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Early diagnosis of chronic conditions and lifestyle modification

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Early diagnosis of chronic conditions and lifestyle modification*

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Abstract

This study estimates the potential impact of early diagnosis programmes on medication, subjective health and lifestyle. To deal with potential selection bias due to screening, I employ a feature of the *English Longitudinal Study of Ageing* that motivates a regression discontinuity design based on respondents' blood pressure. If their measurements are above a threshold, individuals are advised to visit their family doctor to check for high blood pressure. There is evidence of a temporal increase in use of medication for treating the condition (6.6 percentage points), which almost doubled in the proportion of people taking medication for such blood pressure levels. At the same time, there is a permanent reduction of the probability of consuming alcohol twice a week (10 percentage points) and an increase in fruits consumption. However, there is also evidence of higher smoking frequency (eight cigarettes per week) in those above the threshold. Such lifestyle responses are not related to extra medication. However, no clear effects on either objective or subjective health were found after 4 years of intervention.

Keywords: Hypertension; Biomarkers; Health behaviours; Health investment; Prevention

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1 Introduction

The rise in public expenditure associated with ageing population partly owes to diseases that may be prevented or delayed by modifying people's habits. One potential solution is a preventive strategy based on early treatment of individuals at risk of potential complications. This idea motivates the strategy of periodical health checks for the general population. Large-scale programmes such as the NHS (National Health Service) Health Checks in the United Kingdom, and some preventive care components of the Affordable Care Act in the United States, point in that direction. For instance, the former invites people aged 35-74 for routine health check-ups aimed at detecting signs of chronic conditions such as cardiovascular diseases (CVDs). However, some authors such as MacAuley (2012) consider the impact of such policies may even have a negative impact because of misallocation of resources, over-diagnosis of certain conditions, and behavioural effects.

An initial question about these programmes regards their potential for inducing changes on demand for health care. A review by Krogsbøll et al. (2012) found that these types of programmes generally increased the number of individuals using anti-hypertensive drugs, but did not yield conclusive effects on health benefits. Specifically for the United Kingdom, there is no evidence thus far on the benefits of the NHS Health Checks programme. Some studies such as Artac et al. (2013) and Cochrane et al. (2012) provide descriptive evidence of the potential problems and benefits of this intervention. Robson et al. (2016) suggest that NHS Health Checks is related to an increase in the attendance to general practitioners (GP) practices of individuals in risk of developing CVDs. They observe increased prescription of medication for controlling high blood pressure (HBP) and lowering cholesterol.

Second, there is a particular concern about the effects of periodical health checks on risky behaviours. Evidence exists that individuals may be sensible in terms of information related to their own health, consistent with the idea of rational addiction (Arcidiacono et al., 2007). Moreover, smokers tend to be optimistic about their own mortality (Khwaja et al., 2007), and updated their mortality beliefs at the onset of diagnosis of smoking-related diseases (Smith et al., 2001). However, treatment for mild conditions detected in the checks may induce risk compensating/offsetting behaviours. In other words, individuals could increase their risky behaviour in response to improved prospects of future health owing to medical treatment, or to reassurance when they receive positive news. This is a common concern in areas such as unsafe sexual activity and HIV treatment (Cassell et al., 2006). To understand this potential side-effect, it is necessary to analyse whether medical treatment and health behaviours are complements or substitutes in the context of a competing risks model. Theory suggests complementarities between health investments as reducing one of the risks increases the marginal benefit of reducing the others (Becker, 2007). However, if medical treatment offsets lifestyle gains in reducing a disease-specific risk, a substitution effect may dominate (Kaestner et al., 2014). So far Kahn (1999) found that diabetics lifestyle improved over time without signs of medication, Fichera and Sutton (2011), in an English study, suggest statins were associated with lowering cholesterol and with reductions in smoking. However, Kaestner et al. (2014) found an increase in obesity in response to statins use and no effect on smoking.

This paper contributes to both the understanding of health advice effects and the analysis of complementarity or substitution between medical treatment and health behaviours. First, I identify the medium- and long-term impact of informing individuals of their odds of being hypertensive, a condition that may increase the likelihood of developing CVDs. Second, given this evidence, I test whether individuals modify their lifestyle and beliefs about their current and future health status in response to medical intervention.

My identification strategy to estimate the causal effect of receiving medical advice relies on the protocols of the English Longitudinal Study of Aging (ELSA) and the Health Survey of England (HSE). Over the course of the survey, a nurse records the BP of interviewees. As per ELSA, those with a systolic/diastolic reading $\geq$ 149/85 mmHg are encouraged to visit their family doctor for a proper screening test to confirm the findings. A similar procedure is in place in the HSE with a 160/95 threshold for men aged $\geq$ 50 years. As a result, we can compare individuals aged $\geq$50 years, not previously diagnosed with HBP, and who are very similar in health status but differ only in having being advised, or not, to visit primary care services. This motivates a regression discontinuity design (RDD) that identifies the impact for individuals who are close to the advice thresholds but who have not previously been diagnosed with any cardiovascular conditions.

A significant increase, of 6.6 percentage points, in the use of BP-lowering medication was found around to years after the intervention for those with systolic BP slightly above the advice threshold compared with those below it. It is almost three fold the proportion of individuals who are under such medication at this BP level. After two waves of the survey (approximately 4 years), the difference does not statistically differ from zero. This is in line with previous findings in the literature on health checks, which found an increase in medication use. Additionally, the advice caused a permanent decrease of 10 percentage points in the probability of consuming alcohol twice a week. However, there is also evidence of an increase in self-reported smoking intensity of eight cigarettes per week. The results of this paper contrast those of Kaestner et al. (2014); in the present study there is no systematic improvement or deterioration of lifestyle with respect to medication use.

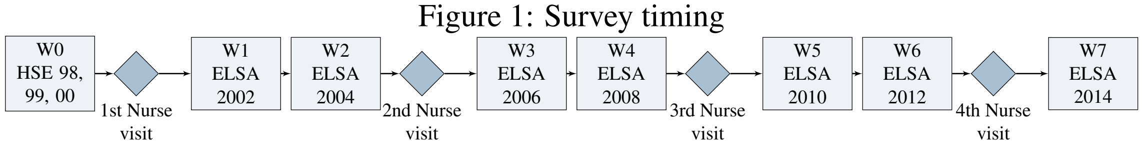
Results suggest this type of information-based intervention may strongly impact demand for preventive care treatments, along with permanent positive effects on behaviour. Moreover, the impacts are stronger on men and on individuals with low risk of developing CVDs, showing that the policy may be effective for targeting this specific population.

The rest of this paper is organized as follows. Section 2 presents the main details of the dataset and the sample employed, and explains the health advice procedure implemented by the survey nurses. Section 3 discusses the empirical strategy and section 4 the main findings. Finally, section 4.5 concludes the paper.

2 Data

I use ELSA (Marmot et al., 2013) for the years 2002-2014. This is a longitudinal study with a representative sample of those aged ≥50 years in England. Its baseline was constructed using the HSE (NatCen and UCL, 2010) and it contains high-quality subjective and objective health information and detailed socio-economic information.[1]

Figure 1: Survey timing



Notes: The *English Longitudinal Study of Ageing* is based on the original sample from the *Health Survey for England*.

Additional to the core interview, I use the biomarkers data collected in waves 0, 2, 4 and 6 (see Figure 1). All core individuals[2] who had an in-person interview were eligible for the BP measurements, and depending on their health, for other measures.[3] After completing the questionnaire, respondents were asked for their approval for a nurse to visit them[4] in the

[1]More details can be found on the survey website:http://www.ifs.org.uk/ELSA/about

[2]ELSA collected information about partners, even if they were not part of the original HSE sample. These 'new' partners were not eligible for biomarkers measurements.

[3]For example, for blood samples, eligibility depended on not suffering from a condition or being under a medication that suggests the test may compromise respondent's health.

[4]They are professional nurses trained by the researchers to take the measures following a strict protocol.

following weeks. If they consented, an appointment was made for between 2 and 4 weeks after the interview. Diastolic and systolic BP were derived by taking into account the last two of three measurements,[5] using an automated monitor under standardized conditions.[6]

As cooperation is a choice, the observed sample may be affected by selection. In particular, there is evidence suggesting respondents are usually more likely to be worried about their health and to engage in practices for preserving it (Guyer et al., 2010).

2.1 Descriptive information

This exercise considers only individuals for whom there are at least three valid BP measurements in at least one of the waves. Table 1 presents the descriptive information of this sample for each wave. In general, from Panel A, the sample is ageing during the observed time despite the refreshment samples that have been added since wave 3.[7] Though younger cohorts are more educated, the levels of education are represented in similar proportions across time as are other characteristics such as ethnicity, sex and marital status.

Panel B presents the evolution of self-reported health conditions. As the sample ages, the prevalence of most diseases increases. The opposite occurs for lifestyle as observed in Panel C. There is a declining trend in the prevalence of smoking[8] (both in the extensive and intensive margins) and alcohol intake.[9] Such a trend is unclear in the case of physical

[5]The protocol discards the first measurement to minimize the likelihood of so-called *white coat syndrome*; essentially, that anxiety and stress impelled by clinical settings temporally increases blood pressure but without association with cardiovascular risk (Pickering, 1996).

[6]People were asked to sit quietly 5 minutes before the measurement. Nurses were also instructed to delay the start of the measurements until at least half an hour after their arrival. Other conditions that might be relevant, such as ambient air temperature, was recorded. If the respondent had eaten, drunk, smoked or exercised in the last half an hour, his answers would be invalid.

[7]HSE 2002-2006 data are not used in some of the specifications because of the lack of information on hypertensive status.

[8]In ELSA, individuals are asked about smoking as part of the health module. If they report they are currently smoking, they are asked whether they use cigarettes and/or roll-ups (hand-rolled cigarettes from loose-leaf tobacco). In both cases, they are asked about their consumption on weekdays and weekends separately: number of cigarettes and/or grams/ounces of tobacco. Around 23% of smokers report to be roll-up consumers only, and I assumed one gram to be equivalent to one cigarette, and one ounce to be 28.35 cigarettes. The top 1% of these measures are excluded as they seem to be outliers. One important concern is variation on prices: Leicester and Levell (2012) and Czubek and Johal (2010) give a good description of the evolution of real prices and consumption trends during the period. Relevant actions were taken in 1998 when the NHS quit was implemented, and in 2007, when bans on smoking in public spaces were put in place.

[9]ELSA questions on alcohol intake are part of a self-completion module, and they vary from wave to wave. The present classification seeks to capture the available information in a way that is comparable across waves.

activity.[10] Two final measures on vegetable and fruit intake are included in ELSA as shown in the table, there is a substantial difference on how they were measured after wave 5.[11] Such discrepancies are not problematic for estimation of the sign of the impacts, as this compares variations within waves. However, the interpretation of the magnitudes is difficult, as the estimates mix both types of measures.

Panels D and E present subjective and objective measures of health. Evolution of objective health measures is not homogeneous. Some deteriorate over time: individuals get heavier (seen in body mass index [BMI] and obesity), with higher levels of cholesterol; but their BP decreases at the same time. First, binary variables for reporting to be in good and bad health are derived from a standard Likert-type scale of questioning for self-rated health. ELSA also involves subjective probabilities on the chances to live beyond age 75; and the chances of suffering an event that limits one's ability to work. The former question is asked to individuals aged $\leq$58 years, and the latter only to those currently working. Interestingly, despite an increasing proportion of individuals being diagnosed with hypertension or diabetes, all subjective health measures are, on average, increasing over time.

Finally, Panel F presents information on financial variables derived by the Institute for Fiscal Studies. Measures of income, savings and wealth, as well as labour supply, are included. Values in the top 1% of these variables are excluded, as they can be considered atypical for the rest of the distribution.

[10] A recoded version of the level of physical activity derived by NatCen; these questions are part of the health module and involve both leisure and work activities.

[11] These questions are part of the self completed questionnaire. For waves 3 and 4, individuals have to record the total number of fruits/vegetables units per item in a list, and then the number was summed to construct the measure. In contrast, waves 5-7 ask directly for the number of portions (units) consumed per day.

