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The effect of education on health behaviour after screening for colorectal cancer

Eline Aas, Tor Iversen and and Geir Hoff

Final version

Abstract

Objectives

We study the changes in demand for health that occur after cancer screening, and more specifically, whether these changes in demand vary with human capital in terms of education level. We expect that misinterpretation of a negative test results may initiate less preventive effort and occur more frequently among individuals with a low level of human capital compared with individuals with a high level of human capital, i.e. human capital makes the information updating based on the screening result more accurate. If this is true, the implications for health policy are profound.

Data

The analyses are based on unique data from a randomized controlled screening experiment in Norway, NORCCAP (NORwegian Colorectal Cancer Prevention) running from 1999 to 2001. The dataset consists of approximately 50 000 individuals born between 1935 and 1950, of whom 21 000 were invited to participate in a once only screening with sigmoidoscopy. Information on screening participation status and screening outcome (positive and negative test and cancer diagnosis) was provided by the Cancer Registry of Norway. For all individuals we also have information on outpatient consultations and inpatient stays, human capital measured by education, income, wealth, marital status and working status. Since we are working with data from a randomized trial, we can approximate the result of health behaviour by health care utilization both ex ante and ex post of screening. The result of health behaviour is mainly measured by lifestyle related diseases, such as COPD, hypertension and diabetes type 2, identified by ICD-10 codes either as main or secondary diagnosis. To control for the time trend of change in health care utilization, we also include health care utilization in the same period for non-lifestyle related diseases, such as hip fractures and hearing aid.

Methods

Linear probability models and two stage least square regressions are used to estimate whether the interaction between screening outcome and human capital changes the utilization of health care for lifestyle related diseases. We start by dividing the sample into invited and control groups, to see if there are changes in lifestyle related utilization in an intention-to-treat setting. Further, we divide the invited according to participation status, and finally participants according to screening outcome. In these models we take account of the non-random selection of the participants among the invited by using the random assignment to screening as an instrumental variable.

Results

The results according to intention-to-treat indicate that the change in lifestyle related diseases due to screening is smaller among individuals with a high level of education. These results are supported by the further analyses among individuals with a negative screening test.

1 Introduction

Although health screening programs may result in a decline in disease specific mortality, reduction in overall mortality is rare. Thiis Evensen et al. (1999) report from the Telemark Polyp Study I, conducted in Norway during the 1980s, a reduction in the incidence of colorectal cancer (CRC) in the screening group compared with the control group. They also find a higher overall mortality in the screening group compared with the control group. Shaukat et al. (2013) find in a long term-follow up of the results of randomized trials with faecal occult-blood testing (FOBT) in Minnesota, USA that FOBT reduces mortality from colorectal cancer. They find no reduction in all-cause mortality. Holme et al. (2014) present ten years follow-up results of cancer incidence and mortality from The Norwegian Colorectal Cancer Prevention Trial (NORCCAP). In the NORCCAP 100,210 individuals aged 50 to 64 years, identified from the population of Oslo city and Telemark County, Norway were randomized to either the screening group or the control group. Individuals in the screening group were invited to undergo screening with once-only flexible sigmoidoscopy or a combination of once-only flexible sigmoidoscopy and FOBT. The control group received no intervention. The authors find that the intervention reduces colorectal cancer incidence and mortality on a population level compared with no screening. They find no reduction in all-cause mortality.

The failure to find a reduction in all-cause mortality may be related to a small sample size. Thiis Evensen et al. (1999) suggest that all-cause mortality should be addressed in larger trials than the Telemark, Polyp Study I. However, also the larger NORCCAP study fails to find a reduction in all-cause mortality. A possible explanation is that CRC screening has some indirect adverse effects on other causes of mortality than mortality from CRC. These possibly adverse effects may for instance be related to the effect of screening on the screened individuals' lifestyle after screening. Berstad et al. (2015) study changes in the NORCCAP participants' lifestyle eleven years after screening by means of a questionnaire survey sent to the screening group and control group. They find that total lifestyle scores improve in both groups. They find further that the improvement is smaller in the 'invited-to-screening' group compared with the control. The authors conclude that possible unfavourable lifestyle changes after CRC screening are modest.

Although useful, questionnaire studies of lifestyle are running the risk of having various types of response biases and do not provide knowledge about whether or not potential changes in lifestyle manifest itself in lifestyle related diseases at a later stage in life. As far as we know, no one has studied the possibly negative effect of population screening on the development of lifestyle-related diseases. The present paper aims at contributing to our knowledge in this area.

The result of a screening test makes it possible to update the subjective probability of future disease. Making a posterior probability according to Bayesian updating is a complicated task and many studies show that even health professionals often do systematic mistakes. We hypothesize that individuals with a high level of human capital are better in information updating than individuals with a low level of human capital. Our hypothesis is inspired by a criticism of screening programmes referred to as the "Health Certificate Effect". The "Health Certificate Effect" means that due to participants' misinterpretation of a negative test result, screening may initiate unfortunate lifestyle decisions and lifestyle related disease. We interpret the "Health Certificate Effect" within an economics framework combined with insufficient capacity of information handling. Some people consider a negative test result and disease preventive effort to be substitutes. Hence, fewer measures are taken to prevent future illness (allocative inefficiency of health production). We expect that misinterpretation of test results occurs more frequently among individuals with a low level of education compared with individuals with a high level of education. Hence, screening may initiate life-style related diseases among individuals with a low level of education. We test our theory with data from NORCCAP merged with register data from the National Patient Register (NPR) from 1997-2009. In an intention to treat perspective we find that for individuals with only primary education the incidence of lifestyle related diseases in the screening group is greater than in the control group during the period after the screening year. We find no such difference for individuals with four years of university education. In general, we find no differences between the screening group and the control group for non-lifestyle related diseases. We also test for differences between education groups for individuals who participated in screening and ended up with a negative test. In these analyses we instrument for participating in screening and having a negative test result. We find similar results as in the intention to treat analyses.

The paper is organized as follows. Section 2 describes the study setting according to the Norwegian health care system and the NORCCAP trial. Section 3 presents our reasoning on possible lifestyle consequences of health screening. Section 4 describes data and Section 5 explains the empirical strategy. Section 6 presents empirical results and Section 7 concludes the paper.

2. Study setting

The Norwegian healthcare system is tax financed and is (nearly) free at the point of access. In 2009, approximately 4800 USD per capita was spent on healthcare, which is the second most in the world, and 50 percent above some other Scandinavian countries. In 2008, 84 percent of health expenditure was publicly financed. Specialized healthcare is need-based and universal, intended to

give people from disadvantaged social groups as equal opportunities to healthcare interventions as any other. There is no second private tier. Individuals would have very limited options to opt out of the public system. Specialized healthcare is organized in four health regions (North, Central, West, and South-East). By population, South-East is by far the largest health region and is the region with the capital of the country.

Our study is based on a randomized controlled trial of screening for colorectal cancer, Norwegian colorectal cancer prevention (NORCCAP) that was carried out from 1999 to 2001 (Bretthauer et al., 2002). A pilot study, carried out prior to NORCCAP, influenced the choice of design for the NORCCAP trial (Hoff et al, 1985). Two counties were represented: Telemark, where the pilot study was carried out, and Oslo. Telemark, with 165,855 inhabitants in 2003, has both urban and rural areas, while Oslo represents a typical urban area with 517,401 inhabitants in 2003. Each year, 7,000 persons were invited to participate, 3500 from each county. During 1999 and 2000, persons in the age group 55 to 64 years were invited to participate, while in 2001, persons in the age group 50 to 54 years were invited. The participation rate was 66 percent in 1999 and 2000, and 62 percent in 2001. In NORCCAP individuals were invited to a screening with once-only flexible sigmoidoscopy or flexible sigmoidoscopy in a combination with faecal occult blood tests (FOBT), which is expected to affect both morbidity and mortality. The first effect reflects the benefits of earlier detection of cancer, which has a positive impact on the survival probability. The second effect is connected to the removal of polyps from the colon, which could develop into cancer in the future. A proportion of the individuals invited to the screening was not eligible for screening for a variety of reasons. For example, for some, screening could entail increased risk because they would have had to discontinue another treatment in order to participate; while for others screening could not be carried out because the colon already had been removed.

