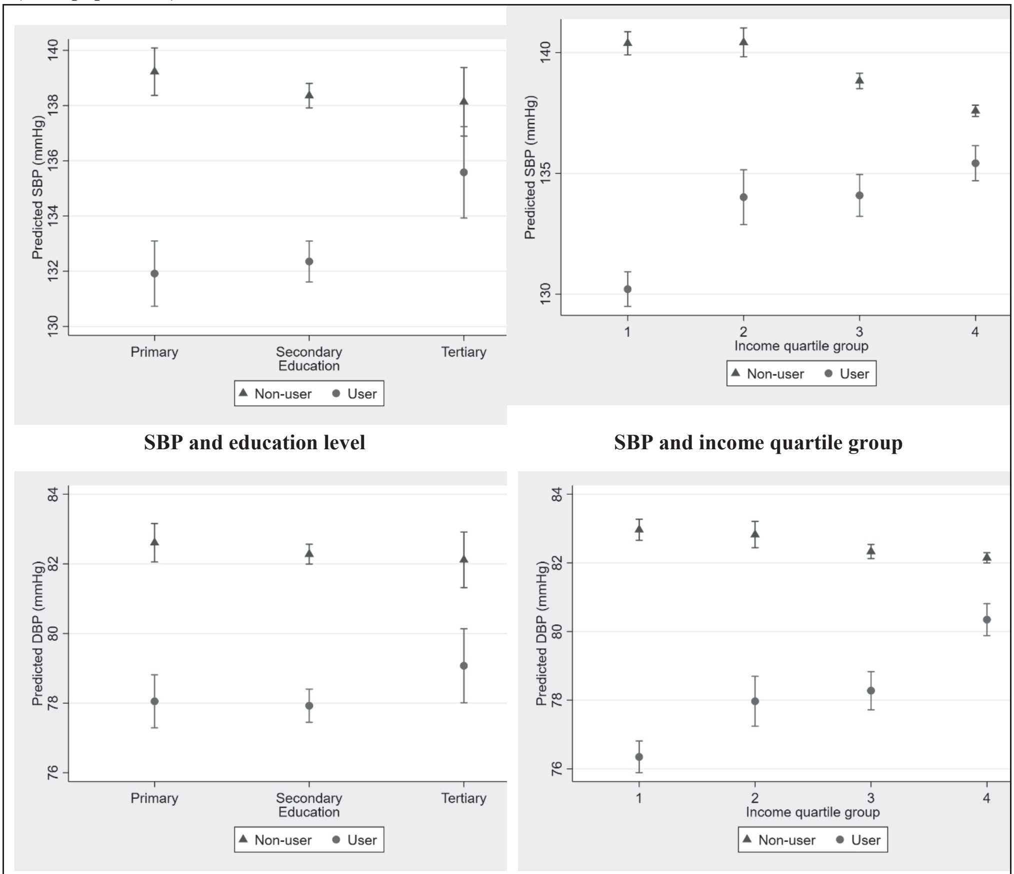
When assessing model fit, we can read that the within-R^2, the explained variance within each unit, significantly increased for each expansion of the model. Models including the biomedical and lifestyle controls, the medication variable, and the SES measures explained between 12% and 19% of male and female SBP, and between 19% and 25% of male and female DBP.

4.1 Sensitivity tests

To investigate data- and selection-related limitations, several sensitivity analyses were performed. Since people of high BP were more likely to have undergone past BP treatment, the sample was stratified into persons with BP levels above and below the hypertension threshold, and the same analyses were performed on these groups. Further, a dichotomous measure of hypertension (set at SBP/DBP>140/90) was used as a dependent variable, with models else remaining the same. The results of these sensitivity tests were weaker effects and less statistical power, but coefficients with similar values, i.e. similar patterns regarding inequalities between SES and medication groups.

In the registry data, a large share of individuals was listed with an income of 0. Reasons for this may be diverse. They may have had no actual income that year, or they may have received certain kinds of private income and/or public benefits exempted from taxation. Value 0 on the income variable could thus include people with a higher actual income, "disguising" a higher SES and further leading to incorrect estimations. Sensitivity regression analysis were performed without the 0-income group. Some of the associations between the lowest income quartile and DBP was altered or lost statistical significance by this; effects of education remained similar. Cross tabulations showed that the 0-income group was diverse, but with an overweight of low educated, and people belonging to the youngest and oldest age groups. I argue that the 0-income group is a valid representation of low SES and should therefore be included in the analyses.

