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Working Paper

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Working Paper, No. 2016:2

Provided in Cooperation with:

Department of Economics, Uppsala University

Suggested Citation: Dahlberg, Matz; Mani, Kevin; Öhman, Mattias; Wanhainen, Anders (2016) : Health information and well-being: Evidence from an asymptomatic disease, Working Paper, No. 2016:2, Uppsala University, Department of Economics, Uppsala, <https://nbn-resolving.de/urn:nbn:se:uu:diva-274543>

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Health Information and Well-Being: Evidence from an Asymptomatic Disease

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Working paper 2016:2
January 2016
ISSN 1653-6975

HEALTH INFORMATION AND WELL-BEING: EVIDENCE FROM AN ASYMPTOMATIC DISEASE

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Health Information and Well-Being: Evidence from an Asymptomatic Disease*

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January 21, 2016

Abstract

We examine how health information affects individuals' subjective well-being using a regression discontinuity design on data from a screening program for an asymptomatic disease, abdominal aortic aneurysm (AAA). The information provided to the individuals is guided by the measured aorta size and its relation to pre-determined levels. When comparing individuals that receive information that they are healthy with those that receive information that they are in the risk zone for AAA, we find no effects. However, when comparing those that receive information that they have a small AAA, and will be under increased surveillance, with those who receive information that they are in the risk zone, we find a weak positive effect on well-being. This indicates that the information about increased surveillance (positive) may outweigh the information about worse health (negative).

Keywords: Information, Health, Screening, Abdominal Aortic Aneurysm

JEL Classification: D80, I12, I31

*We thank Lars Johansson, Damon Clark, Linda Lyttkens, Linuz Aggeborn, Pernilla Jernerén Maathz and Erik Grönqvist, as well as participants at the HEFUU seminar at Uppsala University and at the SHEA conference in Lund for helpful discussions, comments and suggestions. Mattias Öhman gratefully acknowledges financial support from U-CARE.

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1 Introduction

It is well-known that information may affect individual behavior. For example, it has been shown that information to smoking, pregnant women about the dangers of smoking and on how to quit smoking significantly affects their children's weight and height at birth (Sexton and Hebel 1984). Likewise, some of the information experiments conducted by the Minnesota Department of Revenue in 1995 (the Minnesota Income Tax Compliance Experiment), such as information to tax payers about increased examination and auditing of tax returns, had a significant impact on reported income and taxes paid (see Slemrod, Blumenthal, and Christian (2001) and the references cited therein).¹

However, information might not only affect behavior, it might also affect individuals' well-being. This might of course be true for many types of (positive or negative) information, but it is not the least true in connection with medical examination and medical treatment where new information about one's own ill-health is often revealed. The information in itself might cause extra suffering (i.e. in addition to the suffering from the actual illness). So far we know very little of this extra patient suffering, both to what extent it exists and, if it exists, what the magnitude of it is.

The purpose of this paper is to examine how new health information affects individuals' subjective physical and psychological well-being (or mental health).

The main methodological problem in answering this question is to ensure the exogeneity of the information of ill-health from the doctor to the patient. Symptoms of an illness might affect an individual's subjective well-being already before a doctor inform the individual about the illness. To get around this problem, we will use data from a screening program for abdominal aortic aneurysm (AAA). Screening for AAA is well suited for answering the question at hand. First, AAA is well described as an asymptomatic disease, meaning that an individual do not know about it and, hence, the illness cannot affect the individual's subjective well-being before information about it is provided by the doctor after examination. Second, based on certain pre-determined cut-offs, given by the measured size of the aneurysm, individuals are given different information about their health. More specifically, we will compare differential information at two cut-offs, 25 mm and 30 mm. At 25 mm, we will compare those who receive the information that they are healthy (below 25 mm) with those that receive the information that they have an enlarged aorta size and are in the risk zone for AAA (above 25 mm but below 30 mm). At 30 mm, we will compare those that receive the information that they

¹Other studies that show that information affects individual behavior include Strömberg (2004), Engström, Hesselius, and Persson (2007), and Zhao, Konishi, and Glewwe (2013).

have a small AAA and therefore will be under increased surveillance by the health care system (between 30-34 mm) with those who receive the information provided between 25 and 29 mm, i.e., enlarged aorta and increased risk for AAA, but only sparse surveillance by the health care system. Comparing individuals on either side of these cut-offs, we can use a regression discontinuity (RD) design to estimate the causal effect of new health information about ill-health on the individuals' subjective well-being.

The literature on the psychological consequences of screening for AAA is limited and somewhat inconsistent (Lucarotti et al. 1997; Participants 1998; Lindholt, Vammen, et al. 2000; Scott and Group 2002; Spencer et al. 2004; Hansson et al. 2012). These papers do however all suffer from the same type of methodological problem (or use qualitative methods); since they are only comparing group-averages, typically groups of individuals on either side of a cut-off for an aneurysm, they do not control properly for observed and unobserved confounders such as smoking history and/or an unhealthy lifestyle in general. By using the RD design, we are able to handle this methodological problem.

We use data from the Swedish screening program for AAA in Uppsala County.² The individuals' subjective physical and psychological well-being is measured via the SF-36 and EQ-5D questionnaires as well as an AAA-specific questionnaire, questionnaires that the patients fill out a couple of weeks after the information about their health has been revealed.

We find no statistically significant effects at the 25 mm cut-off. At the 30 mm cut-off, however, we find weak evidence of a positive effect of the information provided to the patients on the patients' subjective psychological well-being. This result indicates that the information about increased surveillance (positive information) may outweigh the information about worse health (negative information).

The rest of the paper is organized as follows: In the next section, we discuss AAA, the set-up of the screening program and the information provided within the program. In section 3, we provide a theoretical framework to organize the thinking on the question at hand. After describing the data (section 4) and setting up the econometric model (section 5), section 6 provide the baseline results and section 7 the sensitivity analyses. Section 8 discusses the results and section 9 concludes.

²In Sweden, there are two local governments, one at the municipal level and one at the county level. There are 290 municipalities and 21 counties, implying that each county constitute a fairly large geographical area. The county councils are mainly responsible for the health care system.

2 Background

In this section we will briefly discuss AAA, the set-up of the screening program and the information provided within the program.

2.1 AAA

AAA is a common disease with potentially life-threatening consequences. Most AAAs are asymptomatic until rupture. The best therapy for AAA is pre-symptomatic elective surgical repair in appropriately selected individuals. However, most AAAs are undiagnosed and the large majority of patients with a ruptured AAA die if they do not receive immediate surgery.

There is no agreement on how to exactly define an AAA (Wanhainen 2008). The normal abdominal aortic diameter in elderly men varies between 15 mm and 24 mm (Sakalihasan, Limet, and Defawe 2005). The most accepted definition of an AAA in clinical practice is a maximum infrarenal aortic diameter of at least 30 mm (McGregor, Pollock, and Anton 1975; Moll et al. 2011).

In developed countries, AAA cause 1-3 percent of all deaths among men aged 65 to 85 years (Sakalihasan, Limet, and Defawe 2005). It is estimated that about 600 men and 200 women die as a result of a ruptured AAA each year in Sweden (SBU 2008). Besides male sex and age, the most important risk factor for AAA is smoking; the prevalence of AAA among individuals with a history of smoking is more than four times that in non-smokers (Wanhainen, Bergqvist, et al. 2005; Sakalihasan, Limet, and Defawe 2005; Svensjö et al. 2011). To reduce the high mortality, early detection by screening has been advocated.³

2.2 Screening for AAA in Sweden

Following the introduction of a general AAA screening program for 65-year-old men in the County of Uppsala in 2006, other counties in Sweden launched similar programs (Wanhainen and Björck 2011). Today all counties in Sweden have implemented an AAA screening program for 65-year-old men, which is also recommended by The National

³Several studies have demonstrated that screening for AAA cost-effectively reduce the AAA death rate by more than 50 percent (Ashton et al. 2007; Cosford, Leng, and Thomas 2007; SBU 2008; Lindholt and Norman 2008; Lindholt, Sørensen, et al. 2010; Thompson et al. 2012), and nation-wide screening programs have been launched in several countries (Lederle 2008; Wanhainen and Björck 2011; Davis, Harris, and Earnshaw 2013). However, how the information from the screening programs affect the patients' subjective physical and psychological well-being has not been considered in the cost-benefit calculations.