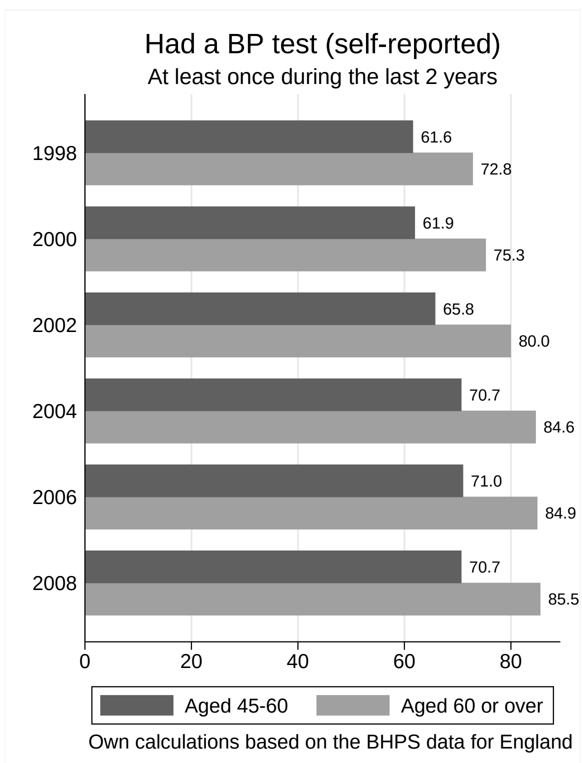
Table 1: Sample Means by Wave

Variables	Wave 0	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7
Panel A. Socio-demographic Characteristics								
Age	60.7	63.6	65.8	68.0	66.3	67.4	68.5	70.0
Male	43.9%	43.9%	44.0%	44.4%	44.8%	44.9%	45.0%	45.1%
Educ: No qualifications mentioned	39.1%	39.1%	36.8%	33.4%	31.0%	27.9%	27.6%	25.1%
Educ: Some medium qualif.	36.6%	36.6%	37.4%	39.2%	39.7%	40.4%	40.7%	41.7%
Educ: Some high level or above qualif.	24.3%	24.3%	25.8%	27.4%	29.3%	31.7%	31.7%	33.2%
Non white ethnicity	33.9%	2.7%	8.1%	7.2%	8.4%	4.0%	4.8%	4.3%
Married	71.3%	71.1%	63.5%	61.2%	61.3%	64.3%	61.6%	61.9%
Panel B. Health Conditions								
Diagnosed HBP ever	15.3%	23.8%	47.8%	51.7%	49.7%	48.8%	54.0%	54.3%
High Cholesterol, wave 2 onwards			19.0%	34.4%	35.7%	42.1%	45.8%	45.0%
Diagnosed Diabetes ever	2.5%	6.0%	8.5%	10.9%	11.2%	11.9%	100.0%	100.0%
Takes BP medication	11.5%	17.6%	32.6%	35.9%	33.6%	35.0%	37.2%	38.4%
Takes Lipid-lowering medication				21.3%	22.7%	25.8%	27.8%	29.4%
Diagnosed with any CVD-related condition	20.7%	36.9%	57.5%	61.5%	58.1%	57.8%	62.7%	63.8%
Panel C. Lifestyle								
Current smoker	17.3%	16.1%	13.6%	10.0%	11.7%	10.5%	10.1%	8.2%
Cigaretes per week (including rollups)	92.5	92.7	90.1	86.4	88.0	84.0	83.8	76.5
Alcohol twice a week or more	64.5%	59.3%	43.6%	42.8%	40.9%	40.9%	38.3%	37.7%
Sedentary or low physical activity		30.0%	30.2%	30.8%	29.6%	29.7%	31.2%	30.8%
Portions of vegtables per day				5.3	5.7	2.8	2.9	3.0
Portions of fruits per day				5.5	5.2	2.2	2.2	2.3
Panel D. Health Perceptions								
Self-reported GOOD health	70.0%	71.6%	73.1%	68.7%	74.7%	75.8%	72.6%	73.4%
Self-reported bad health	7.6%	24.4%	26.9%	31.3%	25.3%	24.2%	27.4%	26.6%
SSP: Chances to live to age 75		65.5	65.4	67.1	67.7	68.9	67.3	68.5
What are the chances that your health will limit your ability to work before you		37.7	35.4	33.4	33.0	32.4	31.5	29.9
Panel E. Health Measures								
BMI: Body Mass Index (kg/m2)	27.4		27.9		28.3		28.3	
Waist-to-height ratio (WHtR)			0.6		0.6		0.6	
Overweight or above: BMI 25+	68.7%		72.7%		73.5%		73.1%	
Obesity level 1 or above: BMI 30+	23.3%		28.9%		31.3%		31.3%	
Blood HDL level (mmol/l)	1.5		1.5		1.6		1.7	
Blood total cholesterol level (mmol/l)	5.9		5.9		5.6		5.5	
Blood glucose level (mmol/L) - fasting samples only			5.0		4.9		5.4	
(D) Valid Mean Systolic BP	138.4		135.2		132.7		132.7	
(D) Valid Mean Diastolic BP	76.2		75.0		74.3		73.4	
Panel F. Economic activity								
BU total yearly income (1000£ of May2005)		20.9	21.3	21.0	22.5	22.6	22.8	21.9
BU total savings (1000£ of May2005)		22.6	27.2	32.5	37.2	36.5	35.5	35.3
BU total net (non-pension) wealth (1000£ of May2005)		232.9	276.4	307.1	308.7	302.5	300.4	327.0
Hours of work all jobs (employed or self employed)		35.9	34.7	32.8	33.9	33.2	32.6	31.3
Working		40.6%	34.9%	30.4%	35.9%	32.6%	28.9%	24.6%
Individuals	6757	6757	8681	6080	9286	7503	8431	6485
Year	98-00	2002	2004	2006	2008	2010	2012	2014

Source: Own calculations using HSE 1998,1999,2000 for wave 0 and ELSA waves 1-7.

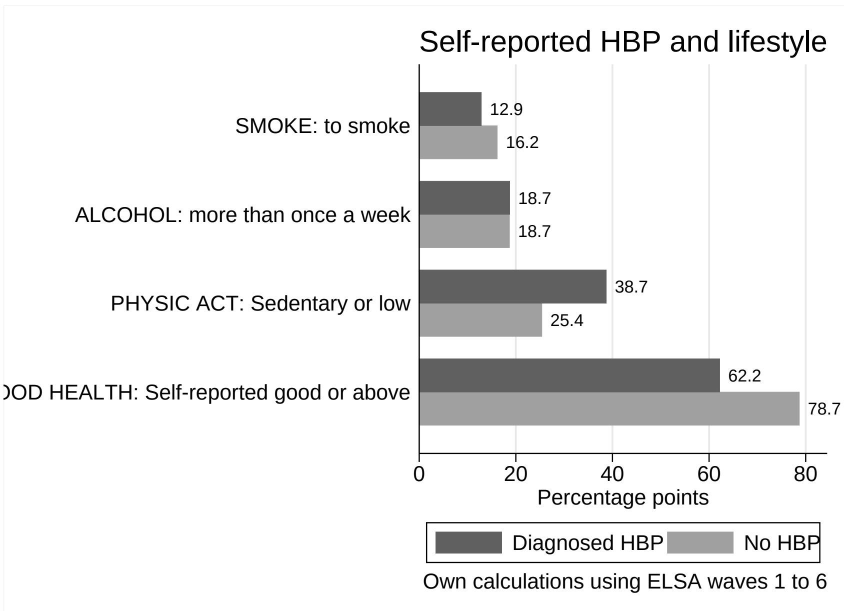
As this study aims to understand the effects of receiving advice about potential undiagnosed hypertension, the objective population must be those at risk of such a condition and less likely to be tested for it. Falaschetti et al. (2014) document that both systolic and diastolic BP increase with age until 60, when the diastolic measurement starts to systematically decrease. They also show that by 2011, prevalence of hypertension was 28% for the 40-49 age group, 40% for 50-59, and 60% for 60-69. Nevertheless, the authors document an increase in awareness and management of the condition between 1994 (46%) and 2011 (71%). This is related to the proportion of individuals who regularly underwent BP measurement. Between 1998 and 2008, data from the *British Household Panel Survey* (ISER, 2010) show an increase from 61% to 80% on the proportion of individuals aged 45-60 reporting having had their BP tested in the preceding 2 years (see Figure 2). The proportion is larger for the older group, from 73% to 86%. As a result, despite improvements over time, while prevalence is higher in older individuals, testing is lower in the middle-age group. Therefore, this type of intervention is expected to be useful for younger individuals.

Figure 2: Demand for Blood Pressure Screening Tests



Another aspect of discussion is the relationship between lifestyle and diagnosis of hypertension. Figure 3 presents the correlation between habits and self-reported HBP that arises from ELSA. It shows that, in general, individuals who report having been told by a doctor about being hypertensive are less likely to smoke or consume alcohol more than once a week, but at the same time are more likely to have a sedentary lifestyle.

Figure 3: High Blood Pressure and Lifestyle

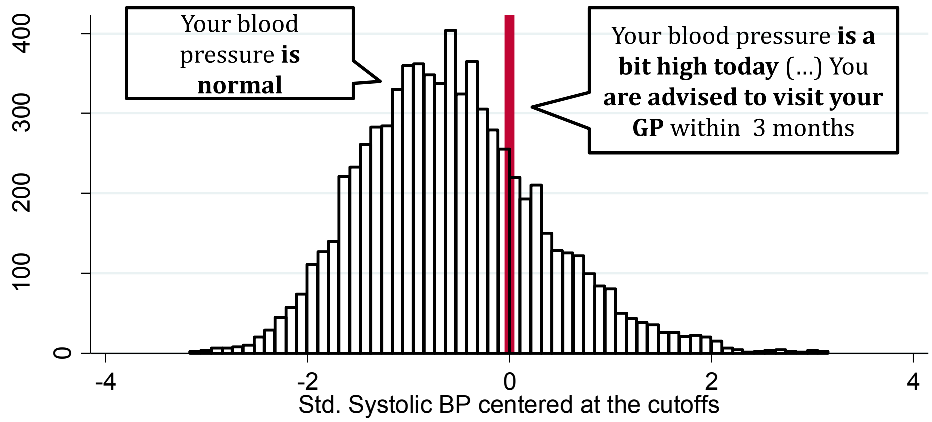


2.2 Health Advice Intervention

A particular characteristic of ELSA makes it ideal for our purposes. As previously indicated, nurses hired for ELSA visit the survey respondents 2 weeks after the survey interview and take their BP readings. According to the ELSA protocol, the nurses advise respondents to visit their family doctor (GP) if at least one of the respondents' BP measures is above a certain threshold (see below). This message may impel some individuals to visit their GP and undergo a more comprehensive screening to confirm whether or not they are hypertensive.

Essentially, the advice varies with the last two out of three measurements of respondents' systolic/diastolic BP. In ELSA, the thresholds are 140/85 mmHg for mildly raised BP, 160/100 mmHg for moderately raised and 180/115 mmHg for considerably raised. BP below 140/85 mmHg is considered normal. In the HSE, the values were the same for

Figure 4: Systolic Blood Pressure Distribution and Nurses' Advice



women and men < 50 years old, but changed for men aged ≥ 50 years.[12] Respondents with mildly raised blood pressure were instructed to visit their GP within 3 months, for moderately raised it was 3 weeks, and for considerably raised, 5 days. These thresholds are similar to the official recommendation for systolic BP used by the NHS, wherein hypertension is diagnosed at 140/90 mmHg (NICE, 2011). For diastolic BP the recommendation is quite conservative, and this is reflected in the results. Figure 4 presents the strategy followed in this paper: BP measurements are standardised around the relevant mildly raised cut-off according to respondents' age, sex and the year of the survey. For this analysis, an individual is treated if such a measure is ≥ 0, and is a control otherwise.

Nurses were clearly instructed to provide only the survey interpretation. Respondents were allowed to avoid feedback from the readings, or to allow the results to be sent to their GP.[13] That information could be left written in a 'measurement record card' along with other biomarkers.[14] The suggestion nurses gave was homogeneous, as stated by the survey protocol. For instance, in the case of moderately raised BP, they would tell the respondent:

Blood pressure can vary from day to day and throughout the day so that

[12] 160/95, 170/105 and 180/115 mmHg, respectively

[13] Unfortunately, publicly available data does not report these choices.

[14] There were no other comments or suggestions based on the survey's biomarkers.

one high reading does not necessarily mean that you suffer from high blood pressure. You are advised to visit your GP within 2-3 weeks to have a further blood pressure reading to see whether this is a once-off finding or not.

3 Empirical Strategy

The previously described nurse protocol motivates a sharp regression discontinuity Design. The idea therein is to compare the value of the outcomes in the post-measurement waves, for those individuals just below and just above the threshold. By doing this, it is assumed that having the maximum standardised BP measurement slightly above or below the advice cut-off is essentially random once the trend is taken into account. Formally, following Imbens and Lemieux (2008), the impact of a nurse's advice at wave t, $W = 1$, on outcome Y_{t+s} at wave $t + s$ ($s \in \{1, 2\}$) is identified by the discontinuity in the conditional expectation of such outcome at the advice cut-off $BP = 0$:

$$\begin{aligned}\delta_0 &= E[Y_{i,t+s}(W=1) - Y_{i,t+s}(W=0)|BP_{i,t} = 0] \\ &= \lim_{BP \downarrow c} E[Y_{i,t+s}|BP_{i,t} = 0] - \lim_{BP \uparrow 0} E[Y_{i,t+s}|BP_{i,t} = 0]\end{aligned} \tag{1}$$

This strategy identifies the impact of the policy on the outcomes of a particular group of individuals. First, it tells us how individuals potentially considered to have mildly raised BP would react to the diagnosis of such a condition. Second, it measures how people who comply with the advice react: that is, those who visit their GP as the advised, and those who would not do so in the absence of the nurse's advice.