Figure 1 describes the patient flow in NORCCAP. A participant fulfilling the inclusion criteria[1] had to empty his bowel before he could undergo the sigmoidoscopy. The individual would either have a positive or negative sigmoidoscopy. A positive sigmoidoscopy was defined as having an adenoma ≤ 10 mm and/or having a polyp ≥ 10 mm (it is more than 95 percent certain that such a polyp is an adenoma). Adenomas are growths that are benign, but some are known to have the potential, over time, to transform into cancer. An individual with a positive sigmoidoscopy (and/or a positive FOBT test) was referred to colonoscopy. Colonoscopy, like flexible sigmoidoscopy, enables the physician to observe the inside of the large intestine. Unlike flexible sigmoidoscopy, colonoscopy is an examination of the entire large intestine, both sigmoid and colon. Some of the individuals who were referred to

[1] The exclusion criteria for NORCCAP included being treated for cancer and taking anticoagulants.

colonoscopy were recommended to have a new colonoscopy after some years (ranging from 3 to 10 years). The individuals are themselves responsible for complying with the recommendation.

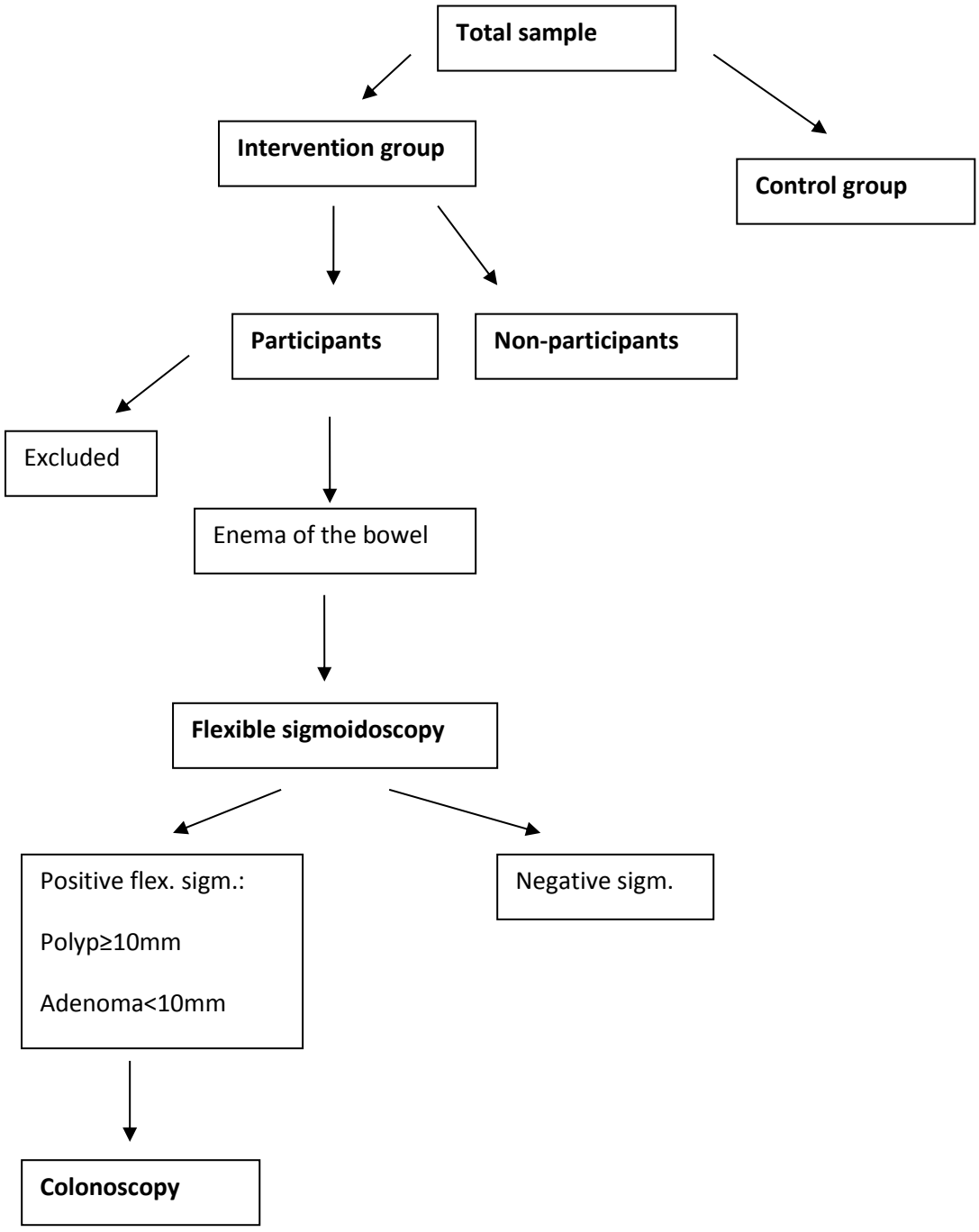

Figure 1: The patient flow in NORCCAP, 1999 to 2001.

The total sample originally consisted of 100,588 individuals, out of whom 79,808 were included in the control group and 20780 were included in the intervention group. The screening was carried out during 1999 to 2001 and different age-cohorts are included each year: In 1999 individuals born in 1935, 1936, 1938, 1940, 1942 and 1944 were invited; in 2000 individuals born 1937, 1939, 1941, 1943 and 1945 were invited and in 2001 individuals born 1946, 1947, 1948, 1949 and 1950 were included. Individuals were excluded from the dataset if they were diagnosed with cancer and/or died up to December 31st of the year before they should have been included in the study. Thus an individual born in 1937 with a cancer diagnosis in 1999 is excluded from the sample.

3. Human Capital and health behaviour

Several studies show that human capital is positively related to participation in health screening programmes (Vernon, 1997; Petersen, 2002; McCaffery *et al.,* 2002; Aas, 2009). This result is consistent with the literature on human capital and health (Grossman (2000), Kenkel (2000)), which concludes that human capital is expected to increase the demand for health because of several reasons. Human capital seems to be related to a preference for the future and a preference for health. Human capital contributes to a higher future income which makes it more rewarding to stay healthy. Also, human capital makes it easier to interpret health information and to make use of health information in decisions that impact on future health.

In this paper we emphasize the last mentioned explanation and aim at contributing to the literature by examining the changes in health behaviour that occur after screening, and more specifically, whether these changes in health behaviour vary with human capital. The study is inspired by a criticism of screening programmes referred to as the "Health Certificate Effect" (Larsen et al., 2007, and van der Alst et al., 2010). The "Health Certificate Effect" means that due to participants' misinterpretation of the screening outcome (test result), unfortunate lifestyle decisions is an adverse effect of screening. For instance, a negative test result is misinterpreted as a verification of being in perfect health; hence fewer measures are taken to prevent future illness (allocative inefficiency of health production). We would expect that misinterpretation of test results occurs more frequently among individuals with a low level of human capital compared with individuals with a high level of human capital.

The "Health Certificate Effect" can be interpreted within the framework of Bayesian updating of disease probabilities from test results. In the present exposition we only consider the point estimate of the posterior probability. According to Bayes' theorem we have:

$$P(\mathrm{H} \mid \overline{\mathrm{B}}) = \frac{P(\overline{\mathrm{B}} \mid H)P(H)}{P(\overline{\mathrm{B}} \mid H)P(H) + (1 - P(\mathrm{B} \mid \overline{H})(1 - P(H))} \quad , \tag{1}$$

where *H* is the healthy state, $\overline{H}$ is the state with illness, *B* is a positive test result and $\overline{B}$ is a negative test result. $P(\mathrm{H})$ is the prior probability of being healthy, and $(1 - P(H))$ is the prior probability of being ill. $P(\mathrm{B} \mid \overline{H}) \equiv \gamma$ is the test sensitivity and $P(\overline{\mathrm{B}} \mid H) \equiv \delta$ is the test specificity. $P(\mathrm{H} \mid \overline{\mathrm{B}}) \equiv \tilde{\mathrm{p}}$ is the posterior probability of being healthy given a negative test result.