Board of Health and Welfare. Thereby, Sweden is the first country with a nationwide coverage. In this paper we use data from the screening program in Uppsala County.

Most counties have adopted a centralized hospital-based screening program to which all 65-year-old men, identified through the National Population Registry, are invited. The attendance rate is high, about 85 percent of the invited men participates in the screening. The baseline examination includes a single ultrasound scan where the maximum infrarenal anteroposterior diameter is measured according to the “leading edge to leading edge” principle with the ultrasound transducer longitudinally to the aorta. The ultrasound is estimated to have an error margin (variability) of about ± 4 mm (Gürtelschmid, Björck, and Wanhainen 2014).

In addition to the screening of the 65-year-old men, from 2011 and onwards, all 70-year-old men are also invited to the screening in Uppsala County, which follows the same procedure as for the 65-year-old men. This older group also includes individuals who were on the earlier screening when they were 65-year-old.⁴

Most counties use 30 mm as the cut-off diameter. However, Uppsala County use 25 mm as the cut-off diameter based on the results from contemporary reports indicating that an aorta between 25 and 29 mm should be classified as a subaneurysmal aorta, or an “aneurysm in formation.” Rescanning after five years has been recommended for this subgroup.

About 2,000 individuals annually are invited to an ultrasound examination of the abdominal aorta in Uppsala County. About 1.5 percent of those examined have an aorta between 25 and 29 mm and 1.5 percent an aorta equal to or larger than 30 mm.

2.3 The information provided within the screening program

The result from the ultrasound scan is instantly communicated to the participant by the ultrasound technician, and subjects with a screening-detected AAA, or with an subaneurysmal aorta, are scheduled for an appointment with a vascular surgeon or nurse and are included in a surveillance program depending on size of the aneurysm. The information given to the patients is standardized and summarized in Table 1.

At the follow-up appointment, from 2009 and onwards in Uppsala County, all individuals are asked to complete a health questionnaire with questions about height, weight, earlier/current illnesses, tobacco usage (i.e. if the individual is or has been a smoker) and current medication, as well as questions about marital status and country of birth. The

⁴Hence, individuals with an aorta size less than 25 mm when they are 65 years old will have the same surveillance as 65-year old individuals with an aorta size of 25-29 mm. The information of ill-health given at the screening will, however, differ.

TABLE 1
Screening program procedure

Size of aorta	Main information	Surveillance
≤ 24 mm	Healthy	None.
25-29 mm	Risk zone	Five years.
30-39 mm	Small AAA	Two years.
40-44 mm	Medium AAA	One year.
45-49 mm	Large AAA	Six months.
50-54 mm	Very large AAA	One month.
≥ 55 mm	AAA needing surgery	Immediately.

Notes: Surveillance consists of a follow-up screening at the specified time.

individuals also complete three questionnaires which measure the subjective physical and psychological well-being, the health related quality of life and AAA specific problems. In general, the individuals answer the questionnaires within two months of the screening (see Table 6). When applicable, life style advices (e.g. “quit smoking”) are given, and individuals with a very large AAA (at least 55 mm) are assessed for surgery.

Each year about 50-70 randomly picked individuals from the healthy group (≤ 24 mm) from the cohort of 65-year-olds and 70-year-olds respectively are asked to answer the same questionnaires as the other groups with the exception of the AAA specific questionnaire. This group is considered to be the “healthy group” in this study.

In the analysis we use individuals with a minimum aorta size of 20 mm and a maximum aorta size of 34 mm, implying that we will use the information provided at the 25 mm and the 30 mm cut-offs respectively.⁵ This means that, at the 25 mm cut-off, we compare those individuals that receive the information that they are healthy and that there will be no further contact with the health care system with those individuals that receive the information that they are in the risk zone for AAA and that there will be a follow up after five years. We consider this as being a comparison between one that is given information about being healthy with one that is given information about not being healthy.

At the 30 mm cut-off, we compare those individuals that receive the information that they are in the risk zone for AAA and that there will be a follow up after five years with those individuals that receive the information that they have a small AAA and that there will be a follow up after two years. We consider this as being a comparison between

⁵Relatively few individuals have an aorta size above 34 mm, making the RD regressions problematic. We drop individuals below 20 mm both because a very small aorta can be a problem in itself and to make the sample bandwidth symmetrical.

two individuals in which one receives the information about having worse health than the other, but in which the one with worse health also receives the information that he will have a quicker follow-up. It is worth stressing that the information provided to the two groups about AAA, its risk factors, and its natural development is very similar.

3 Theoretical framework

What effects should we expect from the information provided in the AAA screening program on the individuals' subjective well-being? To structure our thoughts on this issue, we will provide a theoretical framework that is inspired by Zhao, Konishi, and Glewwe (2013) adapted for our setting.

Suppose that the individual's true health capital in the next period, H_{t+1} , depends on a vector of known variables, \mathbf{S} , including variables like smoking, BMI, and physical practice, that might affect the individual's health positively or negatively, aorta size growth (ϵ) and health capital in period t :

$$H_{t+1} = I(\mathbf{S}_t) + (1 - d_t)H_t - \epsilon_t$$

where I is a health capital investment function and $d_t \in [0, 1]$ is the depreciation rate of the health capital. Assume that the depreciation rate is constant, $d_{t+1} = d_t = d$. For illustrative purposes, we assume that the only uncertainty about an individual's health, ϵ , stems from the uncertainty about the size of the aorta.

The individual's growth of the aorta size is

$$\epsilon_t \geq 0$$

Hence, the individual's aorta size in period $t + T$ is

$$b_{t+T} = \sum_{n=0}^{T-1} (1 - d)^n \epsilon_{t+T-n-1}.$$

However, neither b_t nor ϵ_t are directly observed by the individual. The individual's observable health is, therefore,

$$\tilde{H}_{t+1} = I(\mathbf{S}_t) + (1 - d)\tilde{H}_t.$$

Assume that the individual is aware that he has an uncertainty about his true health (i.e. the aorta size) and that this uncertainty can grow large over time. His belief about his aorta size is \tilde{b}_t .

Individuals maximize utility according to

$$U_t = U(\phi \tilde{H}_t, B_t)$$

where $\phi \in [0, 1]$ and B denotes home goods (enjoyments, pleasures, obligations).

The individual has an option to participate in a screening program which will remove the uncertainty about the health capital, and he will then have knowledge about his true health, i.e. $\tilde{H}_t = H_t$.

Let $a = 1$ if the individual has an AAA and 0 otherwise, and \tilde{a} the individual's belief about his AAA status. An individual is classified as having an AAA if his aorta size b_t is above the cut-off c .

If b_t grows larger than x , the AAA ruptures and the individual dies, but as long as $b_t < x$ the individual is unaware of it since AAA is asymptomatic. In the screening, the treatment cut-off is well below the deadly cut-off, $c \ll x$.

If \tilde{b}_t lies below c but b_t is above c this means that the individual receives a negative information shock, $\tilde{a}_t - a < 0$. If both the belief \tilde{b}_t and b_t is above c the individual receives no information shock ($\tilde{a}_t = a_t$), and if the individuals belief \tilde{b}_t about his aorta size is above c but b_t is below c , the individual receives a positive information shock.

