Preventive Medicine 172 (2023) 107520

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Effects of being eligible for specific health guidance on health outcomes: A regression discontinuity analysis using Japan's data on specific health checkups

Yoichi Sekizawa

Research Institute of Economy, Trade, and Industry, Chiyoda-ku, Kasumigaseki 1-3-1, Tokyo 100-8901, Japan

A R T I C L E I N F O

Keywords:
Specific health checkup
Specific health guidance
Regression discontinuity design
Body mass index
Waist circumference
Japan

A B S T R A C T

The significance of general health checkups and guidance is controversial. To examine the effectiveness of Japan's specific health checkup (SHC) and specific health guidance (SHG) programs, this study applied a regression discontinuity design (RDD) using the SHC results database collected by a private company. We applied a sharp RDD with a cutoff body mass index (BMI) of 25 kg/m^2 for those with a waist circumference (WCF) of <85 cm in men and < 90 cm in women, with risks of hypertension, dyslipidemia or diabetes, and aged between 40 and 64 years. Study outcomes were differences in BMI, WCF, and major cardiovascular risk factors between the baseline year and the following year. We analyzed the data of baseline years of 2015, 2016, and 2017 separately and their pooled data. We judged the results to be robust significant when significant results in the same direction were found in all four analyses. A total of 1,041,607 observations out of 614,253 people were analyzed. We found robust significant results that those eligible for SHG in the baseline year had a lower BMI (both men and women) and lower WCF (men only) in the following year than those not eligible for SHG: BMI for men (−0.12 kg/m^2, 95% CI [confidence interval]: −0.15 to −0.09); BMI for women (−0.09 kg/m^2, 95% CI: −0.13 to −0.06); and WCF for men (−0.36 cm, 95% CI: −0.47 to −0.28) in the pooled data. Robust significant results were not found in WCF for women or in major cardiovascular risk factors.

1. Introduction

Health checkups and guidance programs are used in some countries to promote health among the general public without sufficient evidence of their effectiveness on major cardiovascular diseases and all-cause mortality (Jorgensen et al., 2014; Krogsbøll et al., 2019; Liss et al., 2021). Investigating the effectiveness of these programs is difficult since they are conducted nationwide without prior rigorous evaluation using large randomized controlled trials. However, a regression discontinuity design (RDD) may examine the effects of such programs (Venkataramani et al., 2016). An RDD is applied when an intervention is only conducted when a variable (running variable) measure in people is over a specific cutoff value (Cattaneo et al., 2019). An RDD can examine the effects of interventions on outcome variables around the cutoff.

This study aimed to examine whether eligibility for health guidance, determined by the results of annual health checkups, causes a change in body mass index (BMI, calculated by dividing body weight in kilograms by height in meters squared), waist circumference (WCF), and major cardiovascular risk factors in the next year. Japan has a national health screening and intervention program (NHSIP), consisting of a specific health checkup (SHC) and specific health guidance (SHG) covering the general public aged 40–74 years (Kohro et al., 2008; Ministry of Health, Labor, and Welfare, 2013). To our knowledge, three studies on the NHSIP using RDDs have been published (Fukuma et al., 2020; Narisada et al., 2022; Sekizawa et al., 2020). Fukuma et al. (2020) applied a fuzzy RDD, in which treatment probability jumps at the cutoff, using WCF as the running variable. Narisada et al. (2022) applied a sharp RDD, in which treatment status is solely determined by the cutoff, using age 40 as the running variable and the cutoff. We applied a sharp RDD using BMI and WCF as the running variables, building upon Sekizawa et al. (2020).

Abbreviations: RDD, Regression discontinuity design; BMI, Body mass index; WCF, Waist circumference; NHSIP, National health screening and intervention program; SHC, Specific health checkup; SHG, Specific health guidance; IHG, Intensive health guidance; MEG, Motivation-enhancing guidance; JMDC, Japan medical data center co., ltd.; HDL-C, High-density lipoprotein cholesterol; LDL-C, Low-density lipoprotein cholesterol; CI, Confidence interval..

E-mail address: sekizawa-yoichi@rieti.go.jp.

https://doi.org/10.1016/j.ypmed.2023.107520
Received 11 August 2022; Received in revised form 24 March 2023; Accepted 24 April 2023
Available online 1 May 2023

2. Methods

2.1. Japan's NHSIP

The NHSIP was initiated in April 2008 by the Japanese government and has been implemented by health insurance societies (Ministry of Health, Labor, and Welfare, 2013). This program intends to identify people with obesity and cardiovascular risks (known as metabolic syndrome [Teramoto et al., 2008]) using SHC and provide them with SHG to prevent lifestyle-related diseases. Most adults aged 40–74 years are eligible for SHC and are encouraged to complete it yearly. Those found to be at a high risk of metabolic syndrome using SHC are eligible for SHG and are urged to receive it.

SHG comprises intensive health guidance (IHG) and less intensive motivation-enhancing guidance (MEG), and is intended to improve the lifestyle of its participants (Ministry of Health, Labor, and Welfare, 2013). Eligibility for SHG is determined by the individual's WCF, BMI, current smoking status, and risks for hypertension, dyslipidemia, and diabetes (Table 1). Those on medication for hypertension, dyslipidemia, or diabetes are exempt from SHG.

2.2. Data source and ethics approval

The Japan Medical Data Center Co., Ltd. (JMDC) collected data on SHC from health insurance societies and created a database (the JMDC database), which we used in this study (Nagai et al., 2021). Considering that Japan's fiscal year is from April to March, data from April 2014 till March 2019 were used. We limited the analyzed participants to those aged 40–64 years because the rules of assignment to SHG differ for those over 65 and the JMDC database mainly covers currently employed people and their family members. The first checkup data in the fiscal year was included in cases where the same participants underwent the general health checkup twice or more in a fiscal year, while others were excluded.