By partially differentiating (1) w.r.t. to γ we find:

$$\frac{\partial P(\mathrm{H} \mid \overline{\mathrm{B}})}{\partial \gamma} > 0 ,$$

and by partially differentiating (1) w.r.t. to δ we find:

$$\frac{\partial P(\mathrm{H} \mid \overline{\mathrm{B}})}{\partial \delta} > 0 .$$

Hence, an increase in the test sensitivity and an increase in the test specificity both increase the posterior probability of being healthy.

Several studies show that individuals – both health professionals and lay people – in fact have problems with understanding information updating according to Bayes rule. Bramwell et al. (2006) studied health professionals' and services users' interpretation of a positive test result in screening for Down's syndrome. Responders were given information of occurrence of Down's syndrome in addition to the sensitivity and specificity of the test. For the group of responders as a whole, 14% of the responses were correct. According to sub-groups, 9% of the pregnant women, none of the midwives and 43% of the obstetricians gave correct answers. Whiting et al. (2015) did a systematic literature review of how well professionals interpret diagnostic information. They included 24 studies. The majority assessed the influence of a positive test result on the probability of disease. They generally find health professionals' estimation of post-test probability to be poor, with a tendency to overestimation.

These studies suggest that updating of the probability of avoiding the disease that is screened for, may not be according to the Bayesian framework, represented by (1).. We will in this paper use an economics framework to elaborate on the "Health Certificate Effect" of screening.

In the paper "Health as human capital: synthesis and extensions", Becker (2007) emphasizes three interrelated developments. The first is the analysis of optimal investments in health that follows Grossman (1972, 2000). The second is the value of life literature and the third emphasizes the

importance of complementarities in health and human capital investments and in fighting different diseases, as analysed by Dow et al. (1999). Becker's framework is applied by Kaestner et al. (2014), in their study of whether different investments in disease prevention are complements or substitutes. In their theory model, they distinguish between "income effects" and the "technology effects". The "technology effects" are relevant for the present study and consider whether the prevention technologies are complements or substitutes in the production of health. If prevention technologies are substitutes, an increase in the use of one technology is expected to reduce the demand for the other prevention technology.

In the setting of our study, a negative test result may be interpreted as a technology that reduces the known risk of having CRC in the future. The medical literature may provide information of whether or not prevention technologies are complements or substitutes in our case. Ideally, we are interested in studies that examine whether individuals with a negative test of CRC have a smaller benefit from preventive effort in developing lifestyle related diseases compared with the untested population. We are not aware of any such study. Hence, we search for studies of possible associations between colorectal cancer and lifestyle related diseases. Krämer et al. (2012) review and summarize epidemiological studies assessing the sex-specific association of type-2 diabetes and the risk for CRC. They find that type-2 diabetes is associated with a moderate increase in CRC risk in both men and women. Chan et al. (2007) find in a study population undergoing coronary angiography, that the prevalence of colorectal neoplasm was greater in patients with coronary artery disease. They find a stronger association between the presence of advanced colonic lesions and coronary artery disease in persons with the metabolic syndrome and a history of smoking. In a systematic review of studies, Algra and Rothwell (2012) find that both observational studies and long-term follow-up of randomized trials of aspirin in prevention of vascular events show that daily aspirin reduces the incidence of colorectal cancer and several other cancers and reduce metastasis. These results indicate perhaps a positive association between cardio-vascular disease and colorectal cancer. However, we are not aware of studies that point in the direction of smaller effects of disease prevention because of a negative screening result. Hence, as a benchmark we suggest that an individual who exploits available information in a re-optimization after a negative screening result should leave preventive effort unaffected.

Nevertheless, within an economics framework, the "Health Certificate Effect" implies an assumption of substitution between a negative screening result and other preventive actions. Individuals with these beliefs reduce the level of preventive effort more than they would have done with a better informed assessment of the empirical evidence. An implication is that screened individuals with a

negative test result are expected to develop lifestyle related diseases to a greater extent than unscreened individuals with similar characteristics. We predict that false beliefs occur more often among individuals with a low level of education than among individuals with a high level of education.In the empirical analyses, we shall start by examining the effect of being invited to screening on lifestyle related diseases and the effect of attending (not all the invited attend the screening) screening on lifestyle related diseases. These effects are composed of the effects for the various sub-groups. For instance, the effect of attending screening on acquiring lifestyle related disease is composed of the effect for those with a negative test result and the effect for those with a positive test result. Based on a similar argument as for the participants with negative test result, we suggest that participants with a positive test result and a low level of human capital, will overestimate their probability of having a lifestyle related disease and switch to a healthier lifestyle than they had previously. Hence, we predict that the effect of a positive screening test result pulls in the opposite direction compared with the effect of a negative test result. Since the group with a positive test result is a minority (in NORCCAP 20% of the participants) we hypothesize that total effect of screening attendance is an increase in lifestyle related diseases for those with a low level of human capital.

4. Data

The dataset consists of 53471 individuals born between 1935 and 1950 from two counties in Norway, of whom 21 000 were invited to participate in a once only screening with sigmoidoscopy. Information on screening participation status (participation, non-participation and control) and screening outcome (positive and negative test and cancer diagnosis) was derived from the trial data base at the Cancer Registry of Norway. For all individuals we also have information on human capital, measured by education and income from Statistics Norway, see Table 1 for characteristics of the individuals in the dataset. Since we are working with data from a randomized trial with observations both before and after the trial, we can approximate the effect of screening on health behaviour by health care utilization, both ex ante and ex post of screening. Information on outpatient consultations and inpatient stays are collected from the Norwegian Patient Register from 1997 to 2009 (except the years 2005 to 2007). Health behaviour is identified by utilization of treatment related to the following lifestyle related diseases: Chronic obstructive pulmonary disease (COPD), hypertension, ischemic heart disease; diabetes mellitus and end-stage-kidney failure, identified by ICD-10 codes either as main or secondary diagnosis (see Appendix 1 for details). To control for the time trend of changes in health care utilization, we also include health care utilization in the same period for non-lifestyle diseases, such as hip fractures, arthrosis and osteoporosis.

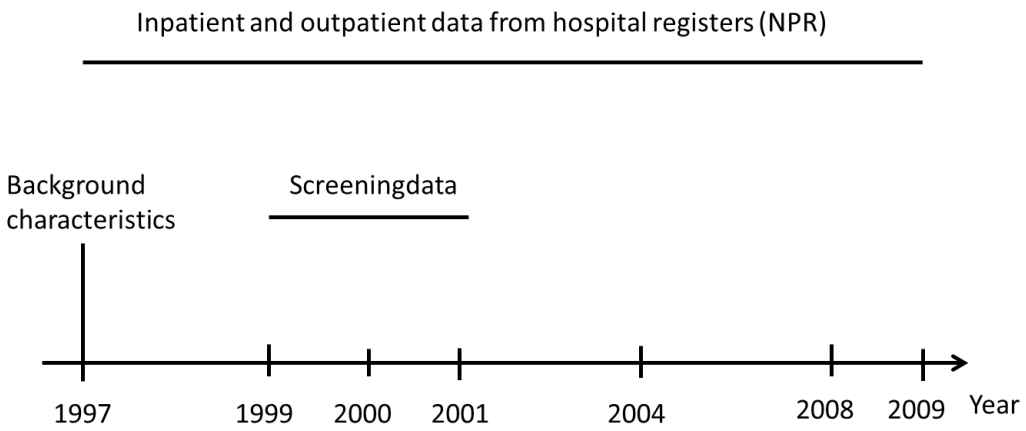

Figure 2: Structure of data according to data sources and type of data (cross-sectional, trial data or panel data)

Table 1: Individual characteristics of the study sample (all numbers in proportion if other not stated)

Variable		**Control**	**Intervention**
Age *mean (st.dev)*		59.7 (4.4)	60.9 (4.4)
County	Telemark	0.51	0.49
	Oslo	0.50	0.50
Education	Primary < 10 years	0.23	0.24
	High school 10-13 years	0.49	0.49
	University	0.26	0.24
	Not given or unknown	0.03	0.03
Income*	< €11 111	0.14	0.15
	€11 112 - €22 222	0.27	0.28
	€22 223 - €32 222	0.32	0.32
	€32 223 - €44 444	0.14	0.13
	€44 445 - €66 666	0.08	0.07
	€66 667 and more	0.05	0.05
Gender (ref Male)	Female	0.50	0.50
Findings Groups	Control	0.61	
	CRC at screening	<0.001	
	Participants – positive test	0.04	
	Participants– negative test	0.20	
	Non-participants	0.15	

*€1 is equal to NOK9

The structure of the data can be illustrated by Figure 2, where we see that individual characteristics contain cross-sectional information from 1998, invitation to screening data with screening information from 1999 to 2001 and treatment data from NPR for the whole period 1997 to 2009.