Assume that the individual considers the AAA status as an important part of his unobserved health capital. Most risk averse individuals would then participate in the screening since the potential negative effect of an AAA is severe (deadly).

An individual who receives a negative information shock will get a lower utility, and an individual who receives a positive information shock will get a higher utility. Since b_t is unobserved and AAA is asymptomatic, it is likely that most individuals with AAA underestimate b_t , implying that

$$\tilde{a}_t < a_t \Rightarrow \tilde{H}_t > H_t$$

and, therefore, when the true AAA status, a_t , is revealed, $U_{t+1} < U_t$. Hence, we expect that most individuals who receive information that he has an AAA react negatively on the information of ill-health.⁶

How shall we then interpret the information provided in the actual screening program (see Table 1) in terms of hypotheses generated by the theoretical framework? For the information provided around the 25 mm cut-off we think it is fairly straightforward: since this can be considered as a comparison between one that is given information about being healthy with one that is given information about being less healthy, we would expect to see a negative effect on subjective well-being at the 25 mm cut-off.

However, for the information provided around the 30 mm cut-off, we think it is less clear: since this can be considered as being a comparison between two individuals who receives different information on health and surveillance (one individual is less healthy, but also receives information that he will be under better surveillance), it is not clear whether we should expect a positive or a negative effect at 30 mm. If the health information dominates the surveillance information, we would expect a negative effect at the 30 mm cut-off; if it is the other way around, we would expect a positive effect at the cut-off.

4 Data

To measure the subjective health status of the individuals, we use the three different questionnaires that are provided to the patients: SF-36, EQ-5D-3L and an AAA specific questionnaire developed by Anders Wanhainen (which we call the Wanhainen questionnaire).

These three questionnaires are rich on information on several potential health outcomes. The richness enable us to measure the subjective physical as well as the subjective psychological well-being. The downside of the richness is that it is hard to know on beforehand which of the outcomes that are relevant for the case under study. We proceed by not making a selection of outcome variables ex ante, but rather to let data speak by itself (see further discussion on this in section 6.1).

⁶Individuals who become worried that they have the illness after reading the invitation to the screening are the most likely to participate. Therefore, the invitation to the screening could lower their utility beforehand, and it is not clear whether the original utility level is restored if they are healthier than expected. However, it should be clear that most individuals react negatively to the information of ill-health. Only a few individuals suffer from hypochondria, and even if one does, information of ill-health should lower the utility even further.

As the main measure of physical and psychological well-being we use the Short Form-36 (SF-36) questionnaire (Ware, Kosinski, et al. 2000). SF-36 has repeatedly demonstrated high reliability and validity (Ware and Sherbourne 1992; McHorney, Ware Jr., and Raczek 1993). We construct the two standard summary measures, Physical health and Mental health, and eight suboutcome indexes, as explained in the SF-36 manual.⁷ In all cases, a higher value represents a better health. See Table 2 for the ten outcomes.

To assess health related quality of life, we use EQ-5D-3L (The EuroQol Group 1990). EQ-5D consists of two parts: A self-reported classification on five dimensions of health, and a self-rated global valuation of perceived health using a Visual Analogue Scale (VAS). There is evidence supporting the reliability and validity of the EQ-5D (Brooks and The EuroQol Group 1996). EQ-5D has two outcomes, a summary score measure and the VAS. The score measure is calculated according to the EQ-5D manual.⁸ In both outcomes a higher value represents a better health. See Table 3 for a description.

The Wanhainen questionnaire is a questionnaire created specifically for the AAA screening in Uppsala. It consists of ten questions on a Likert scale from 0 to 10. We have constructed a summary index measure by calculating the average of all questions. We transformed the answers to the questions so that better subjective health (less anxiety, more knowledge etc.) gives a higher value in the index.⁹ For a description of the questions, see Table 4.

We have questionnaires for in total 1,019 individuals between the years 2009-2014.¹⁰ We only use the first set of questionnaires from each individual, i.e., we do not use follow-up questionnaires. We exclude all individuals with ages other than 64-66 and 69-71, i.e., individuals that is not part of the main screening program (see Table 5). We also exclude all individuals in the sample with an aorta size smaller than 20 mm (427 observations) or larger than 34 mm (81 observations). This is due to two reasons. First, we want all individuals in the sample to be roughly comparable to the individuals close the nearest cut-off. A very small aorta is a health risk in itself, which could bias our results. Second, in the screening program there are cut-offs at 40 mm, 45 mm, 50 mm and 55 mm, but there are too few individuals around each cut-off to make estimations meaningful. Some individuals answered the questionnaires after more than four months,

⁷The weights used for the summary measures are calibrated for the US. There are no calibrated measures available for Sweden. However, since we are only interested in comparing individuals in this study with each other and not the absolute levels, this poses no problem for us.

⁸The weights used for the summary measures are calibrated for the GB. See footnote 7.

⁹More specifically, we recoded questions Q1, Q2, Q3, Q4, Q5 and Q10 so that an answer of 0 is 10 and vice versa when calculating the index measure.

¹⁰All 65-year old men in Uppsala County were eligible, and, additionally, from 2011 and onwards, all 70-year old men.

TABLE 2
SF-36 outcomes

Variable	Range	Description
Physical health	0–100	Physical health (summary measure)
Mental health	0–100	Psychological well-being (summary measure)
Physical func	0–100	Physical functioning
Role lim phys	0–100	Role limitations due to physical health
Role lim emo	0–100	Role limitations due to emotional problems
Energy	0–100	Energy/fatigue
Emo well-being	0–100	Emotional well-being
Social func	0–100	Social functioning
Pain	0–100	Pain
General health	0–100	General health

Notes: Higher value represents better health.

TABLE 3
EQ-5D-3L outcomes

Variable	Range	Description
EQ-5D Score	-0.33–1	Score (summary measure)
EQ-5D VAS	0–100	Visual Analogue Scale

Notes: Higher value represents better health.

TABLE 4
Wanhainen questionnaire outcomes

Variable	Range	Description
Wan index	0–10	Wanhainen index (summary measure)
Q1	0–10	<i>“I wonder what caused my AAA”</i>
Q2	0–10	<i>“I feel fear/anxiety about my AAA”</i>
Q3	0–10	<i>“My relatives are concerned about my AAA”</i>
Q4	0–10	<i>“My relatives concern can be troublesome for me”</i>
Q5	0–10	<i>“My relatives sometimes treat me different because of my AAA”</i>
Q6	0–10	<i>“My doctor has informed me sufficiently”</i>
Q7	0–10	<i>“I try to learn more about AAA”</i>
Q8	0–10	<i>“I do not feel ill because of my AAA”</i>
Q9	0–10	<i>“I am glad to learn about having an AAA”</i>
Q10	0–10	<i>“Because of my AAA I have been forced to give up activities”</i>

Notes: The questionnaire consists of ten different statements on a Likert scale. The index variable is constructed so that a higher value represents better health.

or 120 days, and are excluded from the sample (see Table 6 for the cumulative response rate in the sample used).

As is often the case with questionnaires some individuals do not answer all questions. We exclude 12 individuals who did not fully respond to the EQ-5D and the SF-36 questionnaires. There are 15 individuals left who did not fully respond to the Wanhainen questionnaire.¹¹ Since this questionnaire is not our primary outcome, it would be too restrictive to also exclude these individuals.

The final sample consists of 407 males with an aorta size between 20 and 34 mm. 188 observations belong to the healthy group (≤ 24 mm), 163 to the risk zone group and 56 to the small aorta size group (30-34 mm).

From the health related questionnaire we have information about smoking history (all observations) and BMI (390 observations). We use this subsample to check the RD identification assumption.

A histogram of the aorta size of the individuals is shown in Figure 1. The age frequency and the response time for the sample are presented in Table 5 and 6 respectively. Means and standard deviations for each group and variables used are presented in Table 7.