Ethical approval was not required according to the Ethical Guidelines for Medical and Biological Research Involving Human Subjects by the Japanese government since this study used only anonymous data obtained from the JMDC on a fee-paying basis.

2.3. Study design and participants

Unlike typical RDDs, this study has two running variables: WCF and BMI. We conducted separate analyses for the two running variables following the suggestions by Wong et al. (2013) and Porter et al. (2017). We created two groups of study participants: WCF group and BMI group. The inclusion criteria for the two groups are shown in Table 2. Study participants in the WCF group were compared using the RDD, considering a cutoff WCF of 85 cm. Participants with WCF <85 cm were provided with their health information, including the results of their SHC, while those with WCF ≥85 cm were eligible for SHG and were urged to receive it. Participants in the BMI group were compared using the RDD, considering a cutoff BMI of 25 kg/m^2.

Table 1
Factors to determine the eligibility for SHG.

WCF and BMI	Number of additional risks	Current smoking	Type of health guidance: Age 40 to 64	Type of health guidance: Age 65 to 74
Men: WCF ≥85 cm	Two or three	Yes or no	IHG	MEG
Women: WCF ≥90 cm	One	Yes	IHG	MEG
		No	MEG	MEG
Men: WCF <85 cm and	Three	Yes or no	IHG	MEG
BMI ≥25 kg/m^2	Two	Yes	IHG	MEG
Women: WCF <90 cm		No	MEG	MEG
and BMI ≥25 kg/m^2	One	Yes or no	MEG	MEG

Note. The additional risk was calculated as the sum of the risks for hypertension (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg), dyslipidemia (triglycerides ≥150 mg/dL or high-density lipoprotein cholesterol [HDL-C] <40 mg/dL), and diabetes (fasting blood glucose ≥100 mg/dL or hemoglobin A1c ≥5.6%). Those on medication for hypertension, dyslipidemia, or diabetes are exempt from SHG. SHG, specific health guidance; BMI, body mass index; WCF, waist circumference; IHG, intensive health guidance; MEG, motivation-enhancing guidance.
(Source) Ministry of Health, Labor, and Welfare (2013).

2.4. Outcomes

The primary outcomes were differences in BMI and WCF between the baseline year and the following year (for example, BMI in 2017 – BMI in 2016). Other outcomes were differences in systolic blood pressure (mmHg), diastolic blood pressure (mmHg), hemoglobin A1c (%), HDL-C (mg/dL), and low-density lipoprotein cholesterol (LDL-C) (mg/dL) between the baseline year and the following year. In the JMDC database, WCF and BMI are indicated to the first decimal place, as determined by the Ministry of Health, Labor and Welfare (2013).

2.5. Statistical analysis

Before applying an RDD, it is necessary to confirm that the running variables are not manipulated around the cutoff (Cattaneo et al., 2019). In addition to visual checks by the histograms around the cutoff, we conducted statistical manipulation tests proposed by Cattaneo et al. (2020). In a previous study similar to ours (Sekizawa et al., 2020), the WCF group was unsuitable for RDD analyses. Hence, we conducted manipulation testing prior to other analyses.

Upon confirmation by testing that there was no evidence of manipulation, analyses based on the RDD were performed following Cattaneo et al. (2019). We implemented a local linear regression to estimate the effects of being eligible for SHG on outcome measures at the cutoff. We used a triangular kernel function, where points near the cutoff were more heavily weighted than those distant from the cutoff. To select the bandwidth, we used the mean square error optimal bandwidths proposed by Calonico et al. (2014). In our analyses, covariate adjustments were not conducted because they are not necessary for the RDD

Table 2
Inclusion Criteria for the two groups to apply RDDs.

Groups	Inclusion criteria	Running variable	Cutoff
WCF group	1. Aged 40–64 years in the baseline year 2. With one or more risks for hypertension (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg), dyslipidemia (triglycerides level ≥ 150 mg/dL or HDL-C < 40 mg/dL), and diabetes (fasting blood glucose level ≥ 100 mg/dL or hemoglobin A1c ≥5.6%) 3. Completed SHC in the baseline year and the following year 4. Not receiving medications for hypertension, dyslipidemia, or diabetes in the baseline year 5. With a BMI <25 kg/m^2	WCF	85 cm in men and 90 cm in women
BMI group	1–4 are the same as for the WCF group. 5. With a WCF of <85 cm for men (<90 cm for women)	BMI	25 g/m^2

Note. RDD, regression discontinuity design; WCF, waist circumference; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; SHC, specific health checkup.

(Cattaneo et al., 2019). We analyzed the data of baseline years of 2015, 2016, and 2017 separately and their pooled data. We judged the results to be robust significant when significant results in the same direction were found in all four analyses. We clustered standard errors by individuals for the analyses of the pooled data since the same individuals were observed repeatedly in different baseline years.

We applied RDDs with cutoffs WCF of 84 and 86 cm and cutoffs BMI of 24 and 26 kg/m^2 as placebo tests. We examined the effect of being eligible for SHC on attrition to assess attrition bias. We defined an outcome variable in which the value for those who participated in SHC at the baseline year and did not next year was one and zero otherwise, and conducted a similar RDD analysis.

Several secondary analyses were performed. First, we limited the study participants to those not eligible for SHG and not on medication for hypertension, dyslipidemia, or diabetes one year before the baseline year to determine the effects of being newly eligible for SHG. Second, we conducted the same analyses as our main analyses for IHG and MEG separately. Third, outcome measures were changed to those two years after the health checkup to examine the effects of longer follow-ups. In this case, baseline years were set at 2014, 2015, and 2016 and the pooled data from 2014 through 2016.