In the analysis, we split the intervention group in two different ways. First, we apply the intention-to-treat approach, were we compare all invited to screening with the control group. By definition of randomized controlled trials, these two groups are comparable as they have similar characteristics. We can therefore conclude that any differences in outcomes are caused by screening. Second, we group the invited according to participation status and screening result. We are mainly interested in the individuals with a negative test result.

Year of screening is allocated over three years and is an important component in the analysis as our main focus is related to changes occurring as a consequence of screening. In order to balance the dataset between invited and control group, all individuals in the control group are randomly allocated to a fictive date of invitation. This implies that all individuals in the age cohorts allocated for screening in 1999 (similar for 2000 and 2001) are given a date of invitation, independent of being in the control group or not.

We have coded lifestyle related and non-lifestyle related diseases dichotomous. (0 and 1). First, for each of the ICD-10 codes above, an individual is coded with 1 if the individual is registered with either a main or a secondary diagnosis in at least one year from 1997 to 2009, 0 otherwise. An individual could potentially be coded with 1 for more than one of the ICD-10 codes. Second, if an individual is coded with 1 in 1997, the individual is coded with 1 for the following years independent of whether the individual is observed with the same code in the hospital registers in the following years. We therefore assume that an individual diagnosed with a disease cannot recover from that specific disease. Third, when aggregating the ICD-10 codes into lifestyle- and non-lifestyle related diagnoses, we code an individual with more than one lifestyle related disease (similar with non-lifestyle) with 1. The fact that one individual could have several diseases is not accounted for.

In the analysis, we are especially interested in the proportion of individuals without a lifestyle related disease before screening (not observed with a lifestyle related disease), who develop a lifestyle related disease after screening. The cut off for lifestyle related diseases before and after screening is defined by screening year. An individual is coded as 0 before screening if the individual is not observed with a

lifestyle related disease in any of the years prior to screening, and 1 otherwise (similar for non-lifestyle related). Further, an individual coded with 1 after screening could either had a lifestyle related disease prior to screening or is diagnosed with a lifestyle related disease after screening. An individual coded with 0 is observed with a lifestyle related disease neither before nor after screening (similar for non-lifestyle related). We are mainly studying the group of individuals moving from 0 before screening to 1 after screening (but 1 to 1 is also reported). In Appendix 1, descriptive statistics are reported for all transitions before and after screening. In the following tables A1 and A2, we have reported proportions of lifestyle related and non-lifestyle related diseases, respectively, according to screening groups and level of education. Table A1 shows that the proportion diagnosed with a lifestyle related disease after screening is higher in the intervention group than in the control group (20.6 versus 18.9). This indicates that screening has an effect on the proportion of lifestyle related diagnoses. When we account for education, we see that the difference between intervention group and control group in the percentage with a lifestyle related disease after screening is greater for individuals with a low level of education than for individuals with higher education (High school and University). The proportion of lifestyle related diseases is also higher among individuals with lower level of education who either did not participate, had a positive test or a negative test.

In the Table A2 non-lifestyle related diseases are reported. For intention to treat (control versus intervention group), we see the same trend of an increasing proportion of diagnosis in the intervention group. The effect of education is not following the same trends as for lifestyle related diseases. The cumulative proportion of lifestyle related and non-lifestyle related diseases are reported in Figure 3. The increase in lifestyle related diseases is greater than for non-lifestyle related, and in 2009 about 100 per 1000 for non-lifestyle related and 275 for lifestyle related.

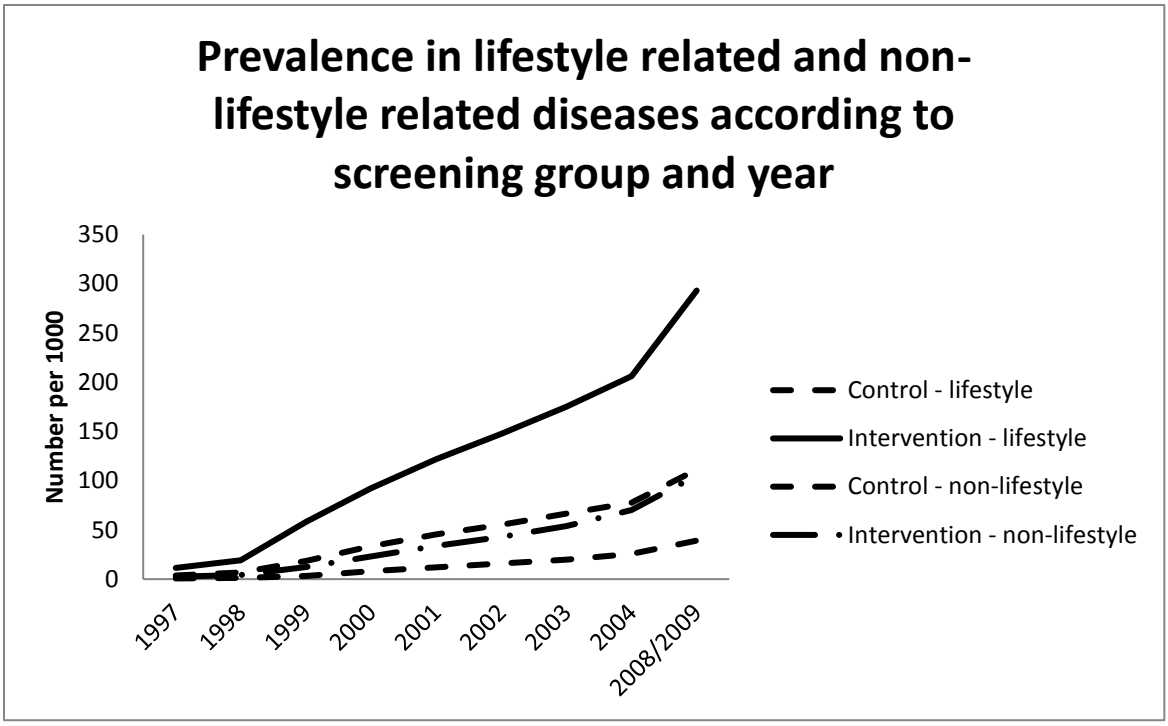

Figure 3: Cumulative proportion of lifestyle related and non-lifestyle related diseases according to screening group from 1997 until 2009. All numbers are per 1000.

5. Empirical specification

Two issues are analysed in this paper: first, the effect of human capital on lifestyle related treatment after participation in screening. To adjust for general trends in access to health care, we also perform similar analyses on non-lifestyle related treatment.