The distribution of the aorta size is not ideal for the RD design, with some spikes in the frequency. This can be due to a couple of reasons. We cannot expect the distribution to be smooth around the 25 mm cut-off since the healthy group consists of only a subsample of the individuals with an aorta size below 25 mm. Therefore, the absolute levels of the number of observations are not comparable around this cut-off. However, we can also expect that the ultrasound technician, who knows about the cut-offs and the error margin of the ultrasound scan, have a tendency to register aorta sizes just below a cut-off as being on or slightly above the cut-off since it is often regarded better to be treated (or “overtreated”) than non-treated. Humans also have a tendency to prefer “anchor numbers” (20, 25, 30, etc.). The RD design demands that the assignment variable, the aorta size, is smooth in the sense that the individuals cannot self-select into being in a specific group. In this case this should not be a problem, since it is the ultrasound technician, not the patient, who makes the decision without the patient’s knowledge. If the ultrasound technician is systematically biased, however, it would still be a violation of the RD assumption. In the sensitivity analyses we will deal with this potential problem by adopting a donut estimator.

¹¹The results does not change in any important sense due to the exclusion/inclusion of these individuals. Only individuals with an aorta size of at least 25 mm answers the Wanhainen questionnaire, so this outcome is measured only for the 30 mm cut-off.

TABLE 5
Age frequency

Age	Frequency	Percent
64	36	8.85
65	231	56.76
66	1	0.25
69	38	9.34
70	100	24.57
71	1	0.25
N	407	

Notes: Frequency of individuals by age.

TABLE 6
Response days

Days	Treatment	Control	All
0	0.00	86.70	40.05
7	0.00	95.21	43.98
14	4.11	98.40	47.67
30	40.64	99.47	67.81
60	83.11	100.00	90.91
90	94.98	100.00	97.30
120	100.00	100.00	100.00

Notes: Cumulative percent of the number of days between screening and questionnaire answers.

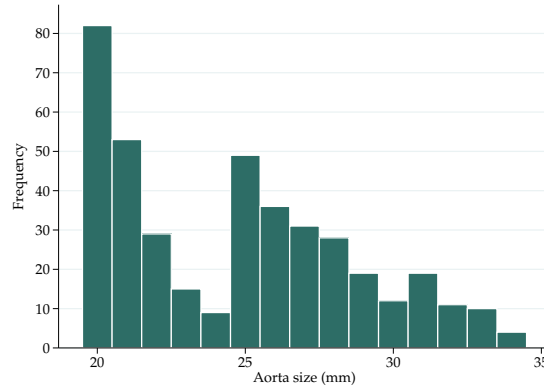


FIGURE 1. Below 25 mm the data consists of a random sample of the healthy individuals, while all individuals with an aorta size of 25 mm or larger are included.

TABLE 7
Descriptive statistics

	20-24 mm		25-29 mm		30-34 mm		All	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Aorta size	21.02	1.16	26.58	1.38	31.55	1.22	24.70	3.97
<i>Covariates:</i>								
Age	66.64	2.42	66.55	2.33	66.09	2.10	66.53	2.34
Height (cm)	180.17	6.54	180.58	6.52	181.61	5.67	180.52	6.43
Weight (kg)	89.69	13.68	88.74	13.14	89.80	11.20	89.33	13.15
BMI	27.70	4.25	27.19	3.64	27.16	3.07	27.43	3.88
Smoking history	0.59	0.49	0.77	0.42	0.88	0.33	0.70	0.46
<i>Aggregated:</i>								
Physical health	50.90	7.92	48.98	9.68	46.95	10.85	49.59	9.17
Mental health	58.02	5.98	55.72	8.00	56.10	9.42	56.84	7.44
EQ-5D Score	0.88	0.17	0.86	0.18	0.81	0.23	0.86	0.18
EQ-5D VAS	84.69	14.01	80.95	16.53	76.84	21.38	82.11	16.40
Wan index	.	.	7.86	1.23	7.73	1.12	7.82	1.20
<i>Disaggregated:</i>								
Physical func	87.68	17.07	83.18	20.75	80.00	24.77	84.82	19.93
Role lim phys	89.89	25.02	81.90	33.02	79.91	36.75	85.32	30.41
Role lim emo	94.50	17.22	88.96	26.20	85.12	32.98	90.99	23.87
Energy	80.29	17.26	72.70	22.09	70.36	25.35	75.88	20.89
Emo well-being	89.32	13.48	84.66	17.00	86.64	17.04	87.09	15.59
Social func	93.22	15.37	90.41	17.98	90.40	15.99	91.71	16.56
Pain	81.54	22.46	79.63	25.29	75.07	28.72	79.88	24.57
General health	79.55	17.14	73.10	20.88	68.51	22.59	75.45	19.88
Q1	.	.	4.15	3.71	5.13	3.73	4.41	3.73
Q2	.	.	2.27	2.75	2.79	2.96	2.41	2.81
Q3	.	.	2.44	2.93	3.45	2.96	2.71	2.97
Q4	.	.	1.41	2.23	1.89	2.56	1.54	2.33
Q5	.	.	0.78	1.68	0.73	1.70	0.77	1.68
Q6	.	.	9.30	1.64	9.65	0.67	9.39	1.45
Q7	.	.	4.82	3.45	5.64	3.13	5.04	3.38
Q8	.	.	7.98	3.72	7.88	3.76	7.95	3.72
Q9	.	.	8.35	3.06	8.58	2.90	8.41	3.01
Q10	.	.	0.57	1.52	0.53	1.53	0.56	1.52
<i>N</i>	188		163		56		407	

Notes: Individuals with an aorta size less than 25 mm do not answer the Wanhainen questionnaire. There are missing data for BMI, smoking history and the Wanhainen questionnaire for some individuals.

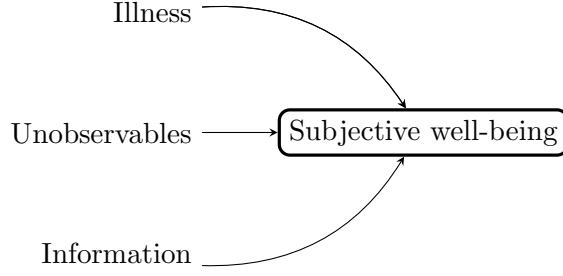


FIGURE 2. AAA is an asymptomatic illness and will not affect well-being, but unobservable background characteristics and the information of having the illness may.

5 Empirical strategy

We apply the quasi-experimental regression discontinuity (RD) design. An RD design may be appropriate when we want to estimate a causal effect of a treatment, but randomization of the individuals by the researcher for some reason is unfeasible or not appropriate. If there is a rule which decide whether an individual is treated or not this could create discontinuities which RD can exploit (Angrist and Pischke 2009; Lee and Lemieux 2010).

The ideal experiment would be to randomize the individuals into different groups and give them different information about their health regarding AAA. Due to the randomization, the groups can be regarded as equal in unobservable characteristics that otherwise could bias the estimated effect of the treatment. A randomization of the individuals would therefore allow a causal interpretation of the information effect. The identification problem is illustrated in Figure 2.

However, in this case there has been no opportunity to randomize the individuals. Even if it had been possible it could be argued that it is unethical to randomize the individuals into groups which are given different information about an illness that is potentially fatal. Instead, we exploit the use of fixed boundaries in the screening program that determine the information the individuals are given.

By applying the RD design we compare individuals in the sample just below and just above the boundary for a treatment, the so called cut-off point. In this context this specific strategy is called local linear regression.¹² For example, we can compare

¹²Another commonly used strategy in the RD context is to use higher order polynomials, which try to mimic the data when moving away from the cut-off. However, the drawback is that we then have to rely on points far away from the cut-off when estimating the causal effect of the treatment, and therefore we will not use this strategy here.