Analyses were conducted separately for men and women. We reported 95% confidence intervals (CI) and p-values based on the robust bias-corrected standard errors proposed by Cattaneo et al. (2019). All analyses were performed using the 'rddensity,' 'rdrobust,' and `rdplot' commands (Calonico et al., 2017; Cattaneo et al., 2018) with Stata 15 (Stata Corp, College Station, TX, USA). Statistical significance was set at $p < 0.05$.

3. Results

3.1. Results of manipulation testing

Distributions of WCF for the WCF group and BMI for the BMI group around the cutoff are shown in Fig. 1. Non-random heaping, which can lead to biased estimates (Barreca et al., 2016), was found for the WCF group. There was no graphical evidence of manipulation for the BMI group. Manipulation tests for the WCF group rejected the null hypothesis of no manipulation (Table 3). Manipulation tests for the BMI group didn't reject the null hypothesis except for women in the baseline year 2015. Considering the existence of non-random heaping and the possibility of manipulation in the WCF Group, we limited our analyses to the BMI Group, in which the eligibility for SHG was determined by BMI ≥25 kg/m^2.

3.2. Participant characteristics

Fig. 2 shows a study flow chart that extracts analyzed participants for the pooled data from 2015 to 2017 and from 2014 to 2016 as the baseline years. The JMDC database has 13,157,681 observations out of 3,233,271 persons. Those who met the criteria of the BMI group were 1,041,607 (636,940 men and 404,667 women) observations out of 614,253 persons (369,023 men and 245,230 women). Percentages of the participants who had records of receiving SHC the next year are shown in Table 4 (the percentages for two later years are shown in Supplementary Table 1). The percentages were 91.7% for men and 85.6% for women in the pooled data from 2015 to 2017. Participants'

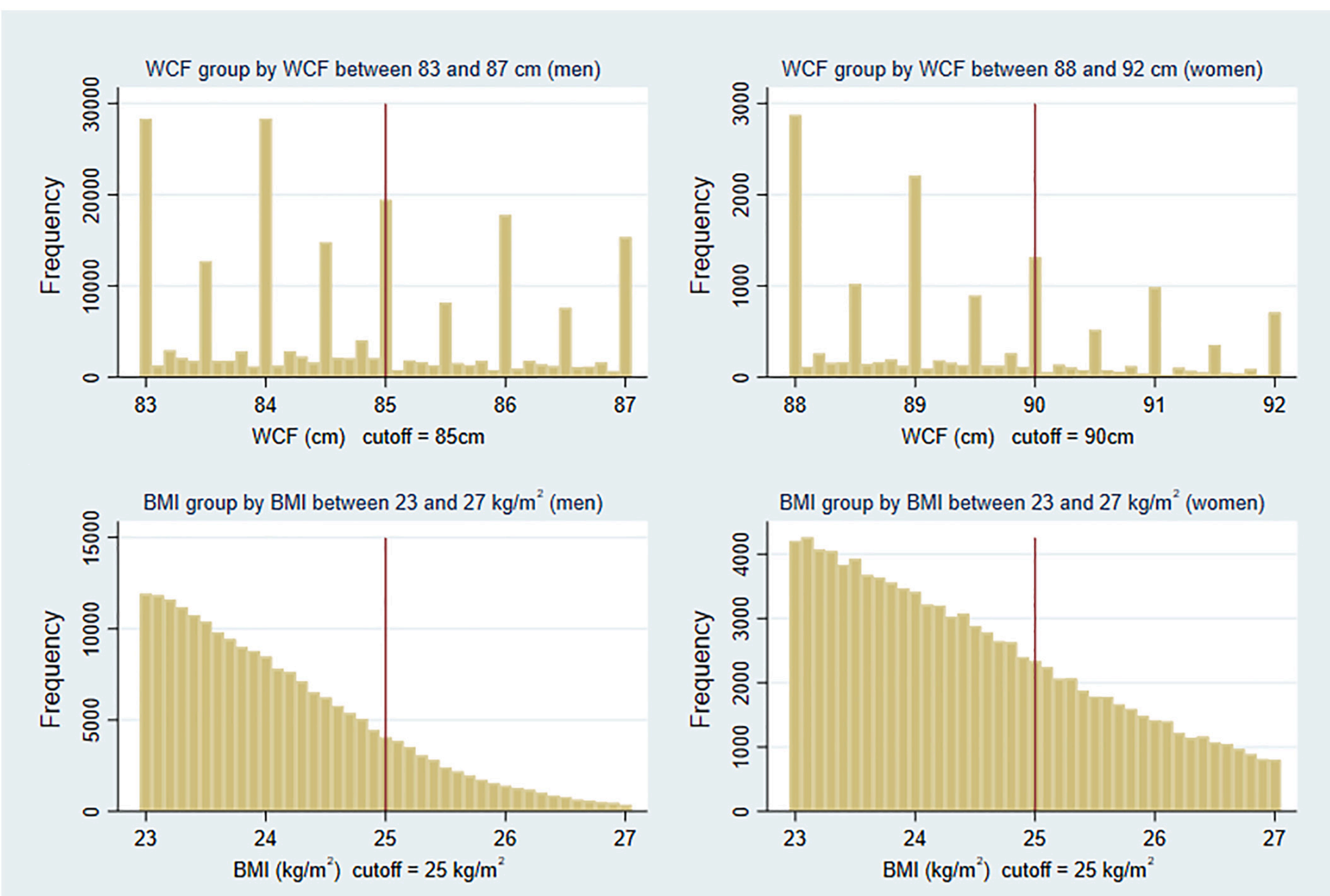

Fig. 1. Distribution of the WCF group and the BMI group around the cutoffs.
Note. Inclusion criteria for the WCF group and the BMI group are shown in Table 2. Pooled data of the baseline years from 2015 through 2017 are shown. WCF, waist circumference; BMI, body mass index.