Human capital and the Health Certificate Effect (HCE)

In order to test for a HCE, we run several analyses. Firstly, we analyse a reduced form by testing the effect of intention-to-treat (ITT) on acquiring lifestyle related treatment (similar for non-lifestyle related). A positive effect of ITT on lifestyle related treatment will, by the randomization, stem from behavioural changes among the individuals participating in screening. But, the coefficient will be an average as the ITT includes both participants and non-participants. Among individuals participating in screening, the proportion who experience a positive test result is likely to increase their preventive effort and thereby reduce the likelihood of future lifestyle related treatment, while individuals with a negative test result, will, as explained in Section 3, reduce the preventive effort and increase the risk of lifestyle related diseases given a low level of human capital. From Table 1 we know that the proportion with a positive test is dominated by the proportion with a negative test result, hence we would expect that the sign of the coefficient for ITT will be dominated by the effect among the individuals with a negative test. We therefore argue that a significant positive effect of ITT on lifestyle related treatment is an indication of a HCE. Secondly, we analyse the effect of participation in screening

on acquiring lifestyle related treatment. We will then expect the coefficient to increase as we do not include the average effect for both participants and non-participants. In these analyses, we would also argue that a significant positive effect stems from a HCE among the individuals with a negative test result, as explained in Section 3. Lastly, we analyse the effect of a negative test result on acquiring lifestyle related treatment. The challenge in the last analyses, is to identify a good instrument. But, even if the instrument in the final analyses would not satisfy all properties of an instrument, we claim that the first two analyses have the potential of supporting the hypothesis of a HCE.

For the ITT group, the HCE would be identified if being observed with lifestyle related treatment after screening is significantly higher in the screening group compared to the control group. Further, if the effect declines with the level of human capital (measured by level of education), this could be interpreted as an indication of a more accurate updating among individuals with a high level of human capital (education).

For each level of education, let the binary variable $z_{edu,i}$ be defined as

$$z_{edu,i} = \begin{cases} 1 \; if \; lifestyle \; related \; disease \; after \; screening \\ 0 \; otherwise \end{cases}$$

For each level of education we estimate the probability of having acquired a lifestyle related treatment by a linear probability model by ordinary least square regression (similar with non-lifestyle related) disease after screening, given by:

$$Prob(z_{edu,i} = 1) = \alpha_0 + ITT_i\alpha_1 + X_i\theta,$$

where $\alpha_0, \alpha_1 \; and \; \theta$ are unknown parameters, ITT_i is representing the group invited to screening (defined by 1 when invited) and X_i a vector of other individual characteristics (sex and county). Differences in utilization of health care services between the control group and the screening groups will be identified by α_1.

In the next step, we want to analyse the change in lifestyle related diseases (and non-lifestyle related treatment) among individuals participating in screening and among individuals with a negative test result. As a reference, we start out by estimating the coefficient with OLS. These coefficients will be biased if there is selection bias in participation in screening. We use these estimates as comparators

when proceeding to the two stage least square (2SLS) estimation. If the coefficients with OLS are equal to the 2SLS coefficients, this indicates that the adjustment for selection bias is not necessary.

We expect that in order to estimate the marginal effect of participation in screening on lifestyle related treatment, we need to account for possible selection in the dataset, as not all invited to screening, participate. In particular, there is a tendency that the individuals who participate are healthier than individuals who abstain from participating despite being invited. Hence, participating is likely to be an endogenous variable in the sense that it is correlated with the error term in the structural equation. Following Angrist (2006) and Angrist and Pischke (2009, 2014) we make use of the treatment assignment (ITT) in the randomized experiment as an instrument. This instrument has a causal effect on participation (*first stage*). The instrument is randomly assigned and independent of for instant the level of education (independence assumption). The instrument does not impact on the outcome variable though other channels than the first stage (exclusion restriction). We have the first and second stage, respectively:

$$P_{edu,i} = \beta_1 + \delta ITT_i + \vartheta_1 X_i + \epsilon_{1i}$$
$$Y_{edu,i} = \beta_2 + \lambda_{2SLS} \hat{P}_{edu,i} + \vartheta_2 X_i + \epsilon_{2i}$$

$P_{edu,i}$ is a binary variable equal to one if an individual participates in the screening; and zero otherwise, $\hat{P}_{edu,i}$ is the predicted $P_{edu,i}$ from the first stage, X_i is a set of exogenous control variables, $Y_{edu,i}$ measures the outcome in terms of having acquired lifestyle related (not lifestyle related) disease and ϵ_{1i} and ϵ_{2i} stochastic error terms. We do two stage least square regressions (*ivreg2 in Stata*) and test for endogeneity (by the Hausman test) and whether we have a weak instrument (F-test).

When analysing the HCE among individuals with a negative test result, there is also a need to account for potential selection bias. We then need to account for the probability of being invited to screening and having a negative test result. In these analyses we also make use of the treatment assignment (ITT) in the randomized experiment as the instrument. As argued above, ITT is a perfect instrument for participation in screening, but probably less convincing with regard to fulfilling the requirements as an instrument for a negative test. We believe the instrument to have a causal effect on participating and having a negative screening test (first stage). Further, the instrument is randomly assigned and independent of for instant the level of education (independence assumption). More doubt is attached to whether the instrument has an impact on the outcome variable through other channels than the first stage (exclusion restriction). When applying ITT as an instrument for participation, we know that

the only impact on lifestyle related treatment is through screening, as both the control and the non-participants have not been exposed to screening. But, when we estimate the effect of screening on a negative test results, there is a potential that screening is not the only channel as individuals with a positive test, exposed to screening, is mixed with controls and non-participants, which are not exposed. In lack of a better instrument and the fact that individuals with a positive test result are few compared to the number of individuals in the control and among the non-participants, we use ITT as an instrument in these analyses too.

$$D_{edu,i} = \alpha_1 + \varphi ITT_i + \gamma_1 X_i + e_{1i}$$
$$Y_{edu,i} = \alpha_2 + \mu_{2SLS}\widehat{D}_{edu,i} + \gamma_2 X_i + e_{2i}$$

$D_{edu,i}$ is a binary variable equal to one if an individual participates in the screening and receives a negative test result; and zero otherwise, $\widehat{D}_{edu,i}$ is the predicted $D_{edu,i}$ from the first stage, X_i is a set of exogenous control variables and e_{1i} and e_{2i} stochastic error terms. We do two stage least square regressions *(ivreg2)* and test for endogeneity (by the Hausman-test) and whether we have a weak instrument (F-test). As a reference, we estimate OLS of the effect on participation on acquiring lifestyle related treatment in order to compare the coefficients from OLS with 2SLS.

6. Results

Table 2 shows the results from estimated linear probability models in an intention-to-treat setting for lifestyle related treatment. All analyses are done separately for each level of education. For lifestyle related treatment we see that being invited to screening increases the probability of acquiring lifestyle related treatment after screening among individuals with primary education (<10 years) and high school (10-13 years), while there is no effect of screening among individuals with education at the university level. In addition, we see that being male and living in Telemark, increases the probability of acquiring lifestyle related treatment.

For non-lifestyle related treatment, the results are somewhat different, see Table 3. There is no significant effect on the probability of acquiring non-lifestyle related treatment among individuals invited to screening, except among individuals with a high school education (10-13 years). Males have a lower probability of acquiring non-lifestyle related treatment than females.

The intention-to-treat analyses indicate that the health certificate effect could be present, as we observe a significantly higher utilization of lifestyle related treatment in the two groups with lowest

level of education. The same effect is not observed to the same extent for non-lifestyle related treatment.

In Table 4a we have estimated the effect of participation and a negative test result on the probability of acquiring lifestyle related treatment by means of OLS. For the regressions on both participation and a negative test results, there is a positive effect of primary and high school education on lifestyle related treatment, while there is no effect among individuals with education at the university level. The size of the coefficients compared to the ITT-analyses, are generally higher for participants, while they are lower for individuals with a negative test results. This result is not as expected as the effect of a negative test result is expected to increase.