The main results are presented based on the estimated parameter δ from Equation 2, which identifies δ_0 in Equation 1. Essentially, within a bandwidth of one standard deviation ($h = 1SD$) of the cut-off, a second order polynomial is fit at both sides of the cut-off to capture the observed relationship between prescriptions and BP (see Figure 5, described in detail in the Results section).

$$\begin{aligned}Y_{i,t+s} = \delta W_{it} + \alpha_0 + f_l(\alpha_l, BP_{i,t}|W_{it} = 0) + f_r(\alpha_r, BP_{i,t}|W_{it} = 1) \quad &, s \in \{1, 2\} \\ f_x(\alpha_x, BP_{i,t}|W_{it} = 0) = \alpha_{x,1} BP_{i,t} + \alpha_{x,2} BP^2_{i,t} \quad &, x \in \{l, r\} \\ \forall BP_{i,t} \in [-h, h] \,, \quad h = 1&\end{aligned} \tag{2}$$

Given that δ_0 can be estimated under different bandwidths h and functions $f(\cdot)$, it is essential to test alternative specifications. The main tables present results based on local linear regressions with rectangular and triangular weights.[15]

Balancing tests were carried out to test the validity of the main assumption. These tests consist of running Equation 3 with $s = 0$. Such regression analysis assesses whether the discontinuities were in place before the nurse's advice transpired. It is also possible to determine if the effect is related to other pre-existing elements in the data. This is done by setting socio-demographic characteristics as left-hand side elements in the regression.

4 Results

4.1 Main Results

The intervention does increase the likelihood of self-reported diagnosis of hypertension, as well as the probability of being treated with medication for BP, in both cases among those who report not being diagnosed with HBP before the nurse's visit, and around 2 years after they received the nurse's advice.[16] Among individuals aged $\leq$58 years at the time of the BP measurement, those above the systolic BP advice threshold were around 6.6 percentage points [p-val=0.07] more likely to report they were taking medication, and 6 percentage points (p-val=0.07) more likely to report that a doctor diagnosed them with HBP. Both figures are large, especially the medication component, as around 2% of the population with such BP levels take medication. For diastolic BP the estimate for diagnosis is -1.59 percentage points (p-val=0.53) and for medication is -0.26 percentage points (p-val=0.88).

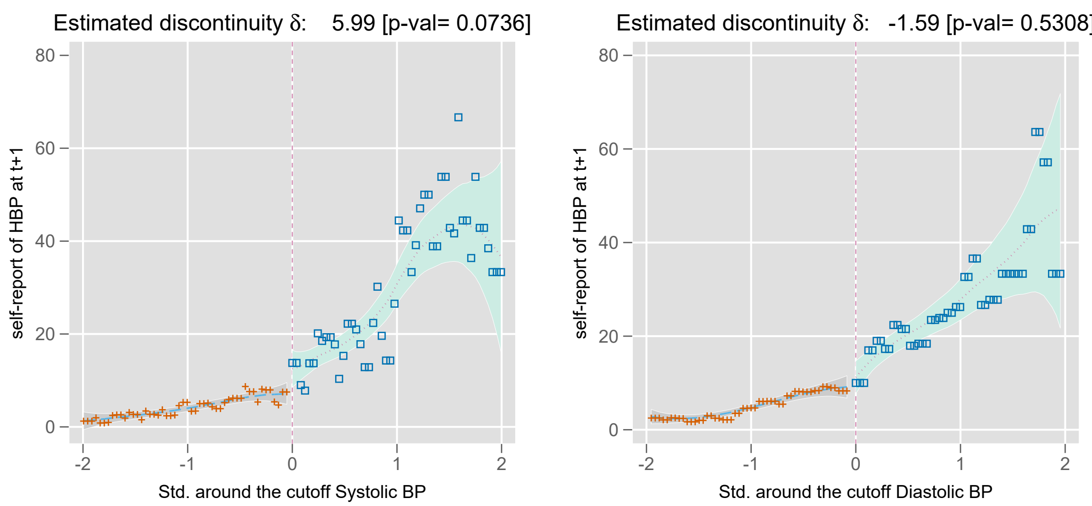
Figure 5 presents a graphic version of the RDD analysis for both variables. Panel A corresponds to the reported diagnosis and Panel B to use of medication. In all graphs, the horizontal axis shows the standardized BP measurement, where 0 is the relevant cut-off. A smoothed average, using the triangular linear kernel, is represented by the dashed lines at both sides of the threshold. This strategy aims to measure the jump between the dashed lines. The value reported in the graph corresponds to Equation 2, and is called the *local*

[15] For further details see Appendix B.

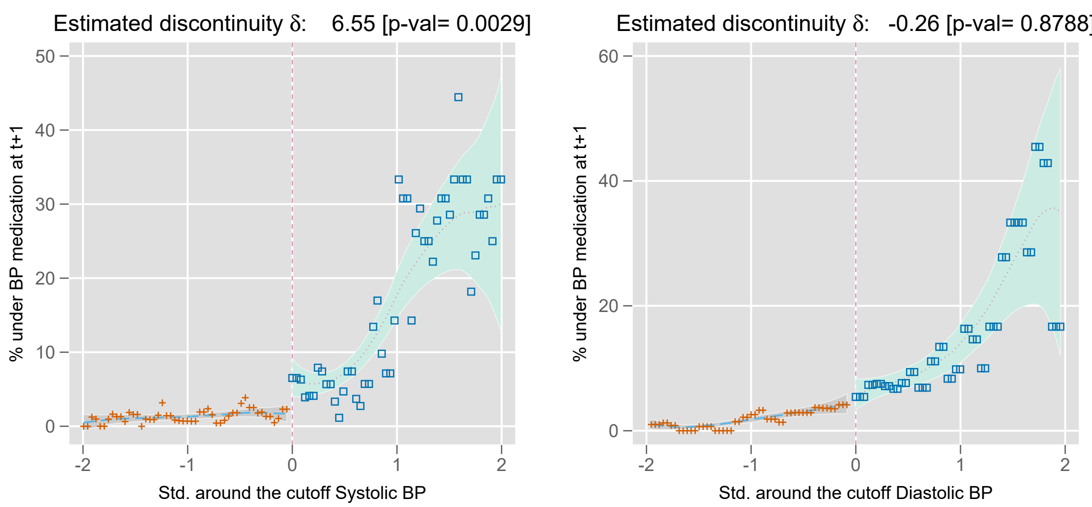
[16] The sample is selected in that manner to avoid confounding factors. First, general individuals above the threshold are more likely to report being diagnosed with HBP even before the nurses visit them. This is expected as the advice cut-off is equivalent to the common diagnosis threshold. Second, individuals in their 50s will benefit most from the health checks, as they are less likely to demand primary health care in the first place as shown in Figure 2. Age is explored in greater detail in section 4.3. For further details, see Appendix A.

Figure 5: Nurse Advice and BP lowering medication at the following-wave

Panel A. Self-reported high blood pressure



Panel B. Blood pressure medication



Sample: Individuals aged $\leq$ 58 years who reported as not diagnosed with high blood pressure or diabetes as per the HSE-ELSA data.

Notes: Calculations using a quadratic function within one standard deviation of the cut-off. A 90% confidence interval is presented.

Significance level: *90%, ** 95%, *** 99%

quadratic rectangular estimator in tables below.

Tables 2 and 3 present the main results for one and two waves after the nurse's visit. In both, the rows present outcome variables. Panel A shows the jump estimator for health conditions and medications, B for lifestyle indicators, C for health perceptions, and D, only in Table 3, covers objective health measures. The first column is the mean of each dependent variable for those observations one standard deviation below the threshold. The other columns present different specifications for the trend between the outcome and systolic BP. The last column, 4, corresponds to the estimate of δ according to Equation 2. In the rows, standard errors are presented, as well as the number of observations included. They differ according to the output variable and method.[17] The common bandwidth of one standard deviation ($h = 1$) can be checked as a comparison between variables. This sample size is used for the main results in column 4.[18] Notably, some variables have fewer observations as they were not collected in every wave (e.g. fruits and vegetables), or because they were conditional on a characteristic (e.g. cigarettes per week for those who reported being smokers at the wave of the nurse's advice).

Before presenting results, Tables 2 and 3 present the differential attrition below and above the threshold. One standard deviation below the threshold, average attrition is around 15% at approximately 2 years after the measurement. This figure is nearly 25% after 4 years. Nevertheless, there is no observed systematic difference above and below the cut-off.

[17] See Appendix B for more details on the optimal bandwidth for local linear regressions estimates presented in columns 2 and 3.

[18] One standard deviation of systolic blood pressure is 19-20 mmHg. Appendix C shows that the BP medication estimates are robust with regard to the bandwidth selection.

Table 2: Regression Discontinuity Design Next Wave (approximately 2 years) Outcomes

RDD on systolic BP standardized around the nurse advice cut-off.

$$Y_{i,t+1} = \delta(BP^c_{i,t} \geq 0) + \alpha_0 + f_l(\alpha_l, BP^c_{i,t}|BP_i < 0) + f_r(\alpha_r, BP^c_{i,t}|BP_i \geq 0) + u_{i,t+1}|Age_{i,t} <= 58$$

Dependent Variable at $t+1$	(1) Mean 1SD Below	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Missing this wave	15.80%	-0.21		-2.41
N: 3975 ($h_1^* = 1.08$), *1012* ($h_2^* =$) , *3783* ($h = 1$)		(2.57)		(3.59)
Panel A. Health Conditions				
Diagnosed HBP ever	5.71%	5.32*	5.52*	5.99*
N: 2041 ($h_1^* = 0.67$), *1671* ($h_2^* = 0.53$) , *3161* ($h = 1$)		(3.02)	(2.95)	(3.35)
High Cholesterol, wave 2 onwards	23.57%	-0.19	-1.57	-0.01
N: 1222 ($h_1^* = 0.85$), *926* ($h_2^* = 0.67$) , *1463* ($h = 1$)		(5.83)	(5.93)	(7.18)
Diagnosed Diabetes ever	0.80%	0.45	0.34	0.60
N: 3313 ($h_1^* = 1.05$), *2340* ($h_2^* = 0.78$) , *3161* ($h = 1$)		(0.95)	(0.96)	(1.27)
Takes BP medication	1.64%	4.91***	4.69***	6.55***
N: 2504 ($h_1^* = 0.82$), *1860* ($h_2^* = 0.61$) , *3161* ($h = 1$)		(1.81)	(1.81)	(2.20)
Takes Lipid-lowering medication	8.92%	4.60	3.81	5.66
N: 1463 ($h_1^* = 1.01$), *1066* ($h_2^* = 0.75$) , *1463* ($h = 1$)		(3.85)	(3.94)	(5.06)
Diagnosed with any CVD-related condition	14.08%	2.59	1.20	1.32
N: 3459 ($h_1^* = 1.15$), *2653* ($h_2^* = 0.87$) , *3170* ($h = 1$)		(2.97)	(3.08)	(4.28)
Already death by this wave	0.82%	-0.36		-0.07
N: 1621 ($h_1^* = 0.43$), *2653* ($h_2^* = 0.87$) , *3783* ($h = 1$)		(0.46)		(0.55)
Panel B. Lifestyle				
Current smoker	17.35%	4.25	4.40	4.85
N: 3437 ($h_1^* = 1.10$), *2330* ($h_2^* = 0.78$) , *3151* ($h = 1$)		(3.08)	(3.32)	(4.30)
Current smoker if smoker at t	83.02%	-0.66	0.54	-1.67
N: 520 ($h_1^* = 0.88$), *405* ($h_2^* = 0.65$) , *607* ($h = 1$)		(6.21)	(6.59)	(8.19)
Cigaretes per week (0 for non-smokers, includes rollups)	14.03	7.06**	6.19*	8.60*
N: 3362 ($h_1^* = 1.14$), *2737* ($h_2^* = 0.92$) , *3080* ($h = 1$)		(3.51)	(3.47)	(4.85)
Cigaretes per week (0 for non-smokers) if smoker at t, include rollups	75.55	33.08**	37.15***	24.83
N: 351 ($h_1^* = 0.62$), *282* ($h_2^* = 0.50$) , *578* ($h = 1$)		(13.79)	(13.87)	(15.10)
Alcohol twice a week or more	56.29%	-9.23*	-10.57**	-10.36*
N: 2083 ($h_1^* = 0.70$), *1948* ($h_2^* = 0.63$) , *3031* ($h = 1$)		(4.89)	(4.62)	(5.60)
Sedentary or low physical activity	16.85%	2.08	1.40	3.48
N: 3642 ($h_1^* = 1.23$), *3129* ($h_2^* = 1.01$) , *3129* ($h = 1$)		(2.84)	(2.80)	(4.22)
Portions of vegtables per day	3.96	0.19	0.26	-0.25
N: 1396 ($h_1^* = 1.10$), *1105* ($h_2^* = 0.87$) , *1333* ($h = 1$)		(0.46)	(0.47)	(0.68)
Portions of fruits per day	3.20	0.44	0.51*	0.28
N: 1699 ($h_1^* = 1.39$), *1644* ($h_2^* = 1.34$) , *1329* ($h = 1$)		(0.31)	(0.31)	(0.46)