Table 3
Results of statistical manipulations tests.

Running variable and group	Sex and cutoff	Baseline year	*t* value	*p* value	Total observation
WCF	Men	2015–7	39.40	<0.001	776,018
(cm)		2015	19.57	<0.001	229,958
	Cutoff	2016	23.76	<0.001	263,859
WCF group	=85	2017	24.70	<0.001	282,201
	Women	2015–7	13.83	<0.001	370,262
		2015	7.39	<0.001	103,822
	Cutoff =	2016	7.82	<0.001	124,525
	90	2017	8.71	<0.001	141,915
	Men	2015–7	1.18	0.237	636,940
		2015	1.33	0.184	189,161
BMI	Cutoff =	2016	0.55	0.584	217,382
(kg/m^2)	25	2017	0.24	0.814	230,397
	Women	2015–7	−1.10	0.272	404,667
BMI group		2015	−2.26	0.024	112,920
	Cutoff =	2016	0.34	0.731	136,170
	25	2017	−0.19	0.852	155,577

Note. Manipulation tests were conducted based on Cattaneo et al. (2018). Inclusion criteria for the WCF group and the BMI group are shown in Table 2. WCF, waist circumference; BMI, body mass index.

characteristics are listed in Table 5. Those eligible for SHG were 575,526 men and 108,816 women out of the total observations of those aged 40–64 years and having observations in the following year. Those eligible for the RDD analyses were 38,687 men (6.7%) and 42,116 women (38.7%) out of those eligible for SHG.

3.3. Results of main RDD analysis

Participants' characteristics in the baseline years (pooled data) within the bandwidths for the outcome variable BMI are shown in Supplementary Table 2. The effects of being eligible for SHG estimated using RDD analyses are shown in Table 6 and Fig. 3. Men eligible for SHG had significantly lower BMI (−0.12 kg/m^2, 95% CI: −0.15 to −0.09) and WCF (−0.36 cm, 95% CI: −0.47 to −0.28) in the following year than those not eligible in the pooled data of 2015 through 2017. Women eligible for SHG had significantly lower BMI (−0.09 kg/m^2, 95% CI: −0.13 to −0.06) than those not eligible for SHG. Significant results were also found separately for 2015, 2016, and 2017. Hence, these results were robust significant. Women eligible for SHG had significantly lower WCF in the pooled data, but significant results were not observed in the baseline years of 2015 and 2016. Hence, the results on female WCF were not robust significant.

Those eligible for SHG had significantly lower systolic blood pressure, diastolic blood pressure (men only), hemoglobin A1c, and LDL-C and significantly higher HDL-C (men only) in the following year than those not eligible for SHG in the pooled data. However, these results were not consistently observed in each of the three baseline years. Hence, these results were not robust significant.

3.4. Results of secondary analyses

Analyses limited to participants not eligible for SHG and not receiving medications for hypertension, dyslipidemia, or diabetes in the previous year showed similar results to those of the main analyses (Supplementary Table 3).

Effects of being eligible for IHG and MEG are shown in Supplementary Tables 4 and 5, respectively. Men but not women eligible for IHG had significantly lower BMI and WCF in the following year than those not eligible in the pooled data and all of the data for each year separately. Those eligible for MEG had significantly lower BMI and WCF (men only) in the following year than those not eligible in the pooled data and all of the data for each year separately. For other outcome measures, robust significant results were not observed.

In the analyses of participants two years after the baseline year, no differences were present in BMI and WCF (Supplementary Table 6). For other outcome measures, robust significant results were not observed.

3.5. Results of placebo tests and attrition analyses

Placebo tests with cutoff BMIs of 24 kg/m^2 and 26 kg/m^2 are shown in Supplementary Tables 7 and 8, respectively. Robust significant results were not observed for any outcome variable for both cutoffs. Results of attrition analyses are shown in Supplementary Table 9. Women eligible for SHG had significantly lower attrition rates than those not eligible in the pooled data. However, these results were not consistently observed in each of the three baseline years. Therefore, these results were not robust significant.

4. Discussion

To analyze the effectiveness of Japan's health checkup and guidance program, this study applied an RDD with a cutoff BMI of 25 kg/m^2 for participants with WCF <85 cm in men (<90 cm in women), at risk for hypertension, dyslipidemia, or diabetes, and aged between 40 and 64 years. We found robust significant results that those eligible for SHG in the baseline year had a lower BMI (both men and women) and WCF (men only) in the following year than those not eligible for SHG. Robust significant results were not found in WCF for women and major cardiovascular risk factors.

This study has the following unique characteristics compared with the previous RDD studies exploring the effect of NHSIP (Fukuma et al., 2020; Narisada et al., 2022; Sekizawa et al., 2020). Fukuma et al. (2020) used WCF as the running variable and applied a fuzzy RDD using the whole sample, including those whose treatment status is not determined by the cutoff. This study used BMI as the running variable and applied a sharp RDD after excluding those whose treatment status was not determined by the cutoff. According to the terminology of Reardon and Robinson (2012), the approach of Fukuma et al. (2020) is termed "fuzzy frontier RD," whereas that of our study is termed "frontier RD." Although the fuzzy frontier RD sounds attractive in increasing sample size (Reardon and Robinson, 2012), Wong et al. (2013) and Porter et al. (2017) recommend against using it based on the results of simulation studies. Hence, studies utilizing the frontier RD like this study may be more appropriate than Fukuma et al. (2020). Another major difference between Fukuma et al. (2020) and this study is that Fukuma et al. used WCF as the running variable. This study suggests that WCF may not be appropriate as the running variable due to non-random heaping (Barreca et al., 2016) and possible manipulation around the cutoff. BMI, which is determined by mechanically measurable body weight and height unlike WCF, seems less easy to manipulate than WCF. Hence, using BMI rather than WCF as the running variable may be more appropriate in the RDD study working on SHC and SHG. Narisada et al. (2022) mainly focused on the status of diabetes and compared those just under age 40 and just over 40 using the cutoff of 40. Hence, the study differs from this one which uses BMI as the running variable and focuses on changes in BMI and other cardiovascular risks. This study builds upon Sekizawa et al. (2020). A major difference between the two studies is that Sekizawa et al. analyzed only the IHG of men with a total sample size of approximately 20,000, which was far smaller than that in this study.