In Table 5 and Table 6 we adjust for potential selection bias and estimate the effect of participation on lifestyle related treatment and non-lifestyle related treatment, respectively. From Table 5 we see that the effect of participation on lifestyle related treatment is significantly positive for both individuals with primary education (<10 years) and high school education (10-13 years), while there is no effect of participation among individuals with education at the university level. Hence, the signs of the effects from the ITT analysis are confirmed with greater magnitude. In addition, being male and living in Telemark has a significant positive effect on acquiring lifestyle related treatment. The F-test indicates that ITT is a strong instrument, and according to the endogeneity test we see that there is no problem with endogeneity in the second stage. The ITT analyses are also confirmed for the non-lifestyle related treatment, see Table 6. Compared with Table 4b we see that the effect of participation on acquiring non-lifestyle related treatment disappears for the groups with primary school and university education with 2SLS. According to the tests there is a problem with the exclusion criteria in the regression for primary education.

In Table 7 and 8 we use ITT as an instrument to adjust for selection bias and estimate the effect of a negative test result on lifestyle related treatment and non-lifestyle related treatment, respectively. From Table 7 we see from the result of the first stage regression that being invited to screening has a highly significant effect on the likelihood of testing negative. Males are less likely to test negative, while individuals from Telemark are more likely to test negative. Testing negative has a significantly positive effect on the outcome variable for all education groups, except for education at the university level. These results support the hypothesis of a “health certificate effect” after screening. The F-test indicates a strong instrument. With regard to endogeneity, endogeneity is a problem for the estimation of high school education.

In Table 8 we have estimated health care utilization for non-lifestyle related diseases with the same estimation methods as for lifestyle related diseases. From Table 8 we see that the effect of a negative test result does not have the same effect as for lifestyle related diseases. For non-lifestyle related diseases, having a negative test result does not affect health care utilization among individuals with primary education and university education The test for endogeneity and the strength of the instrument indicate that we have an good instrument.

Based on our findings, we believe that we have revealed support for the presence of a HCE in the NORCCAP trial. We find evidence for effects according to both ITT and participation, which we have argued must stem from a change in behaviour among individuals with a negative test result. In the analysis with a negative test results, the effects are as expected stronger than in the analyses on ITT and participation, as the results in the former analyses are driven by the effect on acquiring lifestyle related treatment among those with a negative test result. Even though the instrument applied in the two stage regression may not fulfil all required properties of the instrument in all regressions, they support the results from the ITT and participation analyses. As both the ITT and participation regression identify a significantly positive effect among individuals with primary school and high school education, these are all results supporting the hypothesis of a HCE. Further, we have also identified an effect of human capital on health behaviour as individuals with education at the university level do not change behaviour after screening.

Comparing the coefficients for OLS with the 2SLS, we see that for the regressions on participation, the significant effect among individuals with education at the primary school level and the high school level (10-13 years) are greater in magnitude with the 2SLS. The coefficient for education at the University level is reduced with 2SLS. Comparing the findings for a negative test results, the coefficients for education at the primary and high school level are much greater, while there is no difference for education at the university level. The latter finding indicates that endogeneity is less of a problem among individuals with education at the university level. In general, adjusting for selection bias seems to influence the results.

17.11.2016

Table 2: The effect of education on acquiring lifestyle related treatment after screening according to level of education and screening group

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Intention-to-treat	Invited	0.026**	*0.009*	0.016**	*0.006*	0.004	*0.007*
Gender	Male	0.049**	*0.009*	0.076**	*0.005*	0.064**	*0.007*
County (Oslo)	Telemark	0.046**	*0.009*	0.043**	*0.005*	0.029**	*0.007*
Constant		0.204**	*0.008*	0.152**	*0.004*	0.119**	*0.006*

*p-value<0.05. **p-value <0.01

Table 3: The effect of education on acquiring non-lifestyle related treatment after screening according to level of education and screening group

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Intention-to-treat	Invited	0.003	*0.005*	0.008*	*0.004*	0.007	*0.005*
Gender	Male	-0.032**	*0.005*	-0.026**	*0.004*	-0.035**	*0.005*
County (Oslo)	Telemark	0.013**	*0.005*	0.003	*0.004*	0.000	*0.005*
Constant		0.092**	*0.003*	0.094**	*0.004*	0.086**	*0.004*

*p-value<0.05. **p-value <0.01

Table 4a: The effect of education on acquiring lifestyle related treatment after screening according to level of education and screening group, OLS

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Participation in screening		0.034**	0.011	0.019**	0.006	0.008	0.008
Gender	Male	0.050**	0.009	0.077**	0.005	0.064**	0.006
County (Oslo)	Telemark	0.043**	0.008	0.042**	0.005	0.028**	0.007
Constant		0.208**	0.007	0.154**	0.005	0.119**	0.005
Negativ test		0.028**	0.011	0.010	0.007	0.006	0.008
Gender	Male	0.050**	0.009	0.077**	0.005	0.064**	0.007
County (Oslo)	Telemark	0.044**	0.009	0.043**	0.005	0.028**	0.007
Constant		0.210**	0.008	0.157**	0.005	0.119**	0.005

*p-value<0.05. **p-value <0.01

Table 4b: The effect of education on acquiring non-lifestyle related treatment after screening according to level of education and screening group, OLS

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Participation in screening		0.021**	0.006	0.016**	0.004	0.011*	0.005
Gender	Male	-0.031**	0.005	-0.026**	0.004	-0.034**	0.005
County (Oslo)	Telemark	0.012**	0.005	0.002	0.003	0.000	0.005
Constant		0.089**	0.005	0.094**	0.003	0.086**	0.004
Negativ test		0.018*	0.007	0.014**	0.004	0.012*	0.006
Gender	Male	-0.031**	0.005	-0.026**	0.004	-0.034**	0.004
County (Oslo)	Telemark	0.012**	0.005	0.002	0.003	0.000	0.005
Constant		0.090**	0.005	0.095**	0.003	0.086**	0.004

*p-value<0.05. **p-value <0.01

Table 5: Acquiring lifestyle related treatment according to education groups adjusted for endogeneity by Ivreg2 - on participation.

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Participation in screening		0.047**	*0.016*	0.024**	*0.008*	0.006	*0.010*
Gender	Male	0.050**	*0.008*	0.077**	*0.005*	0.064**	*0.006*
County (Oslo)	Telemark	0.042**	*0.009*	0.042**	*0.005*	0.028**	*0.007*
Constant		0.206**	*0.008*	0.153**	*0.005*	0.119**	*0.005*
First-stage (participation)							
Gender	Male	-0.024**	*0.006*	-0.019**	*0.004*	-0.0006	*0.005*
County (Oslo)	Telemark	0.072**	*0.006*	0.055**	*0.004*	0.060**	*0.005*
Invited to screening		0.550**	*0.007*	0.660**	*0.005*	0.701**	0.006
Constant		-0.033**	*0.004*	-0.020**	*0.003*	-0.022**	*0.003*
Endogeneity test		1.116 (p-value=0.291)		0.819 (p-value=0.366)		0.136 (p-value=0.712)	
Test instrument		F=7860		F=27515		F=18331	

*p-value<0.05. **p-value <0.01

Table 6: Acquiring non-lifestyle related treatment according to education groups adjusted for endogeneity by Ivreg2 - on participants .

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Participation in screening		0.007	0.011	0.015*	0.006	0.010	0.007
Gender	Male	-0.032**	0.005	-0.026**	0.004	-0.343**	0.005
County (Oslo)	Telemark	0.013**	0.005	0.002	0.004	0.0003	0.005
Constant		0.092**	0.005	0.094**	0.004	0.086**	0.005
First-stage (participation)							
Gender	Male	-0.029**	0.005	-0.029**	0.004	-0.011*	0.005
County (Oslo)	Telemark	0.068**	0.006	0.050**	0.004	0.054**	0.005
Invited to screening		0.490**	0.007	0.602**	0.005	0.654**	0.007
Constant		-0.028**	0.005	-0.013**	0.003	-0.014**	0.003
Endogeneity test		3.27 (p-value=0.071)		0.241 (p-value=0.623)		0.030 (p-value=0.862)	
Test instrument		F=6812		F=22954		F=15343	

*p-value<0.05. **p-value <0.01

Table 7: Acquiring lifestyle related treatment according to education groups adjusted for endogeneity by Ivreg2 – on negative test result.