TABLE 8
Group comparisons

Information	Surveillance	Size	Size	Information	Surveillance
Healthy	None.	20-24	vs 25-29	Risk zone	Five years.
Risk zone	Five years.	25-29	vs 30-34	Small AAA	Two years.

Notes: The respective groups that will be compared, and the information and surveillance each group receives from the screening. Surveillance consists of a follow-up screening at the specified time. Size in millimeters (mm).

the individuals with a maximum infrarenal aortic diameter of 24 mm, who receive the information that he is healthy regarding AAA, with individuals with a diameter of 25 mm, who receive information that he is in the risk zone for AAA. Since the difference in diameter is so small and the choice of 25 mm as a cut-off is somewhat arbitrary, a group of individuals with 24 mm can be assumed being equal or very similar to a group of individuals with a diameter of 25 mm concerning both observable and unobservable characteristics, with the single exception of the treatment (i.e. the information given). Hence, the RD design will estimate the causal effect of the health information.

The RD design allows for the use of a larger bandwidth if we are willing to assume that the larger difference in aorta size is not important. It is also possible to use more than one cut-off point in the estimation. We use the two lower cut-off points used in the screening program as discussed earlier. The relevant group comparisons and the respective information to the individuals are presented in Table 8. We will use a bandwidth of 5 mm and estimate both the 25 mm cut-off and the 30 mm cut-off in the same equation.¹³

The group with a diameter of 20-24 mm is healthy, and receives no treatment in the screening program. The healthy group will be compared with the group with a diameter of 25-29 mm, who are considered to be in the risk zone for AAA, and will have surveillance follow-up in five years and receives information about this. This will allow an estimation of the effect of the information of being in the risk zone for AAA with a sparse surveillance compared to information about being healthy. The risk zone group will then be compared with the group with a diameter of 30-34 mm. These two groups differ in the way that the latter group receives the information that they have a small AAA and a more frequent surveillance (follow-up in two years). Hence, this will allow an estimation of the effect of information of having a small sized AAA and receive

¹³The point estimates are the same and the standard errors only insignificantly affected compared with single cut-off estimations.

an increased surveillance compared to information of being in the risk zone and sparse surveillance.

While the healthy group will function only as a control group and the small sized AAA group only will function as a treatment group, the risk zone group will function both as a control group and a treatment group, depending on comparison at hand.

The equation to be estimated is given by the following two cut-off RD specification:

$$\begin{aligned} health_i = & \tau_1 I(X_i \geq 25) + \beta_1 [(X_i - 25) * I(X_i \geq 25)] + \\ & \tau_2 I(X_i \geq 30) + \beta_2 [(X_i - 30) * I(X_i \geq 30)] + \\ & \delta X_i + \alpha + \epsilon_i \end{aligned} \tag{1}$$

where X_i is the aorta diameter size in mm, $(X_i - 25)$ and $(X_i - 30)$ are the distances in millimeters from the respective cut-off, and

$$I(X_i \geq 25) = \begin{cases} 1 & \text{if } X_i \geq 25 \text{ mm} \\ 0 & \text{otherwise,} \end{cases} \quad I(X_i \geq 30) = \begin{cases} 1 & \text{if } X_i \geq 30 \text{ mm} \\ 0 & \text{otherwise.} \end{cases}$$

The coefficients of interest are τ_1 and τ_2 , which show the jump in health outcomes at the respective cut-off. The interaction terms allow the slopes to be different before and after the cut-offs.

When the assignment variable is discrete one must rely on an extrapolation of the data at the cut-off point. Lee and Card (2008) recommends clustering of the data on the discrete variable. However, since we would have too few clusters (15), clustered standard errors are unreliable (Angrist and Pischke 2009). Instead, we rely on robust standard errors in our regressions (Wooldridge 2010; Fredriksson and Öckert 2013). The robust standard errors are sometimes larger and sometimes smaller than the clustered standard errors.

6 Baseline results

In this section we present the main results. We do this in two ways; first we provide a graphical presentation of the baseline results in section 6.1, and then we turn to the regression analysis in section 6.2. Sensitivity and robustness analyses are provided in section 7.

6.1 Graphical analyses

We start the graphical analyses with the aggregated measures of the individual’s subjective health. Beginning with the two measures from the EQ-5D questionnaire, we find no jumps at the cut-offs (cf. Figures 3a and 3b). There is, however, indication of a broken trend at the 25 mm cut-off, but the binned values are quite scattered and do not lie closely connected to the regression lines. It seems difficult to draw any clear conclusion from the observed pattern.

Turning to the two aggregate measures of the SF-36 questionnaire, the general pattern seems to be the same as for the EQ-5D measures for physical health (cf. Figure 3c). There is an indication of a positive jump at 30 mm for psychological well-being (c.f. Figure 3d), but nothing at 25 mm. The bins are much less scattered and are relatively tight around the regression lines compared with the EQ-5D measures.

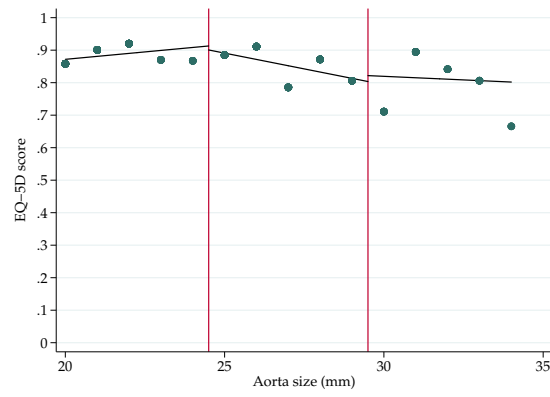
The Wanhainen index (c.f. Figure 3e) does not deviate from the above pattern. The observations are relatively close to the regression lines, with some indication of a positive jump at the 30 mm cut-off.¹⁴

So far we have had a look at the more aggregated measures of subjective health. These measures can, however, hide important variation over the more disaggregated and specific measures of health. We now turn to look separately at the eight different measures within the SF-36 questionnaire.

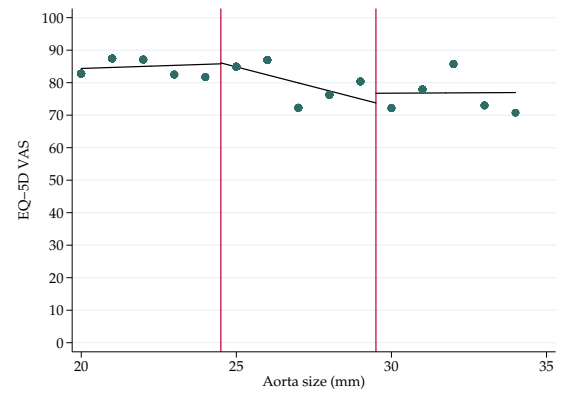
It is clear from Figures 4a-h that we observe the same general pattern for all disaggregated outcomes as for the aggregated measures; that is, no effect at 25 mm and possibly a positive effect at 30 mm. The magnitude of the effects, and the pattern of the binned data, are clearer in some cases, such as for emotional well-being (cf. Figure 4e) and social functioning (c.f. Figure 4f).