Several studies explored the effects of SHG using methodologies other than RDDs (Nakao et al., 2018; Takeuchi et al., 2020; Tsushita et al., 2018). They compared participants in SHG with non-participants out of those eligible for SHG, unlike the RDD studies such as this one. Therefore, direct comparisons between those studies and this study are inappropriate. One concern for these previous studies is that they may contain self-selection biases because participation in SHG is not obligatory. In the study by Nakao et al., self-selection biases were addressed via instrument variable analyses and propensity score matching.

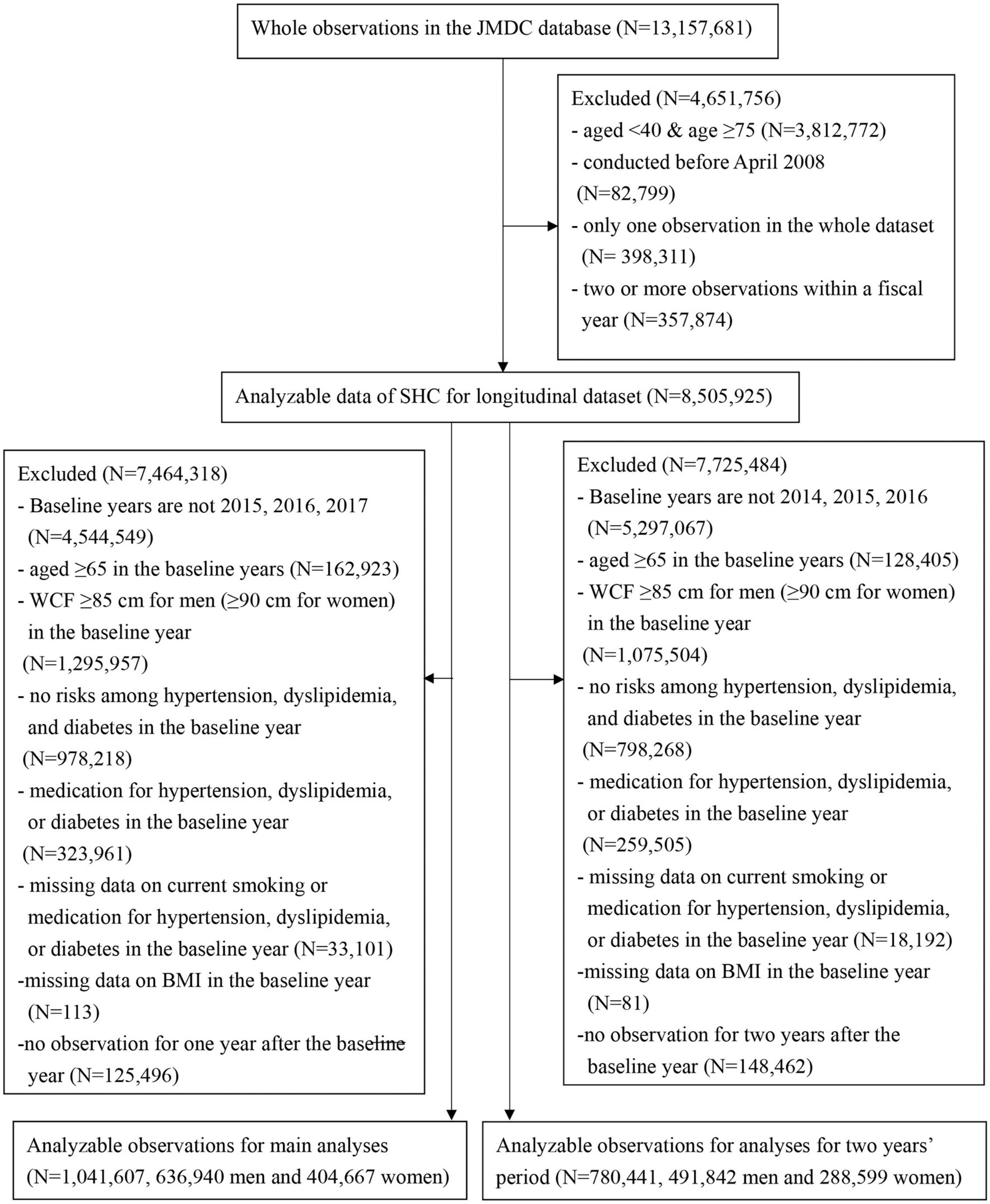

Fig. 2. Study flow chart.
Note. JMDC, Japan Medical Data Center Co., Ltd.; SHC, Specific health checkup; WCF, waist circumference; BMI, body mass index.

However, the validity of the instrumental variable in their study is questionable (Fukuma et al., 2020), and the use of propensity score matching overlooks the concerns of unobserved confounders, such as motivation to lose body weight, which may affect both the treatment status and the outcome measures. Applying a fuzzy RDD with BMI as the running variable may estimate the effects of receiving SHG with less bias. Although such an approach was conducted by Fukuma et al. (2020) using WCF as the running variable, larger-scale studies using BMI as the running variable are hoped for.