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Table 2: (Continued)

Dependent Variable at $t+1$	(1) Mean 1SD Below	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Panel C. Health Perceptions				
Self-reported GOOD health	83.50%	-0.47	-0.43	-0.01
N: 2326 ($h_1^* = 0.76$), *2028* ($h_2^* = 0.63$) , *3146* ($h = 1$)		(3.60)	(3.50)	(4.25)
Self-reported bad health	14.81%	0.69	1.31	-0.54
N: 3146 ($h_1^* = 1.04$), *2632* ($h_2^* = 0.86$) , *3146* ($h = 1$)		(2.87)	(2.84)	(3.98)
SSP: Chances to live to age 75	68.33	-0.05	-0.33	0.84
N: 2299 ($h_1^* = 0.74$), *1478* ($h_2^* = 0.52$) , *3107* ($h = 1$)		(1.98)	(2.24)	(2.31)
What are the chances that your health will limit your ability to work before you	35.89	-1.17	-1.24	-1.87
N: 1701 ($h_1^* = 0.78$), *1361* ($h_2^* = 0.62$) , *2309* ($h = 1$)		(2.87)	(2.95)	(3.45)

Sample: Respondents aged ≤60 years at the moment of the nurse's advice, who were not diagnosed with high blood pressure or had not been taking medication for lowering blood pressure.
Notes: Column 1 presents the mean of each dependent variable for those observations one standard deviation below the threshold. Columns 2-4 present different specifications for the trend (function $f(\cdot)$) between the outcome and systolic blood pressure. Robust standard errors are presented in parentheses. Significance: * 10%, ** 5%, *** 1%.

4.1.1 Health Conditions

Panel A of Tables 2 and 3 shows the impact of advice on objective and subjective measures of health. First,is self-reported diagnosis of HBP, diabetes, high cholesterol and other cardiovascular conditions or events.[19] Second, prescription of BP medication and prescription of lipid-lowering medication[20] are analysed. Note that below the threshold, nearly 6% of the sample reports are diagnosed with HBP, and 2% are using medication for treating it. This panel includes the main results; there is an increase in the probability of reporting a diagnosis of HBP of 6 percentage points and of taking medication for lowering BP of 6.6 percentage points approximately 2 years after the nurse's advice (Table 2). Therefore, at this threshold this is a substantial impact, doubling the proportion of people diagnosed with the condition and tripling it for those treated with medication. The estimate based on the local lineal average using triangular weights is more conservative (4.7 percentage points) for the case of BP prescriptions.[21] There is no robust evidence of any other diagnosis or medication. A conspicuous, but imprecise, increase on medication for cholesterol

[19]The variable, any CVD includes high blood pressure, stroke, angina, heart attack (including myocardial infraction or coronary thrombosis), congestive heart failure, heart murmur, abnormal heart rhythm, or any other heart trouble.

[20]Medication for lowering cholesterol use for prevention of cardiovascular diseases, mostly statins in the United Kingdom.

[21]See Appendix B for more details about this specification.

is also found: 5.6 pp relative to a prescription rate of 9% below the cut-off.

Approximately 2 years later (4 after the nurse's advice), below the cut-offs prevalence of detected hypertension increased from 6% to 12% (Table 3). Prescription of BP medication doubled from 2% to 4%. However, the difference at the cut-off of both measures decreased to around 2.5 percentage points, and such figures do not statistically differ from 0. In all other diagnosed conditions results are similar: there is no difference below and above the threshold after 4 years. A final variable to consider is mortality, for which no significant difference is obtained between individuals below and above the threshold.

Apart from medication, family doctors normally give advice on lifestyle. Panel B of Tables 2 and 3 covers smoking, alcohol intake, physical activity and nutrition variables.

4.1.2 Lifestyle

As described before, ELSA includes questions about smoking on both the extensive and intensive margins. Two years after the nurse's advice, 16% of the sample below the cut-off report smoking (Table 2). However, there is a decreasing trend: nearly 17% of former smokers have abandoned this behaviour. There is no difference in the proportion of those self-reporting as a current smoker below and above the threshold. At the intensive margin, there is a difference of eight cigarettes per week between those below and above the threshold.[22] Four years after the advice, 78% of original smokers are still smoking (Table 3). The difference in intensity below and above the cut-off is estimated at around six cigarettes. However, the effect does not statistically differ from zero for the quadratic specification.[23]

With respect to alcohol intake, there is a clear reduction of 10 percentage points on the probability to report to be drinking at least twice days a week. The impact is the same at both 2 and 4 years after the nurse's advice. This is a substantial impact: more than half of the respondents below the cut-off have such alcohol intake frequency, a figure that 2 years later drops around 40%.

[22]The intensive margin here includes both cigarette and roll-up smokers. In ELSA, roll-ups are measured in ounces or grams f tobacco , which is translated into 'cigarettes' to obtain a measure that avoids substitution between both types of smoking. In the HSE, the question on number of cigarettes included roll-ups by default.

[23]If we condition these intensity measures on being an smoker at the moment of the nurse's advice, the 2-year impact on the roll-ups inclusive measure is estimated to be 25-37 cigarettes (a third of the mean cigarette consumption per week), depending on the specification, significant at the 95% confidence interval except for the quadratic specification. The 4-year estimate is around 17 cigarettes, but cannot be rejected from being 0 in any specification.

Finally, there are no significant effects on physical activity, or fruit or vegetable consumption. There is a non-robust effect on fruit intake, statistically different from zero 2 years after the nurse's advice (Table 2). However, as explained in the data section, the exact amount of portions per day cannot be determined as the measure involves two different elicitation methods.

4.1.3 Health measures

Given there is evidence supporting an effect on medication prescription and lifestyle choices, it is possible to expect an effect on both objective and subjective health.

With respect to perceived health, there is no evidence of an impact on reporting either good or bad health, or any substantial difference on subjective survival probabilities. Moreover, for those who were working at the time of the survey, there is no effect on the reported chances of suffering a problem that limits ability to work.

With respect to objective health measures, there is evidence of an increase of 10 pp. on the odds of being obese (BMI $\geq$30) under the quadratic specification, relative to a prevalence below the cut-off of 27%. This result is not robust to the specification, and while it is also reflected on the waist-to-height ratio, it is not observed in the mean BMI.

Finally, there is no perceived difference in biomarkers as BP or cholesterol, despite an increase in medication.

Table 3: RDD 2 waves (apx. 4 years) later

RDD on systolic BP standarized around the nurse advice cut-off.

$$Y_{i,t+2} = \delta(BP^c_{i,t} \geq 0) + \alpha_0 + f_l(\alpha_l, BP^c_{i,t}|BP_i < 0) + f_r(\alpha_r, BP^c_{i,t}|BP_i \geq 0) + u_{i,t+2}|Age_{i,t} <= 58$$

Dependent Variable at $t+2$	(1) Mean Below	1SD	(2) Loc Linear Triangular h^*_1	(3) Loc Linear Rectang. h^*_2	(4) Loc Quad Rectang. $h = 1SD$
Missing this wave	26.27%		0.32	-0.51	-0.07
N: 3975 ($h^*_1 = 1.09$), *3165* ($h^*_2 = 0.85$) , *3783* ($h = 1$)			(3.19)	(3.25)	(4.49)
Panel A. Health Conditions					
Diagnosed HBP ever	11.66%		4.23	4.99	2.48
N: 3555 ($h^*_1 = 1.39$), *2928* ($h^*_2 = 1.09$) , *2786* ($h = 1$)			(3.11)	(3.15)	(4.75)
High Cholesterol, wave 2 onwards	20.86%		-0.70	-1.58	1.34
N: 2492 ($h^*_1 = 0.93$), *1926* ($h^*_2 = 0.73$) , *2801* ($h = 1$)			(3.83)	(3.96)	(5.02)
Diagnosed Diabetes ever	3.23%		0.56	0.20	2.25
N: 2272 ($h^*_1 = 1.19$), *1802* ($h^*_2 = 0.94$) , *2015* ($h = 1$)			(2.22)	(2.19)	(3.27)

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Table 3: (Continued)

Dependent Variable at $t+2$	(1) Mean 1SD Below	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Takes BP medication	4.10%	1.66	1.57	2.83
N: 3309 ($h_1^* = 1.28$), *2762* ($h_2^* = 1.01$) , *2762* ($h = 1$)		(2.23)	(2.27)	(3.22)
Takes Lipid-lowering medication	11.78%	4.99	4.22	4.75
N: 1429 ($h_1^* = 1.08$), *1133* ($h_2^* = 0.85$) , *1364* ($h = 1$)		(4.38)	(4.39)	(6.05)
Diagnosed with any CVD-related condition	21.67%	−0.69	0.08	−5.80
N: 3401 ($h_1^* = 1.28$), *2843* ($h_2^* = 1.00$) , *2843* ($h = 1$)		(3.54)	(3.54)	(5.34)
Already death by this wave	1.38%	−0.28	−0.38	−0.24
N: 2999 ($h_1^* = 0.81$), *2456* ($h_2^* = 0.63$) , *3783* ($h = 1$)		(0.77)	(0.81)	(1.01)
Panel B. Lifestyle				
Current smoker	14.96%	3.81	2.86	5.15
N: 3219 ($h_1^* = 1.22$), *2612* ($h_2^* = 0.96$) , *2761* ($h = 1$)		(2.90)	(2.94)	(4.20)
Current smoker if smoker at t	77.94%	1.27	−0.88	2.52
N: 528 ($h_1^* = 1.09$), *426* ($h_2^* = 0.86$) , *494* ($h = 1$)		(8.48)	(8.60)	(12.10)
Cigaretes per week (0 for non-smokers, includes rollups)	11.35	6.61**	7.14**	5.87
N: 3538 ($h_1^* = 1.42$), *2942* ($h_2^* = 1.11$) , *2701* ($h = 1$)		(3.14)	(3.14)	(4.56)
Cigaretes per week (0 for non-smokers) if smoker at t, include rollups	71.68	19.47	19.77	16.17
N: 593 ($h_1^* = 1.47$), *482* ($h_2^* = 1.15$) , *430* ($h = 1$)		(12.30)	(12.38)	(19.01)
Alcohol twice a week or more	42.39%	−9.44**	−9.72**	−11.92**
N: 2744 ($h_1^* = 1.13$), *2090* ($h_2^* = 0.89$) , *2514* ($h = 1$)		(4.21)	(4.41)	(6.07)
Sedentary or low physical activity	17.45%	5.29	6.19*	6.35
N: 2604 ($h_1^* = 0.95$), *2026* ($h_2^* = 0.75$) , *2752* ($h = 1$)		(3.41)	(3.48)	(4.53)
Portions of vegtables per day	4.14	0.39	0.40	0.50
N: 1521 ($h_1^* = 1.36$), *1281* ($h_2^* = 1.07$) , *1220* ($h = 1$)		(0.53)	(0.57)	(0.70)
Portions of fruits per day	3.28	0.39	0.43	0.43
N: 1085 ($h_1^* = 0.90$), *821* ($h_2^* = 0.71$) , *1224* ($h = 1$)		(0.39)	(0.40)	(0.49)
Panel C. Health Perceptions				
Self-reported GOOD health	84.32%	3.66	5.29	2.83
N: 1613 ($h_1^* = 0.59$), *1170* ($h_2^* = 0.47$) , *2742* ($h = 1$)		(4.65)	(4.85)	(4.76)
Self-reported bad health	15.68%	−3.66	−5.29	−2.83
N: 1613 ($h_1^* = 0.59$), *1170* ($h_2^* = 0.47$) , *2742* ($h = 1$)		(4.65)	(4.85)	(4.76)
SSP: Chances to live to age 75	68.08	0.33	−0.08	0.62
N: 2004 ($h_1^* = 0.77$), *1601* ($h_2^* = 0.61$) , *2723* ($h = 1$)		(2.13)	(2.22)	(2.54)
What are the chances that your health will limit your ability to work before you	32.49	1.11	0.46	−0.87
N: 1742 ($h_1^* = 0.99$), *1352* ($h_2^* = 0.78$) , *1840* ($h = 1$)		(2.76)	(2.89)	(3.68)
Panel D. Health Measures				
BMI: Body Mass Index (kg/m2)	27.95	0.38	0.32	1.03
N: 2393 ($h_1^* = 1.06$), *1814* ($h_2^* = 0.83$) , *2283* ($h = 1$)		(0.45)	(0.46)	(0.63)