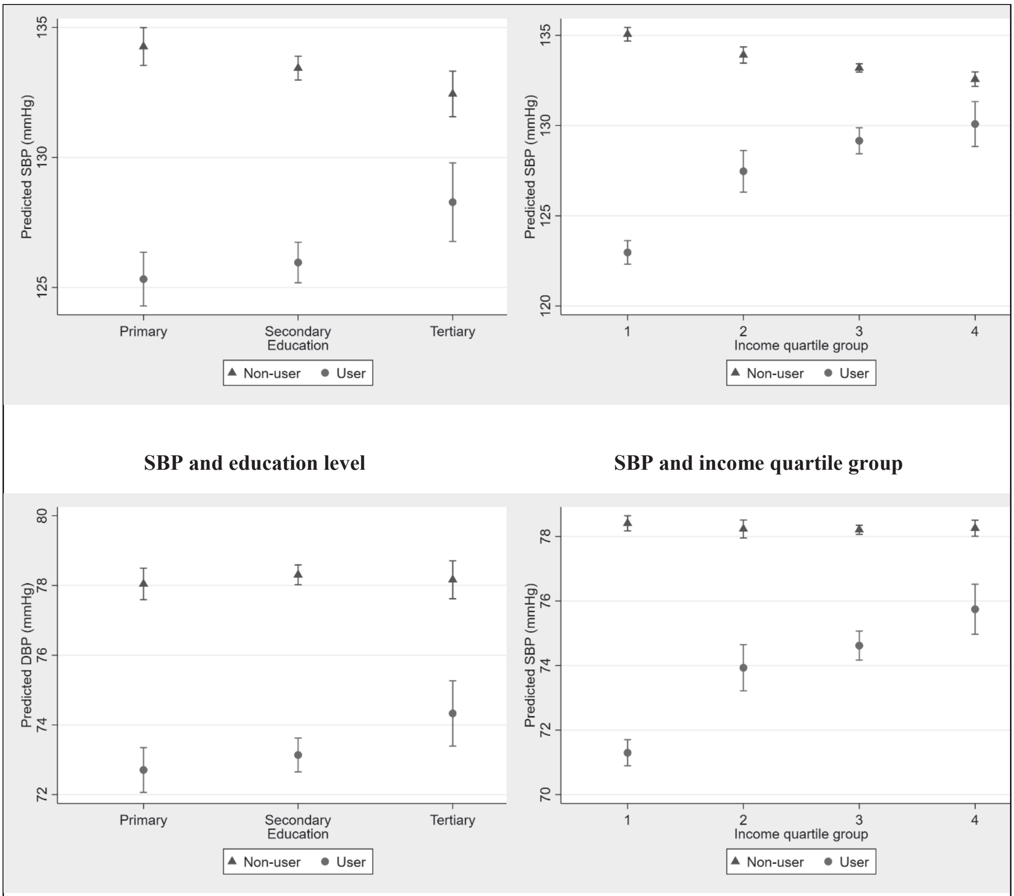
Figure 1: Marginal predictions of SBP and DBP by medication use, education level and income quartile (male population)



SBP and education level **SBP and income quartile group**

DBP and education level **DBP and income quartile group**

Figure 2: Marginal predictions of SBP and DBP by medication use, education level, and income quartile (female population)



SBP and education level **SBP and income quartile group**

DBP and education level **DBP and income quartile group**

5. Discussion

Using educational level and income quartile as socioeconomic indicators, inequalities are observed, particularly in SBP. However, when including interaction terms between SES and medication use, adopting BP medication had a stronger, negative effect on blood pressure for people of low SES. The following discussion chapter will be structured around two findings: 1) the socioeconomic inequalities in BP levels; 2) the possibly levelling effect of medication on socioeconomic inequalities in BP.

5.1 Socioeconomic inequalities in BP levels

Following the FCT, the observed social inequalities in BP may follow from social inequalities in flexible resources such as money, knowledge, power, prestige, and social connections. Variables measuring medication use, indicators of lifestyle, and biomedical factors could all represent time- and context specific mechanisms relevant for the association between SES and BP. However, the effect of SES on BP was also significant in models where these variables were included, indicating that other explanations also could be valid.

Initial bivariate analyses showed that among respondents with high BP, medication use was more common among low-SES respondents, and that for respondents not being on BP medication, an increase in SES was associated with a decrease in BP. This could indicate that people of high SES treat their blood pressure with other measures than prescription drugs. One potential inequality-generating mechanism could be unequal use of a medical innovation that is at an earlier point in the diffusion process than BP medication, for instance BP self-measuring technology. Another could be located within the health care institutions; people of high SES in general utilise primary and specialist health services more often and receive longer consultations, thus are they in better chances of having high BP levels discovered and receiving early treatment, possibly by other means than drugs (Vikum et al., 2013; Elstad 2017; Brekke, Holmås, Monstad, & Straume, 2017). Diao and colleagues' (2012) review study showed that drug treatment of mild hypertension had no effect on mortality. Reviews and meta-analyses have shown that hypertension treatment by drugs may reduce cardiovascular deaths, with the effect progressively increasing for high-risk patients (Blood Pressure Lowering Treatment Trialists' Collaboration, 2014; Sundstrom et al., 2015). These studies make the basis for the Norwegian Directorate of Health's hypertension treatment guidelines (Gjelsvik et al., 2018). From this, we can draw that physicians may be more inclined to advice non-drug treatment to people of high SES. This also resonates with some previous research findings indicating a steeper social gradient for treatments demanding more health agency from the individual patient, and that high SES in general is associated with greater adherence to medical advice (Goldman & Lakdawalla, 2005; DiMatteo, 2004).