We explored the effects of being assigned to, rather than receiving, SHG. This was an intention-to-treat approach also adopted in the previous RDD studies (Fukuma et al., 2020; Narisada et al., 2022; Sekizawa et al., 2020). NHSIP aims to promote the health of the general public and is not limited to those receiving SHG; therefore, conducting an intention-to-treat analyses is valid. Ideally, both intention-to-treat analyses and analyses on receiving SHG using a fuzzy RDD as mentioned in last paragraph should be conducted; however, we could not conduct the latter due to lack of data on participation in SHG. Mainly due to this lack of data, we could not show how eligibility for SHG led to a lower BMI and WCF. Considering that the proportion of those who took SHG was 23.2% in 2018 (Ministry of Health, Labor, and Welfare, 2019), one possible explanation is that even if only less than a quarter of those eligible for SHG had taken it, the effect on them was large enough to explain a considerable part of the observed results of those eligible for

Table 4
Percentages of the participants who had records of receiving SHC the next year.

Sex	Baseline year	Number of participants		Percentage (B/A *100)
		Baseline year (A)	Next year (B)	
Men	2015	200,599	189,161	94.3%
	2016	230,753	217,382	94.2%
	2017	263,023	230,397	87.6%
	2015–7	694,375	636,940	91.7%
Women	2015	129,159	112,920	87.4%
	2016	156,972	136,170	86.7%
	2017	186,597	155,577	83.4%
	2015–7	472,728	404,667	85.6%

Note. In the column of baseline year (A), the number of those eligible for the RDD analyses is shown. These include participants with (1) age range of 40–64 years, (2) WCF <85 cm in men (<90 cm in women), (3) one or more risks of hypertension, dyslipidemia, and diabetes, (4) no medication for hypertension, dyslipidemia, or diabetes, (5) years from 2015 through 2017. Among these, the number of participants having records of receiving SHC in the next year is shown in the "Next year (B)" column. SHC, Specific health checkup; RDD, regression discontinuity design; WCF, waist circumference.

SHG, as suggested in Fukuma et al. (2020). Another possible explanation is that simply receiving information about being eligible for SHG may have motivated the receivers to lose weight, as suggested in previous studies on hypertension (Chen et al., 2019), diabetes (Iizuka et al., 2021; Kim et al., 2019), and obesity (Cook, 2019; Fukuma et al., 2020). A third possible explanation is that some of those eligible for SHG may have initiated medication, particularly for diabetes, due to the eligibility, leading to their body weight loss next year (Yerevanian and Soukas, 2019).

This study showed that BMI and WCF reduction were unobserved two years after being eligible for the SHG. Previous studies on body weight reduction interventions suggest that the maximum weight reduction is attained in the first year, and the effects wane in the following years (Dansinger et al., 2007; Wadden et al., 2011; Takeuchi et al., 2020; Fukuma et al., 2020). A similar phenomenon might have been observed in this study. However, the results observed two years later should be interpreted carefully due to the concern of treatment contamination (Keogh-Brown et al., 2007). SHC and SHG are conducted every year. Therefore, the results of SHC and SHG in the next year may also affect the results two years later, making the comparison between those eligible for SHG and those not eligible for it in the baseline year closer to the comparison between those eligible for SHG earlier and later. Although econometricians addressed this contamination problem as a dynamic RDD in some areas like referenda (Cellini et al., 2010), we could not apply this methodology due to its practical difficulty.

The results of this study cast doubt on the clinical value of the NHSIP. BMI reduction was as small as approximately 0.1 kg/m^2. There were no robust significant effects on cardiovascular risk factors. However, this study is not able to provide definite answers on the effectiveness of the NHSIP due to the following limitations. First, we were not able to make reliable analyses on two years or longer terms under the current NHSIP. Second, we have not analyzed the effects of the SHG on major cardiovascular events. Third, our estimates may be biased due to attrition. The attrition rates for men and women were 8.3% and 14.4%, respectively, in the pooled data. Although there was no consistently significant evidence that eligibility for SHG results in a higher or lower attrition rate, we cannot completely deny the possibility of the attrition bias. Lastly, and possibly most importantly, the participants analyzed in this study are limited. Analyses using RDDs show the effects only around the cutoff. In addition, we excluded those with WCF ≥85 cm for men (WCF ≥90 cm for women). Therefore, only 6.7% of men and 38.7% of women among all the observations eligible for SHG were eligible for the RDD analyses. Men eligible for this study were particularly rare since those allocated to SHG tend to have both large BMIs and WCFs. Therefore, the effects demonstrated in this study may differ from those on individuals with typical metabolic syndrome.

Suggestions for future directions based on the abovementioned limitations are as follows. First, in addition to the doubt about the necessity of an annual general health check (Liss et al., 2021), elongating the interval between each SHC is supported by the viewpoint of more accurate estimations of the effects of SHG. Second, the eligibility criteria for SHG should be reconsidered. WCF may be occasionally manipulated, and its inaccurate measurements may be prevalent, interrupting the accurate evaluation of SHG. One possibility is excluding WCF from the

Table 5
Participants' characteristics in the baseline years (pooled data).