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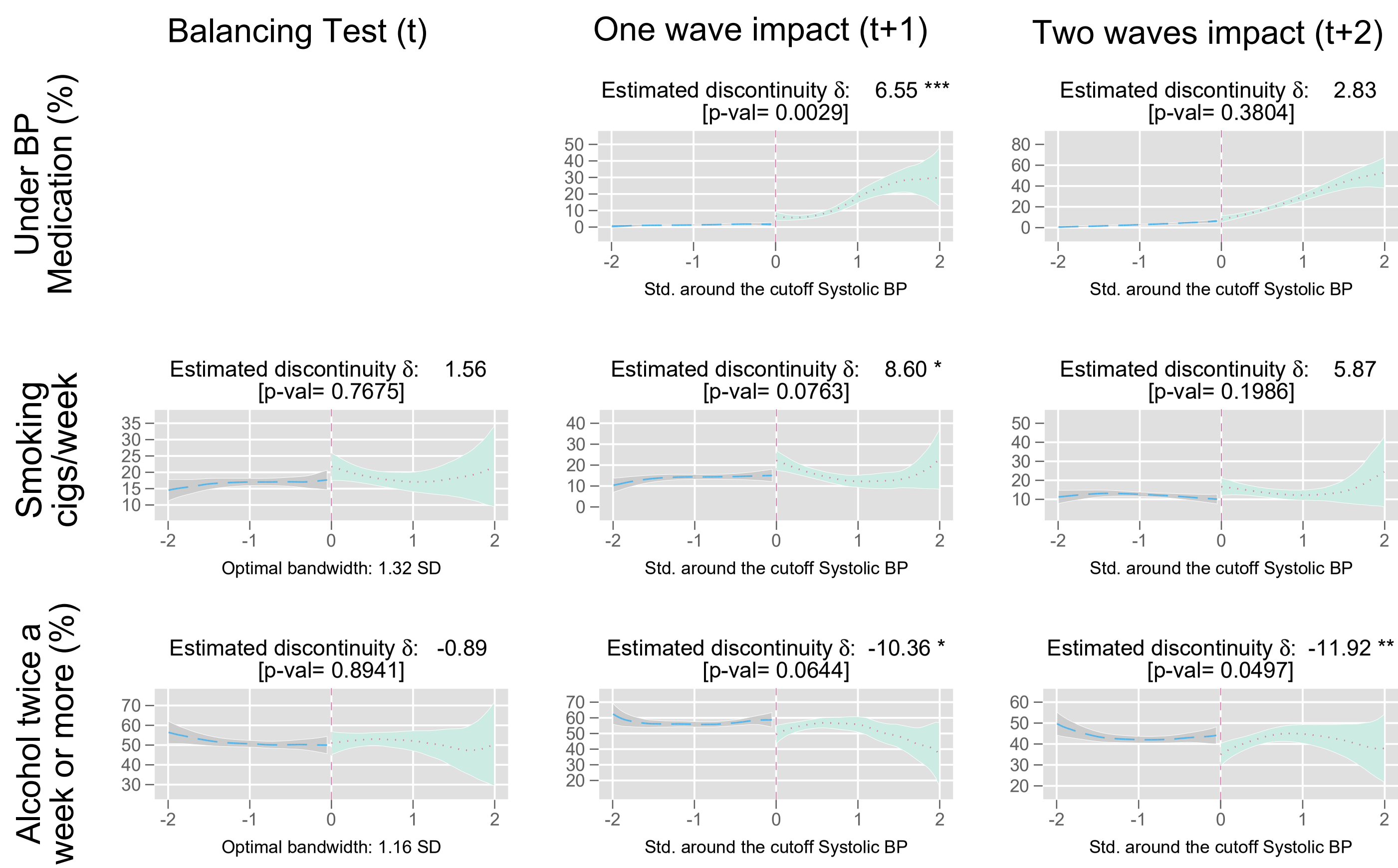
Table 3: (Continued)

Dependent Variable at $t+2$	(1) Mean 1SD Below	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Waist-to-height ratio (WHtR)	0.56	0.01	0.01	0.02*
N: 1483 ($h_1^* = 0.65$), *1107* ($h_2^* = 0.51$) , *2282* ($h = 1$)		(0.01)	(0.01)	(0.01)
Overweight or above: BMI 25+	71.47%	0.03	0.45	4.51
N: 2393 ($h_1^* = 1.07$), *1922* ($h_2^* = 0.84$) , *2283* ($h = 1$)		(3.86)	(3.95)	(5.48)
Obesity level 1 or above: BMI 30+	28.90%	6.60	6.97	10.67*
N: 1690 ($h_1^* = 0.76$), *1362* ($h_2^* = 0.60$) , *2283* ($h = 1$)		(5.26)	(5.35)	(6.25)
Blood HDL level (mmol/l)	1.63	−0.04	−0.04	−0.03
N: 1732 ($h_1^* = 0.91$), *1335* ($h_2^* = 0.72$) , *1943* ($h = 1$)		(0.04)	(0.05)	(0.06)
Blood total cholesterol level (mmol/l)	6.02	−0.09	−0.11	−0.01
N: 2033 ($h_1^* = 1.09$), *1634* ($h_2^* = 0.86$) , *1943* ($h = 1$)		(0.12)	(0.12)	(0.17)
Blood glucose level (mmol/L) - fasting samples only	4.92	−0.07	−0.09	−0.04
N: 1789 ($h_1^* = 1.56$), *1536* ($h_2^* = 1.22$) , *1323* ($h = 1$)		(0.08)	(0.08)	(0.12)
(D) Valid Mean Systolic BP	128.28	0.52	0.98	−0.48
N: 2316 ($h_1^* = 1.15$), *1903* ($h_2^* = 0.90$) , *2128* ($h = 1$)		(1.48)	(1.49)	(2.10)
(D) Valid Mean Diastolic BP	76.26	−0.12	−0.18	0.09
N: 2016 ($h_1^* = 0.96$), *1571* ($h_2^* = 0.76$) , *2128* ($h = 1$)		(0.98)	(1.00)	(1.30)

Sample: Respondents aged ≤60 years at the moment of the nurse's advice, who were not diagnosed with high blood pressure or had not been taking medication for lowering blood pressure.
Notes: Column 1 presents the mean of each dependent variable for those observations one standard deviation below the threshold. Columns 2-4 present different specifications for the trend (function $f(\cdot)$) between the outcome and systolic blood pressure. Robust standard errors are presented in parentheses. Significance: * 10%, ** 5%, *** 1%.

Figure 6 presents a visual summary of the main results, following the style of Figure 5. The first row presents BP prescriptions, the second smoking intensity, and the last alcohol intake. Columns refer to the moment of measurement of each of these outcomes. The first is contemporary to the measurement and the advice. This is done to verify that the discontinuity occurs after the intervention. These are balancing tests that are part of the robustness checks detailed in the next section. The second and third columns correspond to the estimates in column 2 of Tables 2 and 3 but with a fixed bandwidth of 0.053.

Figure 6: Impacts on Blood Pressure Medication, Smoking and Alcohol Intake



Notes: Horizontal axis: Calculations using a quadratic function within 1 standard deviation of the cut-off. A 90% confidence interval is presented. Cigarettes per week includes roll-ups. Significance level: *90%, ** 95%, *** 99%. Sample: individuals aged $\leq$ 58 years with no prior diagnosis of high blood pressure or diabetes.

4.2 Complementarity of medication and health behaviours

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One of the central questions regarding preventive care is the complementary or substitutability of investments, particularly between medication and lifestyle adjustments. While there is not particularly rich information on dietary habits in ELSA, it was still possible to assess whether individuals stopped or reduced their smoking and/or heavy drinking.[24] Panel A of Table 4 shows responses in terms of variations in lifestyle and medication. The first row is the main result discussed above, and the last is how this estimate changes when considering the sample of those individuals for whom there is lifestyle information. The conspicuous reduction in sample size owes to the fact that lifestyle information is part of a self-response module. Panel B presents the 2-year analysis using the potential combinations of the investments as outcomes. There is no evidence of risk compensation; in fact, very few people around the threshold (0.15%) behaved worse while up-taking medication. The opposite, complementarity between health investments, was also not observed. The sole significant result was on the use of medication but without improvements in lifestyle.

A clear limitation of this exercise is that dietary investments cannot be analysed in the same fashion because its main questions are not comparable across all the waves of the study. This is perhaps the dimension in which risk compensation may operate, as it was in the case of statins in Kaestner et al. (2014).

Table 4: Joint Response in Terms of Medication and Lifestyle Adjustments

$$Y_{i,t+1} = \delta(BP^c_{i,t} \geq 0) + \alpha_0 + f_l(\alpha_l, BP^c_{i,t}|BP_i < 0) + f_r(\alpha_r, BP^c_{i,t}|BP_i \geq 0) + u_{i,t+1}|Age_{i,t} <= 58$$

Dependent Variable at $t+1$	(1) Mean Below 1SD	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Panel A. Investments				
Takes BP medication	1.64%	4.91***	4.69***	6.55***
N: 2504 ($h_1^* = 0.82$), *1860* ($h_2^* = 0.61$) , *3161* ($h = 1$)		(1.81)	(1.81)	(2.20)
Better lifestyle	17.05%	1.91	2.24	2.49
N: 2349 ($h_1^* = 1.38$), *2073* ($h_2^* = 1.16$) , *1835* ($h = 1$)		(3.64)	(3.51)	(5.56)

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[24] Lifestyle modification in this section compares all habits both in the wave of measurement and on the following one. Lifestyle became 'better' if a smoker stopped smoking or reduced the amount of cigarettes smoked or a heavy drinker cut down to ≤2 days per week. However, if any of those transitions were in the opposite direction, lifestyle became 'worse'. Note these are not mutually exclusive definitions. For the no changes definition, the number of cigarettes should not vary more than 10 per week (average is 92 for smokers).

Table 4: (Continued)

Dependent Variable at $t+1$	(1) Mean 1SD Below	(2) Loc Linear Triangular h_1^*	(3) Loc Linear Rectang. h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Worse lifestyle	14.09%	-3.55	-3.88	-4.14
N: 1731 ($h_1^* = 0.95$), *1335* ($h_2^* = 0.76$) , *1835* ($h = 1$)		(3.68)	(3.73)	(4.82)
Takes BP medication (sample of lifestyle)	1.21%	3.42*	2.04	5.27**
N: 1835 ($h_1^* = 1.04$), *1517* ($h_2^* = 0.85$) , *1835* ($h = 1$)		(1.92)	(1.88)	(2.54)
Panel B. Joint response				
Medication and better lifestyle	0.23%	0.74	1.18	1.64
N: 2073 ($h_1^* = 1.17$), *1236* ($h_2^* = 0.70$) , *1835* ($h = 1$)		(0.84)	(0.80)	(1.13)
No medication and better lifestyle	16.82%	1.56	2.33	0.85
N: 2138 ($h_1^* = 1.24$), *1835* ($h_2^* = 1.00$) , *1835* ($h = 1$)		(3.72)	(3.66)	(5.49)
Medication and no changes on lifestyle	0.83%	3.55*	3.16*	4.08*
N: 1335 ($h_1^* = 0.75$), *1060* ($h_2^* = 0.60$) , *1835* ($h = 1$)		(1.96)	(1.86)	(2.28)
No Medication and no changes on lifestyle	70.23%	0.38	0.66	-3.02
N: 2645 ($h_1^* = 1.68$), *2138* ($h_2^* = 1.25$) , *1835* ($h = 1$)		(4.15)	(4.24)	(6.77)
Medication and worse lifestyle	0.15%			-0.44
N: 2645 ($h_1^* = 1.68$), *2138* ($h_2^* = 1.25$) , *1835* ($h = 1$)				(0.39)
No medication and worse lifestyle	13.94%	-3.19	-1.88	-3.70
N: 1731 ($h_1^* = 0.98$), *1517* ($h_2^* = 0.84$) , *1835* ($h = 1$)		(3.61)	(3.54)	(4.81)

Sample: Respondents aged $\leq$60 years at the moment of the nurse's advice, who were not diagnosed with high blood pressure or had not been taking medication for lowering blood pressure.
Notes: Column 1 presents the mean of each dependent variable for those observations one standard deviation below the threshold. Columns 2-4 present different specifications for the trend (function $f(\cdot)$) between the outcome and systolic blood pressure. Robust standard errors are presented in parentheses. Significance: * 10%, ** 5%, *** 1%.