To conclude, the overall pattern observed in the graphical analyses is that, if there is an effect, it seems to be positive at the 30 mm cut-off. No effect at the 25 mm cut-off can be seen. However, from an RD analysis point of view, it is difficult to see how a trustworthy analysis can be made and trustworthy conclusions can be drawn for some of the outcomes due to the scattered pattern of the binned data. For the outcomes where we observe a more stable pattern of the binned data (i.e., physical health, mental health, the Wanhainen index, emotional well-being, and social functioning), we will turn to more formal estimations of the potential effects, to examine the significance both statistically

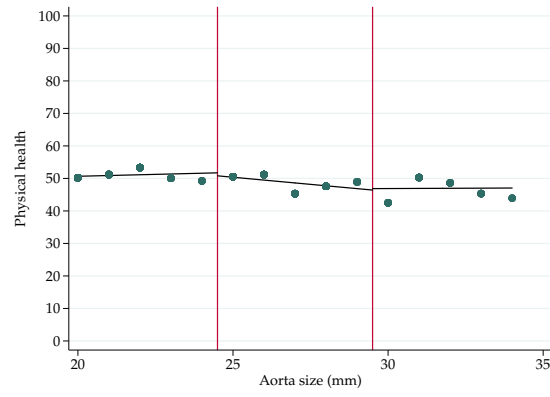
¹⁴There are no measures for those with an aorta size below 25 mm since the healthy group does not answer the AAA-specific questionnaire.



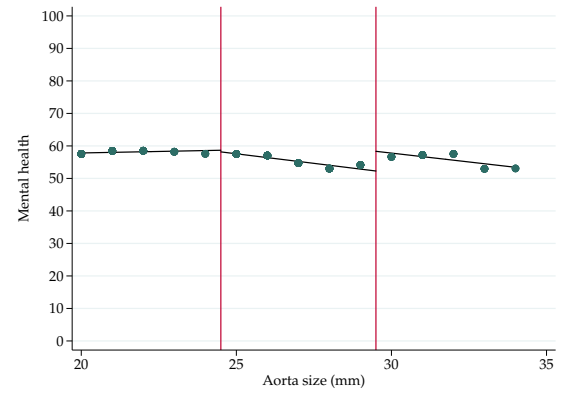
(a) EQ-5D Score



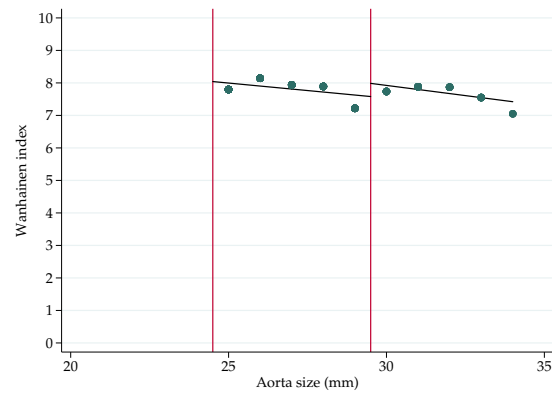
(b) EQ-5D VAS



(c) SF-36: Physical health

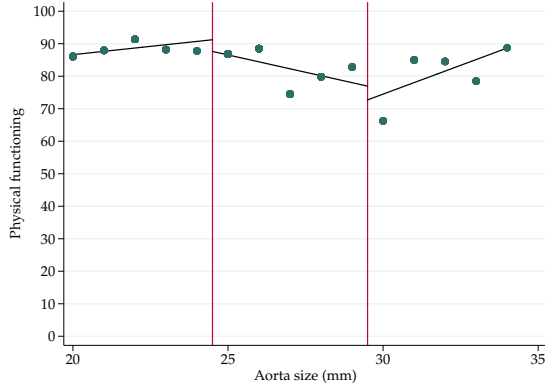


(d) SF-36: Mental health

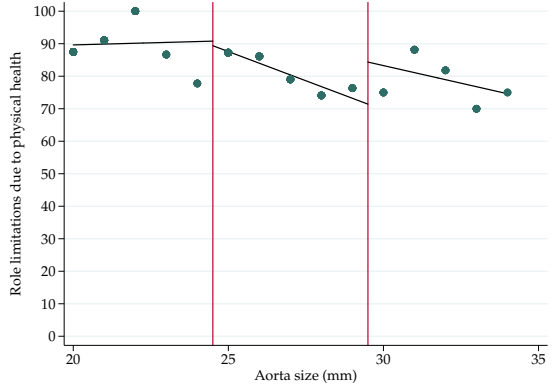


(e) Wanhainen index

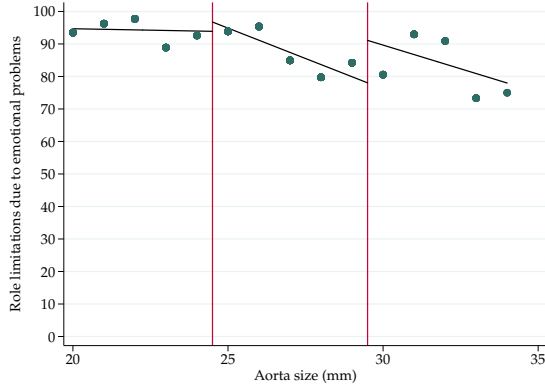
FIGURE 3. Aggregate health outcomes.



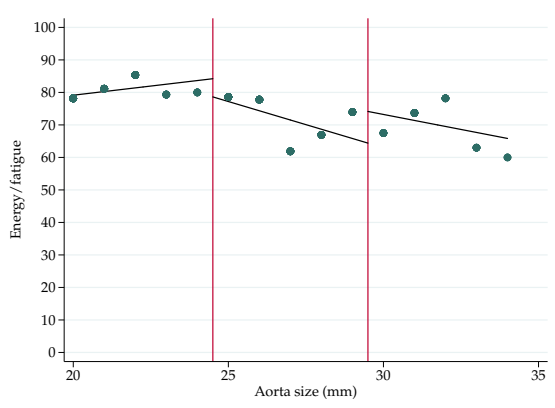
(a) SF-36: Physical functioning



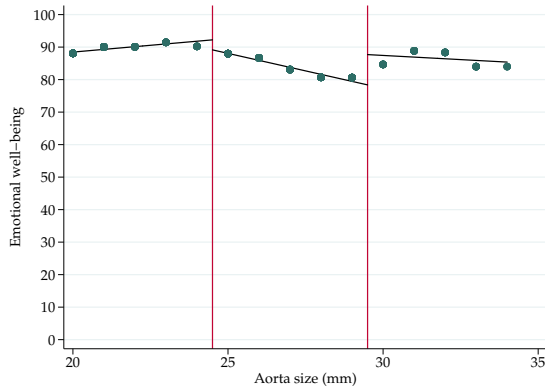
(b) SF-36: Role lim. due to physical health



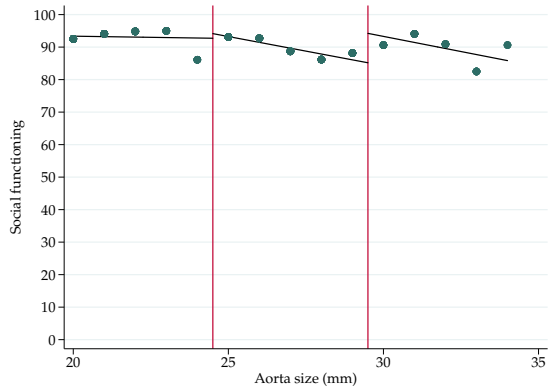
(c) SF-36: Role lim. due to emotional problems



(d) SF-36: Energy/fatigue



(e) SF-36: Emotional well-being



(f) SF-36: Social functioning

Continued on the next page.

FIGURE 4. Disaggregate health outcomes.