Sex	Variables	Total observations		Observations eligible for the RDD analyses					
				All		BMI <25 kg/m^2		BMI ≥25 kg/m^2	
		N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Men	Age (years)	2,276,194	50.52 (6.58)	636,940	50.37 (6.46)	598,253	50.44 (6.48)	38,687	49.21 (6.10)
	BMI (kg/m^2)	2,255,650	23.98 (3.50)	636,940	22.02 (1.97)	598,253	21.78 (1.77)	38,687	25.76 (0.79)
	WCF (cm)	2,249,267	84.68 (9.26)	636,940	78.74 (4.64)	598,253	78.47 (4.64)	38,687	82.87 (1.86)
	Systolic blood pressure (mmHg)	2,255,767	124.13 (15.39)	636,847	124.55 (15.55)	598,165	124.31 (15.58)	38,682	128.28 (14.61)
	Diastolic blood pressure (mmHg)	2,255,767	78.45 (11.23)	636,847	78.75 (11.28)	598,165	78.57 (11.29)	38,682	81.60 (10.85)
	Hemoglobin A1c (%)	2,004,525	5.64 (0.69)	576,674	5.56 (0.46)	542,586	5.56 (0.46)	34,088	5.61 (0.54)
	HDL-C (mg/dL)	2,249,227	58.44 (15.25)	636,735	61.45 (16.25)	598,059	61.90 (16.31)	38,676	54.38 (13.40)
	LDL-C (mg/dL)	2,249,024	124.39 (30.44)	636,640	124.27 (30.68)	597,965	123.70 (30.64)	38,675	133.02 (30.09)
	Current smoking (%)	2,230,190	35.6	636,940	37.7	598,253	38.0	38,687	34.5
Women	Age (years)	1,117,580	50.09 (6.45)	404,667	51.08 (6.33)	362,551	51.23 (6.34)	42,116	49.82 (6.10)
	BMI (kg/m^2)	1,109,544	21.99 (3.74)	404,667	21.40 (2.71)	362,551	20.81 (2.15)	42,116	26.50 (1.40)
	WCF (cm)	1,108,031	78.23 (9.73)	404,667	76.71 (7.06)	362,551	75.71 (6.69)	42,116	85.35 (3.41)
	Systolic blood pressure (mmHg)	1,109,474	116.56 (16.81)	404,592	120.11 (17.77)	362,486	119.29 (17.67)	42,106	127.17 (17.03)
	Diastolic blood pressure (mmHg)	1,109,474	71.39 (11.55)	404,592	73.70 (12.21)	362,486	73.18 (12.16)	42,106	78.13 (11.74)
	Hemoglobin A1c (%)	1,009,740	5.52 (0.49)	381,931	5.64 (0.37)	342,971	5.63 (0.36)	38,960	5.69 (0.50)
	HDL-C (mg/dL)	1,109,099	72.19 (16.65)	404,590	72.83 (17.26)	362,484	74.06 (17.13)	42,106	62.21 (14.49)
	LDL-C (mg/dL)	1,109,038	122.08 (30.89)	404,574	126.70 (31.65)	362,471	125.54 (31.41)	42,103	136.74 (31.88)
	Current smoking (%)	1,098,594	10.3	404,667	10.0	362,551	9.9	42,116	10.9

Note. Pooled data for the baseline years from 2015 through 2017 is shown. The total number of observations is the sum of the observations of those individuals between the ages of 40 and 64 years and having observations in the next year. The total number is 3,393,774 (2,276,194 men and 1,117,580 women) out of 1,540,051 participants (1,004,085 men and 535,966 women). Eligible for the RDD analyses are those with (1) age between 40 and 64 years, (2) WCF <85 cm in men (<90 cm in women), (3) one or more risks out of hypertension, dyslipidemia, and diabetes, (4) no medication for hypertension, dyslipidemia, or diabetes, (5) years from 2015 through 2017, and (6) having observations in the next year. RDD, regression discontinuity design; BMI, Body mass index; WCF, waist circumference; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

Table 6
RDD analyses results (Outcome variable is the difference in one year).