4.3 Heterogeneity on the impact

A pertinent question is whether the impact is heterogeneous according to respondents' characteristics. First, the impact on self-reported HBP diagnosis and BP prescription subsides with age. Figure 7 shows that if older individuals are included in the sample, the estimate of the discontinuity trends toward 0. For self-reported HBP, the estimated difference is not significantly different from 0. Second, the impact is concentrated on males with a 10-year CVD risk $\geq 8\%$.[25] Table 5 presents the discontinuity local linear triangular estimator for a selected group of variables. The difference with previous sections' results is that the sample was stratified according to sex and CVD risk. This conspicuously reduces

[25] CVD risk calculating using the Framingham equation D'Agostino et al. (2008). This is a standard risk calculator for individuals aged 30 to 74 without prior CVD. It involves age, gender, smoking status, total and HDL cholesterol levels, systolic BP, diabetes. For this study, while there are more accurate calculators for England population as QRISK (Hippisley-Cox et al., 2008), this method was selected for its simplicity given the available information.

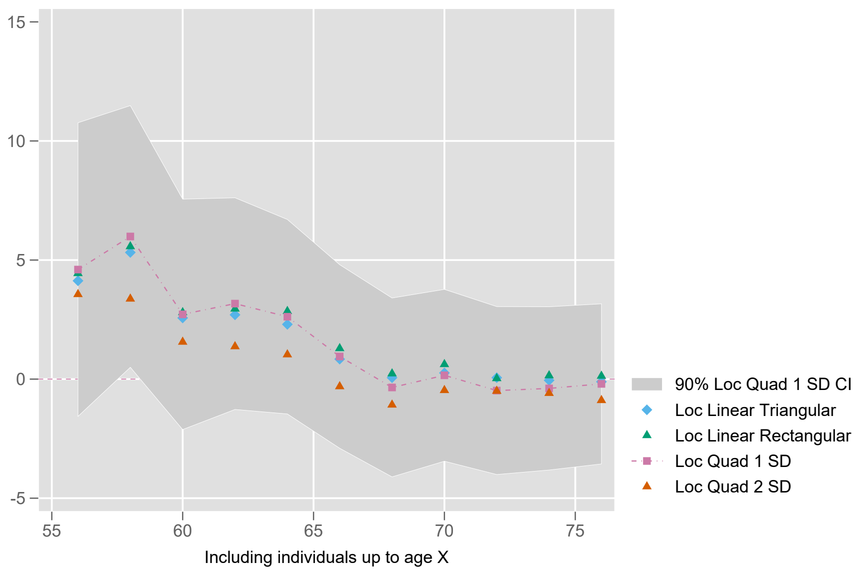
the sample size, resulting in larger standard errors. Differences in HBP medication and self-reported HBP are larger for men; all are significant at least at the 90% level. Finally, the estimates suggest the impact is restricted to those individuals with a 10-year risk of developing a CVD $\geq 8\%$.[26] Reduced alcohol intake is reserved for those with low risk of CVD. A clear limitation of the analysis of this table is that the reduced sample size means the estimates are highly imprecise.

These results suggest the effect is smaller on individuals with low overall risk of developing CVD. The fact the effect is strong for men is likely to be related to the higher thresholds for advising respondents in the HSE (ELSA wave 0). In fact, the National Institute for Health and Care Excellence recommended drug therapy for those with systolic BP $\geq$ 160 mmHg (NICE, 2006, 2011). With respect to age differences, it is expected as older individuals have a higher demand for medical services, the intervention should have no impact on them. Moreover, consequences of hypertension are more important in those aged 40-70 (Chobanian et al., 2003).

[26] This category was defined based on the sample size, rather than clinical standards. However, a more standard 10% risk results in a similar point estimate but is not statistically significant.

Figure 7: Impact on Blood Pressure Medication Estimator by Age

Panel A. Self-reported high blood pressure



Panel B. Blood pressure medication

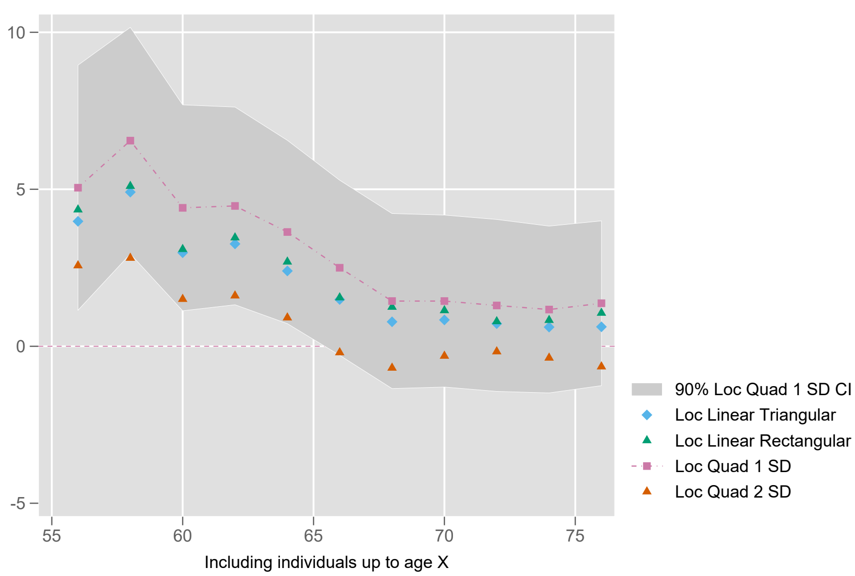


Table 5: RDD by groups: general impact

$$Y_i = \delta(BP_i \geq 0) + f(BP_i|BP_i < 0) + f(BP_i|BP_i \geq 0) + u_i|X_i$$

RDD on systolic BP standarized around 140 mmHg. It is conditional on not been diagnosed before with HBP or being taking medication for blood pressure.

Restriction X_i	(1) HBP	(2) PILLS	(3) N CIGS	(4) ALCOHOL
Base Result	5.99*	6.55***	8.60*	−10.36*
N PILLS: 3161 ($h = 1$)	(3.35)	(2.20)	(4.85)	(5.60)
Male				
Yes	9.24*	10.37***	9.12	−12.71
N PILLS: 1240 ($h = 1$)	(5.48)	(3.71)	(8.34)	(8.87)
No	3.54	3.87	8.26	−8.76
N PILLS: 1921 ($h = 1$)	(4.22)	(2.73)	(5.89)	(7.20)
10 years CVD risk 8% and over				
Yes	9.25	13.00***	−6.90	−5.77
N PILLS: 833 ($h = 1$)	(7.17)	(4.91)	(9.62)	(10.39)
No	2.40	2.03	4.47	−10.42
N PILLS: 1344 ($h = 1$)	(5.55)	(3.31)	(5.04)	(8.73)

Sample: Respondents aged ≤60 years at the moment of the nurse's advice, who were not diagnosed with high blood pressure or had not been taking medication for lowering blood pressure.

Notes: RDD on systolic BP standarized around 140 mmHg. Individuals aged 60 or younger who have not been diagnosed before with high blood pressure or any other cardiovascular related conditions. Column (1), *HPB*, presents estimates for the difference on the probability to be diagnosed with high blood pressure two years after the advice is given. In Column (2), *PILLs*, the dependent variable is the probability to be under medication for controlling blood pressure levels; in Column (3), *NCIGS*, it is the number of cigarettes consumed during the last week; in Column (4), *ALCOHOL*, the probability to have an alcoholic drink twice or more per week. Finally, Column (5) refers to the portions of fruit per day. Robust standard errors are presented in parentheses. Significance: * 10%, ** 5%, *** 1%.

4.4 Specification tests

Several tests were performed to confirm the quality of the results. Principal was a balancing test; that is, if the 'treatment' can be considered as randomly allocated across a wide set of covariates. Table 6 presents the results from applying the same methodology, but using as dependent variables basic demographic controls (Panel A), as well as information on the main results' section outcomes but measured at the moment of the BP measurement (Panels B, C and D). For the entire table, the only difference not statistically equal to zero is an education category in only one specification.

Appendix C presents further checks on the underlying assumptions of the regression discontinuity.

Table 6: Balancing Test. Regression Discontinuity Design on Covariates before Receiving Nurse's Advice

$$X_i = \delta(BP_i \geq 0) + f(BP_i|BP_i < 0) + f(BP_i|BP_i \geq 0) + u_i$$

RDD on systolic BP standarized around the cut-off.

Dependent Variable at t	(1) Mean 1SD Below	(2) Loc Linear Rectang. h_1^*	(3) Loc Linear Triangular h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Panel A. Demographic Characteristics				
Age	52.42	-0.12	-0.10	0.06
N: 4276 ($h_1^* = 1.20$), *3366* ($h_2^* = 0.94$) , *3783* ($h = 1$)		(0.30)	(0.31)	(0.43)
Male	39.20%	-3.27	-3.72	-3.80
N: 3783 ($h_1^* = 1.01$), *2999* ($h_2^* = 0.79$) , *3783* ($h = 1$)		(3.62)	(3.67)	(4.94)
Non white ethnicity	25.16%	2.72	2.87	0.49
N: 2934 ($h_1^* = 0.82$), *2405* ($h_2^* = 0.65$) , *3697* ($h = 1$)		(3.69)	(3.74)	(4.56)
Educ: Some medium qualif.	43.30%	4.11	1.62	8.39*
N: 4374 ($h_1^* = 1.26$), *3560* ($h_2^* = 0.99$) , *3755* ($h = 1$)		(3.37)	(3.45)	(5.04)
Educ: Some high level or above qualif.	32.22%	-2.41	-1.79	-3.84
N: 4768 ($h_1^* = 1.37$), *3945* ($h_2^* = 1.08$) , *3755* ($h = 1$)		(2.99)	(3.02)	(4.62)
Married	76.21%	2.90	2.29	4.48
N: 3165 ($h_1^* = 0.87$), *2633* ($h_2^* = 0.68$) , *3783* ($h = 1$)		(3.40)	(3.43)	(4.34)
Panel B. Health-related Variables				
Diagnosed with any CVD-related condition	5.60%	-1.13	-1.19	-3.02
N: 4803 ($h_1^* = 1.39$), *3975* ($h_2^* = 1.09$) , *3783* ($h = 1$)		(1.42)	(1.48)	(2.24)
Self-reported GOOD health	82.55%	2.55	3.29	3.51
N: 2999 ($h_1^* = 0.83$), *2456* ($h_2^* = 0.65$) , *3783* ($h = 1$)		(3.17)	(3.21)	(3.94)
Self-reported bad health	8.56%	-2.54	-2.22	-3.21
N: 3783 ($h_1^* = 1.05$), *2999* ($h_2^* = 0.82$) , *3783* ($h = 1$)		(2.05)	(2.13)	(2.90)
SSP: Chances to live to age 75	68.56	0.74	0.53	1.53
N: 1356 ($h_1^* = 0.87$), *1099* ($h_2^* = 0.69$) , *1615* ($h = 1$)		(2.47)	(2.54)	(3.09)
(D) Valid BMI - inc estimated¿130kg	27.67	0.08	0.02	0.41
N: 3225 ($h_1^* = 0.91$), *2512* ($h_2^* = 0.72$) , *3627* ($h = 1$)		(0.39)	(0.40)	(0.50)
Waist-to-height ratio (WHtR)	0.57	0.00	0.00	0.01
N: 1504 ($h_1^* = 0.95$), *1165* ($h_2^* = 0.75$) , *1590* ($h = 1$)		(0.01)	(0.01)	(0.01)
Overweight or above	69.12%	3.32	3.17	7.14
N: 2686 ($h_1^* = 0.75$), *2134* ($h_2^* = 0.59$) , *3627* ($h = 1$)		(4.00)	(4.06)	(4.74)
Obesity I or above	26.77%	1.59	0.51	6.22
N: 4958 ($h_1^* = 1.53$), *4097* ($h_2^* = 1.20$) , *3627* ($h = 1$)		(2.97)	(3.00)	(4.73)

Continued on next page

Table 6: (Continued)