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Negativ test		0.059**	0.019	0.030**	0.010	0.006	0.011
Gender	Male	0.052**	0.009	0.078**	0.005	0.064**	0.007
County (Oslo)	Telemark	0.043**	0.009	0.042**	0.005	0.028**	0.007
Constant		0.205**	0.008	0.152**	0.005	0.119**	0.006
First-stage (negative test)							
Gender	Male	-0.043**	0.006	-0.036**	0.004	-0.019**	0.005
County (Oslo)	Telemark	0.053**	0.006	0.039**	0.004	0.048**	0.005
Invited to screening		0.444**	0.007	0.544**	0.005	0.590**	0.007
Constant		-0.013**	0.005	-0.003	0.003	-0.008*	0.004
Endogeneity test		3.49 (p-value=0.062)		6.481(p-value=0.011)		0.003 (p-value=0.954)	
Test instrument		F=5134		F=16841		F=11241	

*p-value<0.05. **p-value <0.01

Table 8: Acquiring non-lifestyle related treatment according to education groups adjusted for endogeneity by Ivreg2 – on negative test result

		Primary school <10 years		High school 10-13 years		University degree	
Variable	**Category**	**Coefficient**	**St.err**	**Coefficient**	**St.err**	**Coefficient**	**St.err**
Negativ test		0.008	0.013	0.017*	0.007	0.012	0.008
Gender	Male	-0.032**	0.005	-0.026**	0.004	-0.034**	0.005
County (Oslo)	Telemark	0.013*	0.005	0.002	0.004	0.0002	0.005
Constant		0.092**	0.005	0.094**	0.004	0.086**	0.004
First-stage (negative test)							
Gender	Male	-0.044**	0.006	-0.043**	0.005	-0.027**	0.005
County (Oslo)	Telemark	0.049**	0.006	0.036**	0.004	0.043**	0.005
Invited to screening		0.395**	0.007	0.496**	0.004	0.550**	0.007
Constant		-0.010*	0.004	0.002**	0.003	-0.002	0.004
Endogeneity test		0.672 (p-value=0.412)		0.240 (p-value=0.624)		0.012 (p-value=0.912)	
Test instrument		F=4625		F=14911		F=9949	

*p-value<0.05. **p-value <0.01

7. Concluding remarks

The idea of this paper stems from reflections on the outcomes of population health screening programs. Evaluations often show a decline in disease specific mortality while the all-cause mortality is constant or even increasing in some screening programs. These results are valid also for the randomized screening experiment we examine in the present paper: The Norwegian Colorectal Cancer Prevention Trial (NORCCAP). In the theory partwe interpret the "Health Certificate Effect" within an economics framework combined with insufficient capacity of information handling. Some people consider a negative test result and disease preventive effort to be substitutes. Hence, fewer measures are taken to prevent future illness (allocative inefficiency of health production) after a negative test result. We expect that misinterpretation of test results occurs more frequently among individuals with a low level of education compared with individuals with a high level of education. Hence, screening may initiate life-style related diseases among individuals with a low level of education.We test whether or not variation in levels of education among screened individuals has an impact on the development of lifestyle related diseases. We find that for individuals with primary education and high school education the incidence of lifestyle related diseases in the screening group is greater than in the control group during the period after the screening year. We find no such difference for individuals with university education. In general, we find no differences between the screening group and the control group for non-lifestyle related diseases, except among individuals with education at the high school level. We also test for differences between education groups for individuals who participate in screening and among those with a negative test result. In these analyses we instrument for participating in screening and for having a negative test result. We find similar results as in the intention to treat analyses.

One could perhaps argue that our empirical results are due to a so-called health awareness effect. Invitation and participation in a screening programme expose individuals to medical care facilities and they become more prone to visit health care facilities after the screening test than before the screening test. We would then expect to find an increase in visits both due to lifestyle related diseases and non-lifestyle related diseases. This implication is neither according to our empirical findings for individuals with primary education nor for individuals with university education. For individuals with high school education results are more mixed.

Our results are in accordance with Berstad et al. (2015) who find from a questionnaire study that life style changes after the NORCCAP trial are less favourable in the screening group than in the control group. Overall they conclude that possible unfavourable lifestyle changes after CRC screening are modest. The present study represents both a supplement and an improvement to Berstad et al. (2015)

in three respects. First, we make use of register data to study the outcome of changes in life-style in terms of lifestyle related diseases. Second, we differentiate the outcome according to individual human capital indicated by level of education. Third, we have information on all individuals, both invited and control, hence our findings is not affected by response rate to a survey and will therefore not include any selection bias. We find that although the overall consequences of screening on lifestyle related diseases may be modest, the adverse effect of population health screening on individuals with a low level of human capital may well be considerable.

In the analysis we have grouped several lifestyle related diseases into one aggregated indicator for lifestyle. The main reason for aggregating was the number of observations for each ICD-10 code, which were low for most of the diseases. With access to more data through a longer observation period, it would be interesting to study some of the ICD-10 codes more specifically, such as COPD, which is known to be related to the lifestyle behaviour in terms of smoking. From Table A6 the percentage developing COPD after screening is about 4 - 5 percent. The outcome variable used in our analysis is dichotomous. One implication is that we are not considering multiple lifestyle related diseases, which also could be of relevance in future studies.

The empirical specifications applied in this paper are related to a dichotomous outcome. With a longer observation period, other methods could be considered, such as duration analysis. Then we could have estimated hazard ratios, expressed as the likelihood of developing a lifestyle related disease in the next period, given that the individual has not developed a lifestyle related disease in this period. In addition to duration analysis, we could also use a diff-in-diff framework. In future research, we will also consider more advanced methods of instrumental variables, as suggested by Basu et al (2007). We see several implications from our study. The assessment of screening programs should include potential adverse effects of screening in terms of health loss, costs of medical care and lost production. The overall benefit of screening individuals with a high level of human capital seems to be greater than the overall benefit of screening individuals with a low level of human capital. That the incidence of colorectal cancer is higher among individuals with a low level of human capital compared with individuals with a high level of human capital points in the opposite direction. Also, the participation rate seems to be negatively related to the incidence of (pre-stages of) colorectal cancer. A next step would be to conduct a field experiment that evaluates the effect of measures to increase the screening participation among individuals with a low level of human capital and also to develop measures to enhance a proper interpretation of the information contained in screening results.

References:

Aas, E. 2009. Pecuniary compensation increases participation in screening for colorectal cancer *Health Economics*. ISSN 1057-9230. *18*(3), s 337- 354 . doi:http://dx.doi.org/10.1002/hec.1371

Algra, A. M., Rothwell, P. M. 2012. Effects of regular aspirin on long-term cancer incidence and metastasis: a systematic comparison of evidence from observational studies versus randomised trials. Lancet Oncology 13, 518–527.

Angrist, J. D. 2006. Instrumental variables methods in experimental criminological research: what, why and how. Journal of Experimental Criminology 2, 23-44.

Angrist, J. D., Pischke, J. S. 2009. Mostly Harmless Econometrics. Princeton University Press.

Angrist, J. D., Pischke, J. S. 2014. Mastering Metrics: The Path from Cause to Effect. Princeton University Press.

Basu, A., Heckman, J.J., Navarro-Lozano, S., Urzua, S. 2007. Use of instrument variables in the presens of heterogeneity and self-selection: an application to treatments of breast cancer patients. *Health Economics.* 16: 1133-1157.

Becker, G. S. 2007. Health as human capital: synthesis and extensions. Oxford Economic Papers 59, 379–410.

Berstad, P., et al., 2015. Long-term lifestyle changes after colorectal cancer screening: randomised controlled trial. Gut 64, 1268–1276.

Bramwell, R., West, H., Salmon, P., 2006. Health professionals' and service users' interpretation of screening test results: experimental study. British Medical Journal 2006; 333:284.

Chan, A. O. O. et al. 2007. Prevalence of colorectal neoplasm among patients with newly diagnosed coronary artery disease. The Journal of the American Medical Association 298, 1412-1419.