Finally, the inclusion of biomedical and lifestyle variables should adjust for socioeconomic differences in diet, smoking, exercise, and more. In the models, BMI is chosen as a measure of dietary traits. However, BMI may not be a precise measurement of more fine-grained dietary differences possibly affecting inequalities in BP levels, such as the intake of fat, alcohol, or salt (Holmen et al., 2016).

5.2 Levelling effect

The perhaps most surprising finding is how BP medication had a significantly stronger effect on BP for low-SES respondents. Innovative medical technology was initially proposed as a potential driver of health inequalities, a mechanism connecting inequalities in resources with inequalities in health outcomes. Overall, these findings indicated that the use and utilization of BP medication does not fit with this description. When seen in coherence with the development of BP medication, the results support aspects of the hierarchical diffusion model; BP medication has reached a late point in its diffusion process, where all groups appear to benefit. But in addition, lower SES groups appear to benefit more. This could indicate saturation as described by Clouston et al. (2016), where high-SES respondents have less room for BP reduction by adopting BP medication. Chang and Lauderdale (2009) wrote of how technology may decrease the marginal value of resources and thus benefit low-SES groups more. If people of high SES are employing their resources by treating high BP with both drug and non-drug measures, the marginal effect of being on drugs may be lower than for people of low SES, with equalizing of BP levels as the result. Similarly, people of low SES may have accumulated risk factors which are more responsive to treatment, whereas hypertension among high-SES respondents, plausibly practicing healthier lifestyles, may be more refractory. Inequalities in health service utilization could also contribute to explain these results; if people of low SES use health care services less, plausibly waiting longer before entering treatment, it could result in the effect of drug treatment being relatively stronger.

Further, the substantial effect of medication on BP for people of low SES could be a sign of overmedication, leading to hypotension – dangerously low BP levels. Most predicted BP values were within both upper and lower thresholds of normalcy, but hypotension can nevertheless be a side effect of medication, particularly among elders (Divisón-Garrote et al., 2016). Finally, the apparent levelling of BP levels could hide other patterns. The analyses did not distinguish between types of BP medication – they may differ in e.g. effectiveness, dosage, and potential side effects. Future research may benefit from operationalizing these aspects of BP medication and exploring their associations with SES.

However, since adopting medication had a stronger effect on BP for low-SES respondents, these individuals were also more sensitive to e.g. varying availability of sufficient health care, or differencing practices in medication prescription. In a universal health care system like the Norwegian, where BP treatment with drugs is contingent on seeing a medical professional, unequal access to medication should not be a cause of social inequalities. Nevertheless, these results indicate that the strongest predictor of high BP is the double marginalised position of low SES and no medication. From this arises the question whether there are mechanisms located within the health care system which generate inequalities between low-SES subgroups. Are there inherent barriers to receiving drug treatment that certain resources – not perfectly correlated with education or income – enable you to traverse?

6. Conclusions

High BP is an example of a condition that in the medical sociology literature can be termed as a *disease* – diagnosed by an expert or medical professional, rather than an *illness* – the ill health a person identifies with, or a *sickness* – the social role of a sick person (Wikman, Marklund, & Alexanderson, 2005). Heightened BP may thus be a 'neglectable' condition, having little direct effect on daily life and activities. Nevertheless, high BP is an important risk factor of more severe CVDs. Social inequalities in BP may therefore predict later inequalities in mortality. The underlying mechanisms can also be indicative in explaining inequalities in other health outcomes conditions where the diffusion of medical innovations is a relevant context. A main finding in this study is that although there are social inequalities in BP levels, use of BP medication contributes to a levelling of these differences. One explanation of this levelling effect can be that BP medication is at a late stage of its diffusion, it is equally accessed and used by all social strata. Additionally, a combination of drug and non-drug treatment could make the marginal gain for high-SES groups small.

A challenge to the FCT has that it does not offer an explanation of how the same flexible resources and mechanisms can have different associations with health outcomes in different contexts. Conjoining the FCT with aspects of diffusion theory has been proposed as a response to this challenge. The present study suggests that this approach may be beneficial. The context has been an innovation late in its diffusion process, and results indicate that adopting such an innovation may reduce the impact of social conditions on health outcomes. However, some perspectives on flexible resources can still contribute to understanding the inequality patterns. When the effect of adopting medication is stronger for those with low SES, they also become more dependent on this type of treatment. Some resources appear to be more relevant for explaining how people of low SES gets access to and better utilise a medical innovation in this particular setting – a universal health care system and an innovative technology late in its diffusion process. I suggest that future research investigate the organizational and institutional obstacles and pathways through which people of low SES gain access to medical innovations and technology in a universal health care system like the Norwegian.

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