Dependent Variable at t	(1) Mean 1SD Below	(2) Loc Linear Rectang. h_1^*	(3) Loc Linear Triangular h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Blood HDL level (mmol/l)	1.54	-0.01	-0.00	-0.01
N: 2897 ($h_1^* = 1.13$), *2230* ($h_2^* = 0.89$) , *2653* ($h = 1$)		(0.03)	(0.04)	(0.05)
Blood total cholesterol level (mmol/l)	5.91	0.11	0.14	0.18
N: 2129 ($h_1^* = 0.82$), *1739* ($h_2^* = 0.64$) , *2658* ($h = 1$)		(0.11)	(0.11)	(0.14)
Panel C. Lifestyle				
Current smoker	20.31%	4.71*	3.54	3.84
N: 4401 ($h_1^* = 1.24$), *3581* ($h_2^* = 0.97$) , *3777* ($h = 1$)		(2.82)	(2.84)	(4.19)
Cigaretes per week (0 for non-smokers, includes rollups)	17.44	3.95	4.28	1.56
N: 4513 ($h_1^* = 1.32$), *3668* ($h_2^* = 1.03$) , *3668* ($h = 1$)		(3.43)	(3.36)	(5.28)
Alcohol twice a week or more	51.01%	0.99	-0.34	-0.89
N: 2465 ($h_1^* = 1.16$), *1940* ($h_2^* = 0.91$) , *2180* ($h = 1$)		(4.62)	(4.71)	(6.67)
Sedentary or low physical activity	16.15%	2.35	1.54	7.68
N: 2133 ($h_1^* = 1.42$), *1768* ($h_2^* = 1.11$) , *1628* ($h = 1$)		(3.74)	(3.79)	(5.74)
Portions of vegtables per day	6.02	0.95	1.11	1.31
N: 634 ($h_1^* = 0.81$), *515* ($h_2^* = 0.63$) , *808* ($h = 1$)		(1.21)	(1.19)	(1.43)
Portions of fruits per day	4.91	0.58	0.59	0.69
N: 1005 ($h_1^* = 1.33$), *812* ($h_2^* = 1.04$) , *812* ($h = 1$)		(0.62)	(0.68)	(0.81)
Panel D. Economic activity				
BU total yearly income (1000£ of May2005)	28.22	0.95	0.86	-0.49
N: 1418 ($h_1^* = 0.93$), *1080* ($h_2^* = 0.73$) , *1587* ($h = 1$)		(2.13)	(2.22)	(2.78)
BU total net (non-pension) wealth (1000£ of May2005)	320.16	91.91	80.78	99.78
N: 1331 ($h_1^* = 0.85$), *1013* ($h_2^* = 0.67$) , *1587* ($h = 1$)		(67.37)	(66.95)	(78.75)
Hours of work all jobs (employed or self employed)	37.61	-0.48	-0.64	-1.58
N: 1275 ($h_1^* = 1.04$), *1012* ($h_2^* = 0.82$) , *1275* ($h = 1$)		(1.74)	(1.76)	(2.52)

Sample: Respondents aged $\leq$60 years at the moment of the nurse's advice, who were not diagnosed with high blood pressure or had not been taking medication for lowering blood pressure.

Notes: Column 1 presents the mean of each dependent variable for those observations one standard deviation below the threshold. Columns 2-4 present different specifications for the trend (function $f(\cdot)$) between the outcome and systolic blood pressure. Robust standard errors are presented in parentheses. Significance: * 10%, ** 5%, *** 1%.

4.5 Conclusion

This paper analysed the impact of health checks, which is free of selection on demand for preventive care services, and that advise individuals with BP around a certain threshold to follow-up with a visit to their family doctor. Before continuing with the analysis, it is important to be clear that it is restricted to individuals with mildly elevated BP. This is relevant in terms of policy analysis as these are the most likely people to be affected by health checks for that specific condition. However, certain conclusions would be difficult to extrapolate to other conditions in terms of behavioural response, with higher risks of further complications, and may be be different.

The first main question raised through this paper is the impact of the advice on early detection of hypertension. Results show a large and significant impact of the advice on the probability to report having been diagnosed with HBP and to receive BP medication. However, the effect is temporal; in around 4 years the difference cannot be distinguished from zero.

The second aspect open for discussion is the impact on lifestyle. Guidelines suggest a lifestyle intervention that curbs smoking, bad dietary habits and heavy alcohol consumption. A clear impact in this direction is found for drinking frequency. One of the central aspects of analysis of preventive care interventions is the complementarity or substitutability between health care and lifestyle modification; independence of health investments could not be rejected. In fact, the heterogeneity analysis signals that improvement in lifestyle seems to be restricted to those with low CVD risk, while medication is preferred by individuals with high CVD risk. This indicates that patients (and their doctors) select their investment based on the underlying risk.

In terms of lifestyle investment, there is an interesting exception for smokers. Steptoe and McMunn (2009) showed that hypertensive individuals within ELSA smoke less and drink more than non-hypertensive individuals. However, in this paper, which focuses on individuals on the borderline of diagnosis, the exact opposite was found. While there is an improvement in heavy drinking patterns, average cigarette consumption of those diagnosed is greater for those who received advice. More importantly, and which is related to selection into demand for preventive health care, is the finding that the reduction in heavy drinking was persistent. This means that even small information-based campaigns may have long-term effects on lifestyle choices.

Finally, whether the advice had a positive effect on respondents' health after nearly 4 years is an unresolved question. None of the effects on BP, cholesterol levels, or blood sugar are statistically different from zero. However, this may owe to the lack of power for detecting small variations, due to the limited sample size of this observational study.

These findings complement the results of Kaestner et al. (2014) on the use of statins, where an increase in obesity was found, yet at the same time physical activity increased for men. Such results can also be contrasted with Fichera et al. (2016), who found that an increase in the quality of medical services in England improved behaviour, including smoking and heavy drinking. When pooling together this evidence, risk compensation and complementary health-investment mechanisms are likely to be relevant elements to consider in preventive care policies. This shows that while the main response to early detection of HBP concerns the use of medication, individuals (and their family doctors) do consider lifestyle investments, such as reducing alcohol intake frequency. Nevertheless, while there was no evidence of risk compensation, the higher consumption of cigarettes for those who received the advice indicates that this particular group may require greater attention.

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A Sample selection

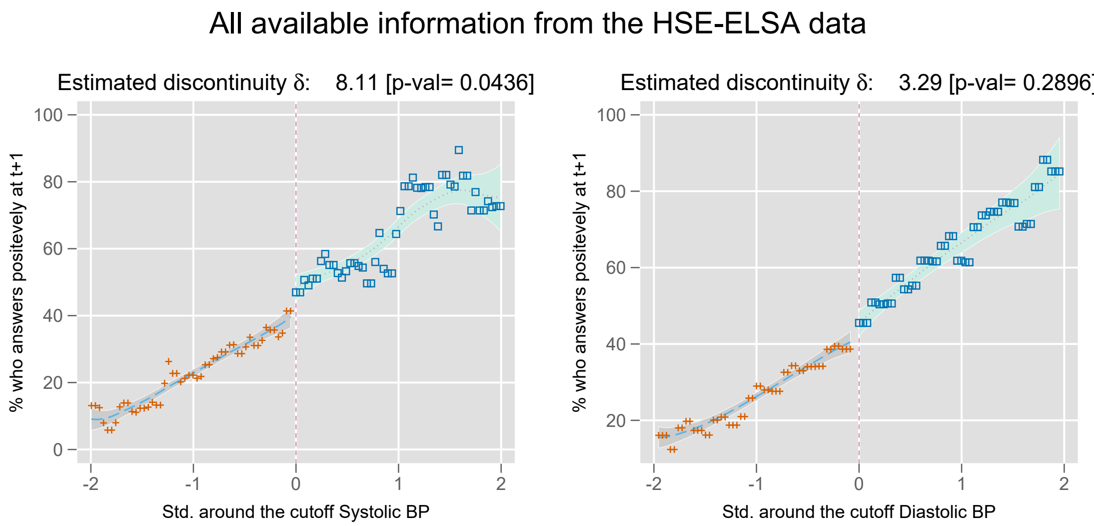
The analysis is carried out on a subset of all available data from the HSE-ELSA data. Individuals not diagnosed with high blood pressure (HBP) or diabetes, and not taking BP-lowering medication[27] are selected. Even though this greatly reduces the sample size, such restriction avoids potential biases, as individuals above the threshold are more likely to report to be diagnosed with HBP before the nurse visit.

Using all the data, the jump estimator for the systolic BP is approximately 8.1 percentage points while for the diastolic it is 3.3 percentage points. Only the first statistically differs from 0. However, Figure 9 shows there may be a potential bias. The outcome is measured at the baseline instead of reporting the proportion of those reported having HBP at the following wave; that is, what was reported before the nurses visited. The same pattern is present: a jump of 5 pp. for both systolic and diastolic BP. While such estimates are not significant under the considered specifications, the coefficient is large enough to attribute other effects to this pre-existent discontinuity. If we consider BP medication instead of the self-reported diagnosis, the difference is actually in the opposite direction (Figure 10).

As a result, to avoid the potential bias provided by pre-existing jumps on the running variable, I restrict the sample to only the new cases, at the expense of larger standard errors.

[27] In ELSA, everyone who is asked about BP medication reports being diagnosed with HBP by design of the survey. That is not the case for the HSE, wherein the analysis of medication is much more detailed.

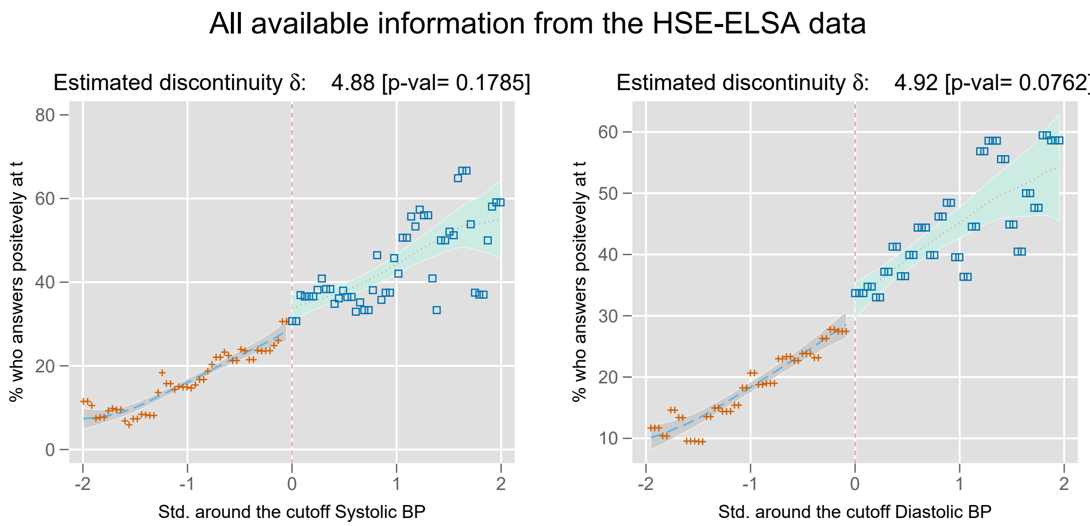
Figure 8: Nurse Advice and Self-report of High Blood Pressure at the Following Wave



Sample: Individuals aged $\leq$58 years from HSE-ELSA data.

Notes: Calculations using a quadratic function within 1 standard deviation of the cutoff. A 90% confidence interval is presented. Significance level: *90%, ** 95%, *** 99%

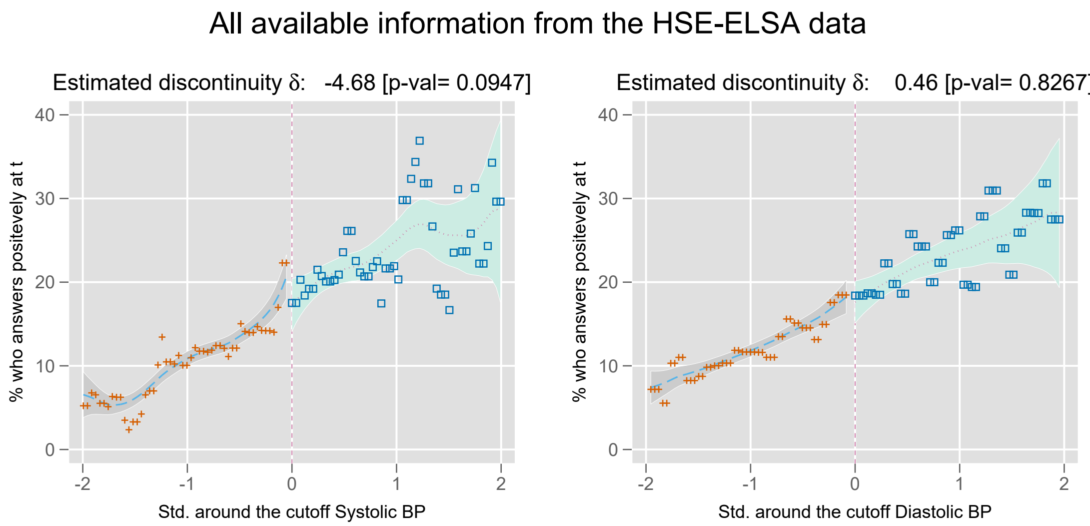
Figure 9: Nurse Advice and Self-Report of High Blood Pressure at the Same Wave (Balance Test)



Sample: Individuals aged 58 or younger from HSE-ELSA data.