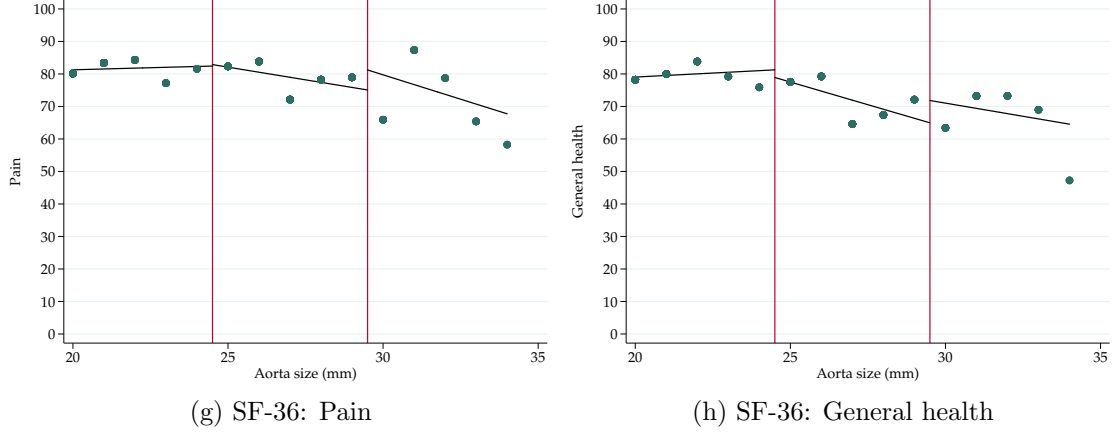


FIGURE 4 (CONT.). Disaggregate health outcomes.

and clinically (i.e. the magnitude of the effects).¹⁵ It is worth noting that the stable patterns observed are mainly on outcomes measuring psychological well-being.

6.2 Baseline estimations

We use the full aorta size interval of 20-34 mm, hence, the two cut-offs simultaneously, and estimate the effects of new health information on the individuals' subjective well-being (as expressed in terms of physical health, mental health, the Wanhainen index, emotional well-being, and social functioning). The RD estimates, obtained from estimation of Equation 1, are provided in Table 9.

The signs of the point estimates follow the pattern observed in the graphical analyses; negative at the 25 mm cut-off (social functioning positive but close to zero) and positive at the 30 mm cut-off. None of the estimates at 25 mm are statistically significant, and are clinically relatively small. However, three of the estimates at the 30 mm cut-off are statistically significant, and arguably clinically significant.¹⁶

7 Sensitivity analyses

A crucial assumption in the RD design is that nothing else changes at the cut-off, i.e. that the observations around the cut-offs are equal in all other characteristics other than the treatment, so that we can consider the treatment as good as randomized. If this is

¹⁵RD estimates for the other outcomes are presented in the appendix.

¹⁶In addition to the multiple cut-off estimations, we have also estimated the two cut-offs separately (for the sample in the interval 20-34 mm with varying bandwidth), but find few statistically significant effects. These additional results are available upon request.

TABLE 9
RD analysis

	Aggregated			Disaggregated	
	Physical health	Mental health	Wan index	Emo well-being	Social func
25 mm	-1.471 (2.437)	-1.182 (1.688)		-4.574 (3.470)	0.594 (5.546)
30 mm	0.902 (3.152)	6.103** (2.777)	0.370 (0.368)	10.140* (5.312)	9.012* (4.958)
Mean	49.589	56.836	7.821	87.086	91.708
<i>N</i>	407	407	204	407	407

Notes: Individuals with an aorta size of 20-34 mm. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

not the case, for example, if the ultrasound technician’s decision of the aorta size is a function of the individual’s background characteristics (like weight or smoking history), and these covariates in turn affect the well-being of an individual, the estimations would be biased.

In this section we will examine if our baseline results are sensitive to potential bunching. To do this, we will use two different sensitivity and robustness analyses. We start out by using covariates as outcomes in the estimations in section 7.1, followed by conducting donut estimations in section 7.2. In the appendix, we provide two additional sensitivity analyses. First, we redo the estimations in section 7.1 using a donut estimator, and second, we redo the main analysis but include the covariates in the estimations.

7.1 Estimations with covariates as outcomes

One way to check if the assumption of treatment assignment being as good as random is fulfilled is to use covariates as the outcome variable instead of the health measures of interest (Lee and Lemieux 2010). If the individuals are as good as randomized, the groups below and above the cut-offs should be balanced, i.e., there should not be any statistically significant effects in the estimations. We have data for five different covariates for a subsample of our sample: Age, smoking history, height, weight and BMI.¹⁷

¹⁷Age is a dummy variable which takes the value 0 if the individual is between 64-66, and 1 if the individual is between 69-71, c.f. Table 5.

TABLE 10
RD analysis with covariates as outcomes

	Age dummy	Smoking history	BMI	Height	Weight
25 mm	-0.091 (0.140)	0.009 (0.129)	1.123 (1.110)	-0.667 (1.818)	3.138 (3.683)
30 mm	0.017 (0.150)	0.083 (0.129)	1.980* (1.136)	-0.575 (2.007)	5.828 (3.905)
Mean	0.344	0.692	27.432	180.490	89.327
<i>N</i>	390	390	390	390	390

Notes: Individuals with an aorta size of 20-34 mm, with information on both BMI and smoking. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results, presented in Table 10, are fairly reassuring. Four of the outcomes (age, smoking history, height, and weight) have no statistically significant changes at the cut-off points. Only for the one remaining outcome variable, BMI, there is one marginally statistically significant change (a positive jump at the 30 mm cut-off), and one insignificant change.

The results in Table 10 looks fairly good overall and indicate that the baseline results are reliable. It is a bit troublesome to get a significant estimate when using covariates as outcomes, but in the end, what matters is to what extent the estimates are sensitive to this. In the appendix we examine how sensitive the baseline estimates are to the inclusion of the covariates.

7.2 Donut estimations

Figure 1 suggests that some individuals just around the cut-offs may be incorrectly registered since there is some indication of bunching to the right of the cut-offs. Bunching violates the assumption of the treatment assignment being as good as random. One reason for the tendency to bunching could be that the ultrasound technician must make a decision whether the aorta size of an individual is below or above the cut-off, and that it is usually regarded as better to be “overtreated” than “undertreated”. If the registration of the aorta size is correlated with characteristics of the patients that might affect their subjective well-being, like weight, this might bias our results.

One way of dealing with the potential problem of sorting at the cut-offs is to estimate a “donut version” of the RD design (Barreca et al. 2011), dropping all observations just around the cut-offs – observations that may be wrong – and only use observations farther

TABLE 11
RD donut analysis

	Aggregated			Disaggregated	
	Physical health	Mental health	Wan index	Emo well-being	Social func
25 mm	-1.661 (3.535)	-0.522 (2.727)		-4.330 (6.049)	-1.820 (6.528)
30 mm	10.471* (5.646)	10.480** (4.399)	0.564 (0.638)	16.594* (9.329)	17.526* (9.022)
Mean	49.765	56.873	7.908	87.333	91.903
<i>N</i>	318	318	133	318	318

Notes: Individuals with an aorta size of 20-34 mm except 24-25 mm and 29-30 mm. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

away from the cut-off, leaving a “donut hole”. Therefore, we proceed with estimating the baseline regressions but drop individuals with 24-25 or 29-30 mm aorta size. We estimate the same outcomes as in the baseline regressions.

The results are presented in Table 11. The effects estimated in the baseline regressions are stable. At the 30 mm cut-off, four of five outcomes are statistically significant (if only marginally) compared with three in the baseline estimation, and the effects are clinically larger. There is no statistically significant effect at the 25 mm cut-off. Overall, the donut estimations indicate that the baseline results are reliable and relatively robust.

8 Discussion of the results

Looking at the general pattern; the results presented in the graphical analysis, the baseline analysis, and the sensitivity analysis, indicate that the effects of the information given in the screening might go in two different directions. At the low cut-off point at 25 mm, if anything, the effects seem to be negative (i.e., the individuals react negatively on the information), and at the cut-off point at 30 mm, the effects seem to be positive.

However, from a statistical point of view, all the action seem to be at the 30 mm cut-off. There are no significant effects at the 25 mm cut-off regardless of specification. In comparison, the estimated positive effects at the 30 mm cut-off are robust to different sensitivity analyses. This leads us to the conclusion that the differential information given to the patients around the 30 mm cut-off seem to have an effect on the patients’

subjective psychological well-being, while the differential information given at the 25 mm cut-off has not.