Dow, W.H., Philipson, T.J., Sala-i-Martin, X. 1999. Longevity complementarities under competing risks. The American Economic Review 89, 1358–71.

Grossman, M. 1972. On the concept of health capital and the demand for health. The Journal of Political Economy 80, 223–55.

Grossman, M. 2000. The human capital model. In A. J. Culyer & J. P. Newhouse (Eds.), Handbook of Health Economics. Amsterdam: Elsevier.

Holme, Ø. et al. 2014. Effect of Flexible Sigmoidoscopy Screening on Colorectal Cancer Incidence and Mortality: A Randomized Clinical Trial. Journal of the American Medical Association 312, 606-615.

Kaestner, R., Darden, M., Lakdawalla, D. 2014. Are investments in disease prevention complements? The case of statins and health behaviors. Journal of Health Economics 36, 151–163.

Kenkel, D. S. 2000. Prevention. In A. J. Culyer & J. P. Newhouse (Eds.), Handbook of Health Economics. Amsterdam: Elsevier.

Krämer, H. U., Schöttker, B., Raum, E., Brenner, H. 2012. Type 2 diabetes mellitus and colorectal cancer: meta-analysis on sex-specific differences. European Journal of Cancer 48, 1269-82.

McCaffery K, J Wardle, M Nadel, W Atkin. 2002. Socioeconomic variation in participation in colorectal cancer screening. *Journal of Medical Screening*, 9:104, DOI: 10.1136/jms.9.3.104

Petersen, GM. 2002. Barriers to preventive intervention. *Gastroenterology of Clinics of North America* 31, 1061-1068.

Shaukat, A., et al. 2013. Long-Term Mortality after Screening for Colorectal Cancer. New England Journal of Medicine 369, 1106-14.

Thiis-Evensen, E., et al. 1999. Population-Based Surveillance by Colonoscopy: Effect on the Incidence of Colorectal Cancer: Telemark Polyp Study I, Scandinavian Journal of Gastroenterology 34, 414-420.

Vernon S. 1997. Participation in colorectal cancer screening: a review. *Journal of the National Cancer Institute* (89):1406–22

Whiting, P. F., Davenport, C., Jameson, C., et al., 2015. How well do health professionals interpret diagnostic information? A systematic review. British Medical Journal Open 2015;5:e008155. doi:10.1136/bmjopen-2015-008155

A1: Diagnosis included

ICD-9 for 1997 and 1998. From 1999 to 2004 we have used ICD-10 codes:

Lifestyle related diseases included in the study:

Diabetes mellitus: E10 to E14 (ICD-10) and 250 (ICD-9)

Hypertension: I10, I11 and I15 (ICD-10) and 401, 402 and 405 (ICD-9)

Cardiovascular disease: 430 to 438 (ICD-9)

Ischemic heart disease: I20-I69: 410 to 418 (I 1997 som IHD og DPC) and 430 to 438 (som CD) (ICD-9)

COPD: J40 to J47 (ICD-10) and 490-496 (ICD-9)

End-stage kidney disease: N18, Z49, Z940, Z992 (ICD-10) and 585 and 586 + V420, V451, V56 (ICD-9)

Non-lifestyle related diseases:

Hip fracture: S72 (ICD-10) - 820 (ICD-9)

Osteoporosis: M80 (ICD-10) 733 (ICD-9)

Arthrosis: M15 to M19 and M47 (ICD-10) 715 (ICD-9)

Dementia: F00 F01 F02 F 03 to F 07 (ICD-10) 290-294 (ICD-9)

A2: Descriptives

Table A1: Percentages of lifestyle related disease after screening according to lifestyle related diseases before screening, level of education and screening group

Education	Lifestyle before/after	Control group	Intervention	Participants	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	22.5	24.9	26.7	26.1	29.6	22.8
	1 to 1	11.2	11.0	9.0	9.5	6.9	13.4
High school (10 to 13 years)	0 to 1	19.3	20.8	21.6	20.8	25.4	19.4
	1 to 1	8.6	8.7	7.5	7.4	7.8	11.0
University	0 to 1	15.6	15.6	16.2	16	17.5	14.4
	1 to 1	5.4	6.7	6.1	5.9	7.0	8.1
Total	0 to 1	18.9	20.6				
	1 to 1	8.4	8.7				

Table A2: Percentages of non-lifestyle related lifestyle disease after screening according to non-lifestyle related diseases before screening, level of education and screening group

Education	Non-lifestyle related before/after	Control group	Intervention	Participation	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	8.3	8.6	10.4	10.2	11.3	6.5
	1 to 1	2.2	2.2	2.4	2.7	1.4	2.0
High school (10 to 13 years)	0 to 1	8.1	8.9	9.7	9.6	9.8	7.4
	1 to 1	2.1	2.4	2.5	2.5	2.2	2.2
University	0 to 1	6.6	7.3	7.9	8.0	7.2	5.9
	1 to 1	1.7	1.7	1.7	1.6	2.0	1.6
Total	0 to 1	7.7	8.4				
	1 to 1	2.0	2.2				

Table A3: Percentages of diabetes after screening according to lifestyle related diseases before screening, level of education and screening group

Education	Lifestyle before/after	Control group	Intervention	Participants	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	4.3	5.1	4.7	4.6	5.0	5.6
	1 to 1	2.3	2.3	2.0	1.9	2.2	2.8
High school (10 to 13 years)	0 to 1	3.7	3.6	3.3	3.3	3.3	4.1
	1 to 1	1.5	1.8	1.6	1.6	1.4	2.3
University	0 to 1	2.7	2.6	2.4	2.3	3.1	2.9
	1 to 1	1.1	1.3	1.0	1.1	0.7	2.0
Total	0 to 1	3.6	3.9				
	1 to 1	1.7	1.9				

Table A4: Percentages of IHD after screening according to lifestyle related diseases before screening, level of education and screening group

Education	Lifestyle before/after	Control group	Intervention	Participants	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	12.9	15.0	15.6	15.2	17.5	14.4
	1 to 1	6.1	5.7	4.2	4.4	3.2	7.5
High school (10 to 13 years)	0 to 1	10.5	11.7	11.8	11.4	14.0	11.4
	1 to 1	4.3	4.3	3.5	3.3	4.4	5.8
University	0 to 1	8.5	9.2	9.4	9.1	11.1	8.7
	1 to 1	2.1	3.1	2.1	2.0	2.8	5.4
Total	0 to 1	10.5	11.9				
	1 to 1	4.1	4.3				

Table A5: Percentages of hypertension after screening according to lifestyle related diseases before screening, level of education and screening group

Education	Lifestyle before/after	Control group	Intervention	Participants	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	12.4	13.8	12.4	14.2	17.3	12.7
	1 to 1	3.1	3.2	2.4	2.5	2.2	4.1
High school (10 to 13 years)	0 to 1	11.0	11.8	12.2	11.9	13.8	10.9
	1 to 1	2.8	2.9	2.5	2.4	2.6	3.7
University	0 to 1	8.9	8.3	8.6	8.5	9.2	7.6
	1 to 1	2.0	2.7	2.8	2.7	3.5	2.5
Total	0 to 1	10.7	11.4				
	1 to 1	2.6	2.9				

Table A6: Percentages of COPD after screening according to lifestyle related diseases before screening, level of education and screening group

Education	Lifestyle before/after	Control group	Intervention	Participants	Negative test	Positive test	Non-participants
Primary school (<10 years)	0 to 1	6.6	7.8	7.5	7.2	9.3	8.2
	1 to 1	2.6	2.9	1.9	2.0	1.4	4.1
High school (10 to 13 years)	0 to 1	4.6	4.9	4.6	4.4	5.6	5.4
	1 to 1	1.8	1.6	1.3	1.3	1.5	2.0
University	0 to 1	2.2	2.8	2.6	2.5	3.0	3.2
	1 to 1	1.0	0.9	1.1	0.9	1.9	0.7
Total	0 to 1	4.4	5.1				
	1 to 1	1.7	1.7				