Notes: Calculations using a quadratic function within 1 standard deviation of the cut-off. A 90% confidence interval is presented. Significance level: *90%, ** 95%, *** 99%

Figure 10: Nurse Advice and BP Medication in the Same Wave (Balance Test)



Sample: Individuals aged $\leq$58 years from HSE-ELSA data.

Notes: Calculations using a quadratic function within 1 standard deviation of the cut-off. A 90% confidence interval is presented. Significance level: *90%, ** 95%, *** 99%

B Alternative Specifications

There are many ways to implement the strategy. The general idea is to choose the parameters that minimize the distance between the observed outcome and the prediction from a model m, giving different weights K to each observation i as shown in Equation 3. Such a model, characterized by a set of parameters α, δ and restrictions, takes into account the relation between Y_{t+1} and the BP index BP_t^c measured at wave t and standardized according to the relevant advice cut-off c (changing according to the year of the survey, sex and age, as described before). The weights K are assigned using an arbitrary rule based on the forcing variable BP_t^c. The simplest specification gives equal importance to all observations between 0 and h standard deviations, and disregards the remaining data (rectangular kernel). A common alternative is the triangular kernel, wherein the relevance of observations decays linearly. For the main results, the value of h is determined following the rule of Imbens and Kalyanaraman (2011).

$$\min_{\{\delta,\alpha\}} \sum_{i=1}^{N} K(BP^c_{it}/h)(Y_{i,t+s} - m(\delta,\alpha,BP^c_{i,t}))^2 \quad , s \in \{1,2\} \tag{3}$$

The model m specifies how BP and the outcomes are related, and in particular the parameter of interest; the difference δ between being above or below the cut-off. The relationship can be allowed to differ above and below the threshold, as shown in Equation 4. In this expression, α is allowed to be specific above and below $BP^c_{it} \geq 0$, a condition defined by the dichotomous variables W_{it}. The implementation was carried out following Nichols (2012), under different bandwidths and specifications for f.

$$m(\delta,\alpha,BP^c_{i,t}) = \delta W_{it} + \alpha_0 + f_l(\alpha_l, BP^c_{i,t}|W_{it}=0) + f_r(\alpha_r, BP^c_{i,t}|W_{it}=1) \tag{4}$$

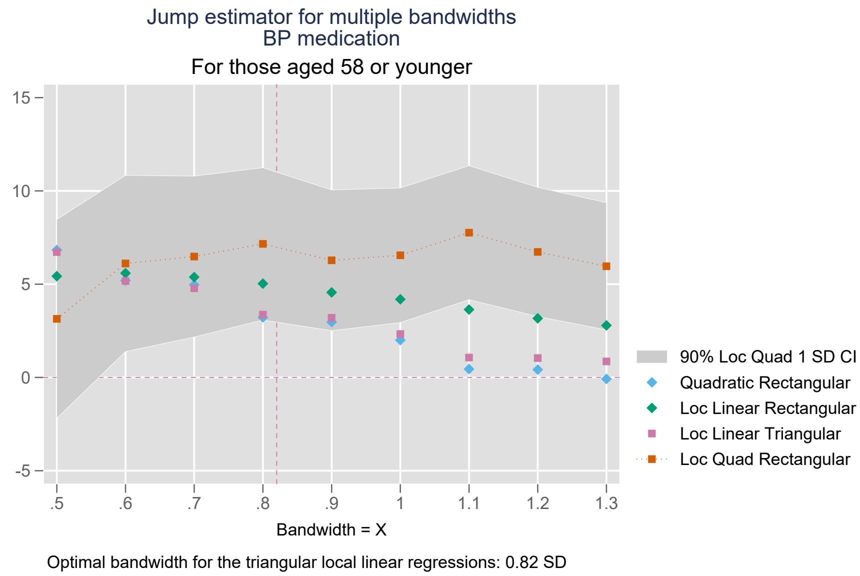
Results are presented using three specifications for $f(\cdot)$:

- Local linear regressions: $f_l = \alpha^l_1 BP^c_{i,t}$ and $f_r = \alpha^r_1 BP^c_{i,t}$. Triangular and rectangular weights are considered. They differ in that triangular weights place great importance on the observations close to the threshold.
- Local quadratic function: using rectangular weights, $f_l = \alpha^l_1 BP^c_{i,t} + \alpha^l_2 {BP^c_{i,t}}^2$ and $f_r = \alpha^r_1 BP^c_{i,t} + \alpha^r_2 {BP^c_{i,t}}^2$.

C Further Robustness Checks

A typical concern with non-parametric estimators is their potential dependence on *ad hoc* parameters. In this particular case, the jump estimator may be very sensitive to the 'bandwidth' selection. Optimal selection procedures such as that presented by (Imbens and Kalyanaraman, 2011) help to determine a proper value for it. Nevertheless, the question on sensitivity is still present. Figure 11 presents the case of use of BP-lowering medication for different values of the parameter, the horizontal axis, and across multiple specifications. As a reference, the optimal bandwidth is highlighted by a vertical line and a 95% confidence interval, which corresponds to the local linear triangular kernel. We can observe that the estimated values of the jump change notoriously according to the underlying assumption but results are relatively stable close to the optimal one.

Figure 11: Jump Estimator for Multiple Bandwidths (Blood Pressure Medication)



One concern may be that the nurses registered a value $\geq$ 140 mmHg for individuals with BP levels slightly below it. This would have been translated into a discontinuity in terms of the density at the threshold. Though the reasons for this potential manipulation are not clear, the McCrary (2008) test can assess whether that is the case. The test creates a histogram of the BP and defines the mid-point of each bin as the dependent variable of the RDD (measured in standard deviations around the mean). Table 8 presents the estimator of the jump θ for different bin sizes around the optimal one. There is no evidence of a discontinuity in the density at such a point.

Table 7: RDD sample restrictions

$$X_i = \delta(BP_i \geq 0) + f(BP_i|BP_i < 0) + f(BP_i|BP_i \geq 0) + u_i|BP_i \notin \Omega$$

RDD on systolic BP standarized around 140 mmHgDependent variable: whether diagnosed with HBP in the follow-up, conditional on not been diagnosed before with HBP or being taking medication for blood pressure.

Restriction Ω	(1) Quadratic 1 SD	(2) Loc Linear Rectangular h^*	(3) Loc Linear Triangular h^*	(4) Local Quad 1 SD	(5) Local Quad 2 SD
Without restriction	2.00	4.91***	3.37**	6.55***	2.81
N: 2504 ($h^* = 0.82$), *3161* ($h = 1$) , *4880* ($h = 2$)	(1.65)	(1.81)	(1.68)	(2.20)	(1.82)
Taking out 139 mmHg†	2.04	5.24***	3.55**	7.19***	2.96
N: 2428 ($h^* = 0.83$), *3085* ($h = 1$) , *4804* ($h = 2$)	(1.69)	(1.78)	(1.69)	(2.22)	(1.82)
Taking out 140 mmHg†	0.68	3.80*	3.22*	5.87**	0.97
N: 2259 ($h^* = 0.76$), *3080* ($h = 1$) , *4799* ($h = 2$)	(1.75)	(1.96)	(1.80)	(2.61)	(2.10)
Taking out 141 mmHg†	2.25	6.70***	6.56***	7.67***	3.13
N: 1614 ($h^* = 0.56$), *3104* ($h = 1$) , *4823* ($h = 2$)	(1.80)	(2.57)	(2.24)	(2.52)	(2.05)
Taking out 139-141 mmHg†	0.75	6.15**	5.29**	8.83**	1.04
N: 1646 ($h^* = 0.60$), *2947* ($h = 1$) , *4666* ($h = 2$)	(2.02)	(2.92)	(2.55)	(3.51)	(2.57)

† For males aged 50 or over in wave 0, the values are 159, 160 and 161 mmHg. Robust SE in parenthesis. Significance: * 10%, ** 5%, *** 1%.

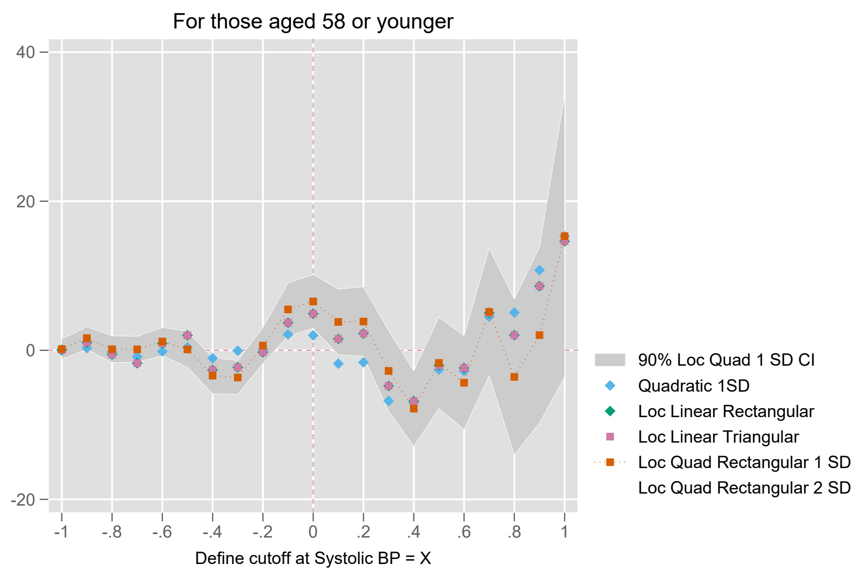
Table 8: McCrary Test for those aged $\leq$ 58 years

	Bin Size (Std Dev)										
	0.011	0.013	0.015	0.018	0.020	**0.022** †	0.024	0.026	0.028	0.031	0.033
θ	-0.02	-0.01	-0.01	0.00	0.01	0.01	0.02	0.02	0.04	0.04	0.05
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)

Standard errors in parentheses. Significance: * 10%, ** 5%, *** 1%. McCrary test on the continuity of the density at the threshold. Triangular kernels are fitted on the means of the bins of a particular bin size. The optimal bin size (†) and, the bandwidths are chosen following McCrary implementation of the test.

A further test consists of considering placebo discontinuities. In other words, given the index of standardized systolic BP, it is possible to perform the exercise, but assuming the jump is at values different from 0. Figure 12 shows that the only values in which a discontinuity is observed are those around 0. If anything, the placebo analysis finds negative 'jumps' in -0.4 and 0.4 standard deviations, which come from the induced slope of including observations both above and below the threshold.

Figure 12: Placebo jumps over Std. Systolic BP index (BP medication)



A final test consists of including controls in the regressions. Normally these should not affect the results in any way. Table 9 presents such a regression for the case of medication. Essentially, there are no noticeable changes; the significance is only affected when the sample size is reduced because of the availability of information.

Table 9: Regression Discontinuity Design Including Covariates for Those aged $\leq$ 58 years: Takes Blood Pressure Medication

$$Y_i = \delta(BP_i \geq 0) + f(BP_i|BP_i < 0) + f(BP_i|BP_i \geq 0) + X_i\beta + u_i$$

RDD on systolic BP standarized around the value. Dependent variable: Takes BP medication, conditional on not been diagnosed before with HBP or being taking medication for blood pressure.

Dependent Variable at $t+1$	(1) Mean	(2) Loc Linear Rectang. h_1^*	(3) Loc Linear Triangular h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Without controls	3.07%	4.91***	5.10***	6.55***
N: 2504 ($h_1^* = 0.82$), *2041* ($h_2^* = 0.65$) , *3161* ($h = 1$)		(1.81)	(1.76)	(2.20)

Continued on next page

Table 9: (Continued)

Dependent Variable at $t+1$	(1) Mean	(2) Loc Linear Rectang. h_1^*	(3) Loc Linear Triangular h_2^*	(4) Loc Quad Rectang. $h = 1SD$
Demographic	3.08%	4.77^{***}	5.11^{***}	6.59^{***}
N: 2496 ($h_1^* = 0.82$), *2036* ($h_2^* = 0.65$) , *3151* ($h = 1$)		(1.79)	(1.76)	(2.19)
+ Health and Behaviour	3.01%	4.97^{***}	5.22^{***}	6.69^{***}
N: 2389 ($h_1^* = 0.82$), *1944* ($h_2^* = 0.65$) , *3026* ($h = 1$)		(1.88)	(1.84)	(2.28)
+ Health and Behaviour (extended)	3.09%	4.87^{*}	4.79	5.71^{*}
N: 868 ($h_1^* = 0.82$), *698* ($h_2^* = 0.65$) , *1102* ($h = 1$)		(2.81)	(2.98)	(3.36)

Robust standard errors in parentheses. Significance: * 10%, ** 5%, *** 1%. Demographic characteristics: Age, sex, ethnicity, education level, marital status. Health and Behaviour: to report to be on bad health, body mass index, any parental cardiovascular diseases-related death, smoking status. Extended variables: cholesterol (total and HDL), Framingham cardiovascular diseases risk, alcohol and physical activity levels.