Are the magnitudes of the estimated positive effects at the 30 mm cut-off of any importance? To get a sense of that, we relate the statistically significant point estimates in the baseline analyses to the mean value of each outcome variable.¹⁸ In doing this, it seems like the magnitude of the estimated effects are of clinical importance. Taking mental health as an example, the point estimate (6.10) constitute almost 11 % of the overall mean of 56.84 (see the next to last column in Table 7). The corresponding figures for the other significant point estimates are both about 10 % (emotional well-being and social functioning).¹⁹

How can we understand the estimated positive effect on the patients' subjective well-being after receiving information about ill-health? The theoretical model suggest that an individual who receives information that he has an AAA (i.e., unexpected information about ill-health) would experience a decrease in his subjective well-being. However, the discussion in section 3 also suggest that it is unclear how to interpret the information provided around the 30 mm cut-off; the patient just above 30 mm receives information that he is less healthy, but also receives information that he will be under better surveillance. Our interpretation of the positive point estimate at 30 mm is that the information of better surveillance by the health care system (a positive effect on subjective well-being) outweighs the information of being less healthy (a negative effect on subjective well-being).

Finally, it can be informative to relate the RD results obtained in this paper differ from the results we would have found had we conducted a traditional OLS analysis, similar to the type of analysis conducted earlier in the literature, e.g. Lindholt, Vammen, et al. (2000) and Spencer et al. (2004). Applying a more naïve estimation strategy, we estimate an OLS model which only include dummy variables for whether the individual has an aorta size above each respective cut-off. Comparing the OLS estimates in Table 12 with the baseline RD estimates, it is clear that the OLS results overstate the negative importance at the 25 mm cut-off in terms of statistical significance, and miss the positive effect at 30 mm. In fact, none of the estimates at the 30 mm cut-off are statistically significant. The *negative* point estimates at 30 mm provided by the OLS estimator is hard to believe given the pattern observed in the figures presented earlier.

¹⁸The point estimates in the baseline analyses are more conservative than the point estimates obtained when applying the donut estimator.

¹⁹If we relate the point estimates to the mean for the individuals in the 25-29 mm or 30-34 mm intervals, we get very similar order of magnitudes.

TABLE 12
Mean comparison

	Aggregated			Disaggregated	
	Physical health	Mental health	Wan index	Emo well-being	Social func
25 mm	-1.921** (0.954)	-2.306*** (0.764)		-4.657*** (1.656)	-2.804 (1.801)
30 mm	-2.029 (1.629)	0.380 (1.401)	-0.127 (0.181)	1.980 (2.628)	-0.012 (2.550)
Mean	49.589	56.836	7.821	87.086	91.708
<i>N</i>	407	407	204	407	407

Notes: Individuals with an aorta size of 20-34 mm. Mean comparison around cut-offs. Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

9 Conclusions

In this paper we have examined how new health information affects individuals' subjective physical and psychological well-being.

To solve the endogeneity problem, we apply a regression discontinuity estimator on data from a screening program for the asymptomatic disease AAA in Sweden. Since screened individuals receive different information about their health, as a function of the measured size of their aorta and its relation to pre-determined cut-off levels, we are able to estimate causal effects.

We find a robust and positive significant effect on the individuals' subjective psychological well-being when comparing those that receive information that they have a small AAA, and therefore will be under increased surveillance by the health care system, with those who receive the information that they have an enlarged aorta and increased risk for AAA, but only sparse surveillance by the health care system. This indicates that the information about increased surveillance (positive information) outweighs the information about worse health (negative information). The magnitudes of the estimated effects also indicate that they are clinically important.

We do not find any statistically significant *negative* effects of the information about ill-health on the individuals' subjective well-being.

The positive effects on subjective well-being indicate that the benefit side in a traditional cost-benefit analysis of the AAA screening program would gain more than the cost side if the patients' subjective well-being were taken into account.

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A Appendix

The appendix consists of two parts. In section A.1 the estimates for the outcomes not included in the main analysis are presented. In section A.2 we provide two additional sensitivity analyses.

A.1 Other outcomes

In Table A1 the estimates for the outcomes which were not included in the main analysis are presented. As the figures in section 6.1 suggest, the estimates are more noisy. There is no statistically significant result. However, it should be noted that the direction of the point estimates in general are in line with the outcomes in the main analysis.

TABLE A1
RD analysis

	Aggregated		Disaggregated					
	EQ-5D Score	EQ-5D VAS	Physical func	Role lim phys	Role lim emo	Energy	Emo well-being	Social func
25 mm	-0.027 (0.048)	-1.111 (4.580)	-5.176 (4.412)	-3.336 (8.477)	1.081 (5.794)	-7.575 (4.955)	-0.464 (6.327)	-3.996 (5.485)
30 mm	0.026 (0.063)	4.225 (5.510)	-1.392 (7.791)	13.655 (10.910)	13.478 (9.623)	10.243 (7.060)	5.437 (8.572)	7.458 (6.534)
Mean	0.863	82.113	84.819	85.319	90.991	75.885	79.882	75.448
<i>N</i>	407	407	407	407	407	407	407	407

Notes: Individuals with an aorta size of 20-34 mm. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A.2 Additional sensitivity analyses

In Table A2 we redo the sensitivity analysis in section 7.1 but use the donut estimator. The results are fairly similar to those in Table 10, but with no statistically significant estimate, indicating that the donut estimator can be used if we are willing to assume that the individuals farther away from the cut-off are as good as randomly assigned.

Finally, we redo the main analysis but include age, BMI and smoking history as covariates. In the ideal case, inclusion of covariates should not affect the point estimates since the covariates are (assumed to be) independent of the treatment. In practice, however, inclusion of covariates can improve the precision, reduce small sample bias and reduce biases when observations further away from the cut-off are included (Imbens and Lemieux 2008; Lee and Lemieux 2010). Since we are only able to do these estimations on a subsample (due to missing data on some of the covariates), the results are not fully comparable with the baseline estimations presented in Table 9.²⁰

Comparing the results with the main analysis, it is clear that we get similar results. The same outcomes at the same cut-off are significant whether we control for covariates or not. In addition, the significant coefficients are very similar. These results indicate, first, that the baseline results are not sensitive to the inclusion of covariates, and, second, that the significant estimate for BMI that we found in the sensitivity analysis is not of qualitative importance for the conclusions since the estimates in general are much the same.

²⁰However, the estimates are close to what we get if we exclude individuals with missing data in the main analysis.

TABLE A2
RD donut analysis with covariates as outcomes

	Age	Smoking history	BMI	Height	Weight
25 mm	-0.038 (0.203)	0.060 (0.185)	0.729 (1.480)	1.424 (2.691)	4.615 (5.612)
30 mm	-0.061 (0.253)	0.052 (0.192)	0.852 (1.938)	1.685 (3.294)	5.353 (7.093)
Mean	0.352	0.681	27.457	180.570	89.530
<i>N</i>	307	307	307	307	307

Notes: Individuals with an aorta size of 20-34 mm except 24-25 mm and 29-30 mm, with information on both BMI and smoking history. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE A3
RD analysis with covariates

	Aggregated			Disaggregated	
	Physical health	Mental health	Wan index	Emo well-being	Social func
25 mm	-0.406 (2.218)	-1.024 (1.658)		-4.040 (3.417)	1.684 (5.522)
30 mm	3.415 (3.283)	6.092** (3.047)	0.452 (0.398)	10.180* (5.786)	10.115* (5.277)
Mean	49.806	56.840	7.847	87.108	92.083
<i>N</i>	390	390	189	390	390

Notes: Individuals with an aorta size of 20-34 mm. Using age, BMI and smoking history as covariates. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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