	Outcome variable	Baseline year	Point estimate	95% CI	*p* value	Bandwidth (kg/m^2)	Total sample	Analyzed samples	
								Control	Treatment
Men	BMI (kg/m^2)	2015–7	**−0.12**	**(−0.15 to − 0.09)**	**<0.001**	1.37	636,525	91,557	31,918
		2015	**−0.12**	**(−0.17 to − 0.08)**	**<0.001**	1.51	189,023	32,804	9873
		2016	**−0.13**	**(−0.18 to − 0.09)**	**<0.001**	1.42	217,260	34,711	11,302
		2017	**−0.10**	**(−0.15 to − 0.05)**	**<0.001**	1.40	230,242	36,934	11,830
	WCF (cm)	2015–7	**−0.36**	**(−0.47 to − 0.28)**	**<0.001**	1.20	635,944	73,084	29,710
		2015	**−0.27**	**(−0.46 to − 0.11)**	**0.001**	1.27	188,857	24,040	9089
		2016	**−0.37**	**(−0.54 to − 0.21)**	**<0.001**	1.33	217,062	31,263	11,014
		2017	**−0.39**	**(−0.57 to − 0.26)**	**<0.001**	1.29	230,025	29,961	11,145
	Systolic blood pressure (mmHg)	2015–7	**−0.44**	**(−0.77 to − 0.13)**	**0.006**	1.73	636,391	133,605	34,763
		2015	**−0.73**	**(−1.41 to − 0.20)**	**0.009**	1.63	188,918	35,926	10,056
		2016	−0.34	(−0.91 to 0.23)	0.244	1.68	217,220	41,938	11,780
		2017	−0.34	(−0.87 to 0.27)	0.301	1.59	230,253	40,612	12,108
	Diastolic blood pressure (mmHg)	2015–7	**−0.25**	**(−0.46 to − 0.04)**	**0.021**	2.02	636,391	168,919	36,071
		2015	**−0.90**	**(−1.59 to − 0.45)**	**<0.001**	0.90	188,918	14,052	7513
		2016	−0.12	(−0.54 to 0.27)	0.517	1.77	217,220	45,725	11,975
		2017	−0.31	(−0.63 to 0.02)	0.069	2.45	230,253	80,029	13,388
	Hemoglobin A1c (% point)	2015–7	**−0.01**	**(−0.02 to − 0.01)**	**<0.001**	1.98	564,782	138,590	30,878
		2015	−0.00	(−0.02 to 0.02)	0.766	0.90	164,598	12,086	6365
		2016	−0.01	(−0.03 to 0.00)	0.071	1.24	193,415	24,816	9316
		2017	−0.01	(−0.02 to 0.01)	0.279	1.63	206,769	39,790	10,791
	HDL-C (mg/dL)	2015–7	**0.30**	**(0.12 to 0.48)**	**0.001**	1.94	635,754	156,922	35,683
		2015	0.28	(−0.17 to 0.65)	0.246	1.34	188,813	26,778	9385
		2016	0.23	(−0.10 to 0.55)	0.180	1.81	216,987	49,641	12,130
		2017	0.30	(−0.03 to 0.60)	0.081	1.77	229,954	48,599	12,546
	LDL-C (mg/dL)	2015–7	**−0.54**	**(−1.28 to − 0.04)**	**0.036**	1.24	635,528	82,050	30,864
		2015	−0.80	(−2.37 to 0.30)	0.130	1.03	188,742	18,820	8386
		2016	−0.48	(−1.72 to 0.45)	0.248	1.34	216,958	31,258	11,010
		2017	−0.32	(−1.48 to 0.52)	0.346	1.43	229,828	36,890	11,810
Women	BMI (kg/m^2)	2015–7	**−0.09**	**(−0.13 to − 0.06)**	**<0.001**	1.66	404,302	51,298	27,331
		2015	**−0.07**	**(−0.13 to − 0.01)**	**0.015**	2.17	112,851	19,873	8505
		2016	**−0.08**	**(−0.14 to − 0.04)**	**<0.001**	2.44	136,105	28,960	11,366
		2017	**−0.11**	**(−0.17 to − 0.07)**	**<0.001**	1.74	155,346	21,504	11,049
	WCF (cm)	2015–7	**−0.16**	**(−0.29 to − 0.06)**	**0.003**	2.17	403,997	72,194	31,538
		2015	−0.12	(−0.36 to 0.07)	0.189	2.56	112,787	25,119	9166
		2016	−0.06	(−0.26 to 0.14)	0.554	2.45	136,035	28,942	11,366
		2017	**−0.29**	**(−0.52 to − 0.12)**	**0.002**	1.94	155,175	24,716	11,722
	Systolic blood pressure (mmHg)	2015–7	**−0.44**	**(−0.88 to − 0.11)**	**0.012**	2.23	404,195	76,704	32,245
		2015	−0.41	(−1.31 to 0.28)	0.207	2.13	112,798	19,862	8499
		2016	−0.57	(−1.37 to 0.11)	0.096	2.09	136,073	22,870	10,423
		2017	−0.36	(−1.04 to 0.28)	0.255	2.22	155,324	29,790	12,642
	Diastolic blood pressure (mmHg)	2015–7	−0.18	(−0.44 to 0.09)	0.196	2.31	404,195	81,316	32,931
		2015	−0.11	(−0.63 to 0.42)	0.694	2.30	112,798	22,429	8868
		2016	−0.10	(−0.57 to 0.49)	0.882	1.77	136,073	18,643	9587
		2017	−0.27	(−0.76 to 0.16)	0.203	2.23	155,324	29,790	12,642
	Hemoglobin A1c (% point)	2015–7	**−0.01**	**(−0.02 to − 0.00)**	**0.004**	2.09	375,310	62,424	28,235
		2015	**−0.02**	**(−0.04 to − 0.00)**	**0.035**	1.93	103,747	15,910	7351
		2016	−0.01	(−0.03 to 0.01)	0.166	2.17	126,550	22,367	9812
		2017	−0.01	(−0.03 to 0.00)	0.052	2.66	145,013	34,365	12,587
	HDL-C (mg/dL)	2015–7	0.16	(−0.06 to 0.38)	0.152	2.76	404,127	100,663	35,227
		2015	0.14	(−0.31 to 0.60)	0.530	2.54	112,815	25,125	9168
		2016	0.33	(−0.12 to 0.77)	0.157	2.10	136,046	24,299	10,676
		2017	−0.00	(−0.40 to 0.43)	0.943	2.11	155,266	28,052	12,362
	LDL-C (mg/dL)	2015–7	**−0.58**	**(−1.28 to − 0.03)**	**0.041**	2.65	404,050	95,745	34,706
		2015	−0.08	(−1.36 to 1.17)	0.883	2.65	112,811	26,535	9303
		2016	−0.54	(−1.66 to 0.55)	0.327	2.78	136,039	33,830	11,924
		2017	**−1.06**	**(−2.32 to − 0.11)**	**0.031**	2.30	155,200	29,761	12,630

Note. Boldface indicates statistical significance at the 5% level (both sides). RDD, regression discontinuity design; BMI, body mass index; WCF, waist circumference; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

eligibility criteria for SHG. Another possibility is using a cardiovascular disease risk prediction score similar to QRISK (Hippisley-Cox et al., 2017) to determine the eligibility. Finally, further studies using RDDs are expected to explore whether eligibility for and receival of SHG reduces major cardiovascular diseases and all-cause mortality.

This study has several other limitations. First, the JMDC database did not include height and body weight data. Available data on BMI were indicated to the first decimal place, which made BMI a discrete number in this study. The method to deal with discrete running variables in RDDs has been under discussion (Cattaneo et al., 2019; Kolesár and Rothe, 2018), and a better approach than that used in this study may appear. Second, data on whether the study participants received information showing eligibility for SHG were unavailable from the JMDC database. Although it seems improbable that SHC completers did not receive health information, including information on whether they were eligible for SHG, we had no way to confirm this.

5. Conclusions

Although the results of this study cast doubt on the clinical value of the SHC and SHG programs, definite answers on their effectiveness cannot be based solely on the results of this study. Therefore, program

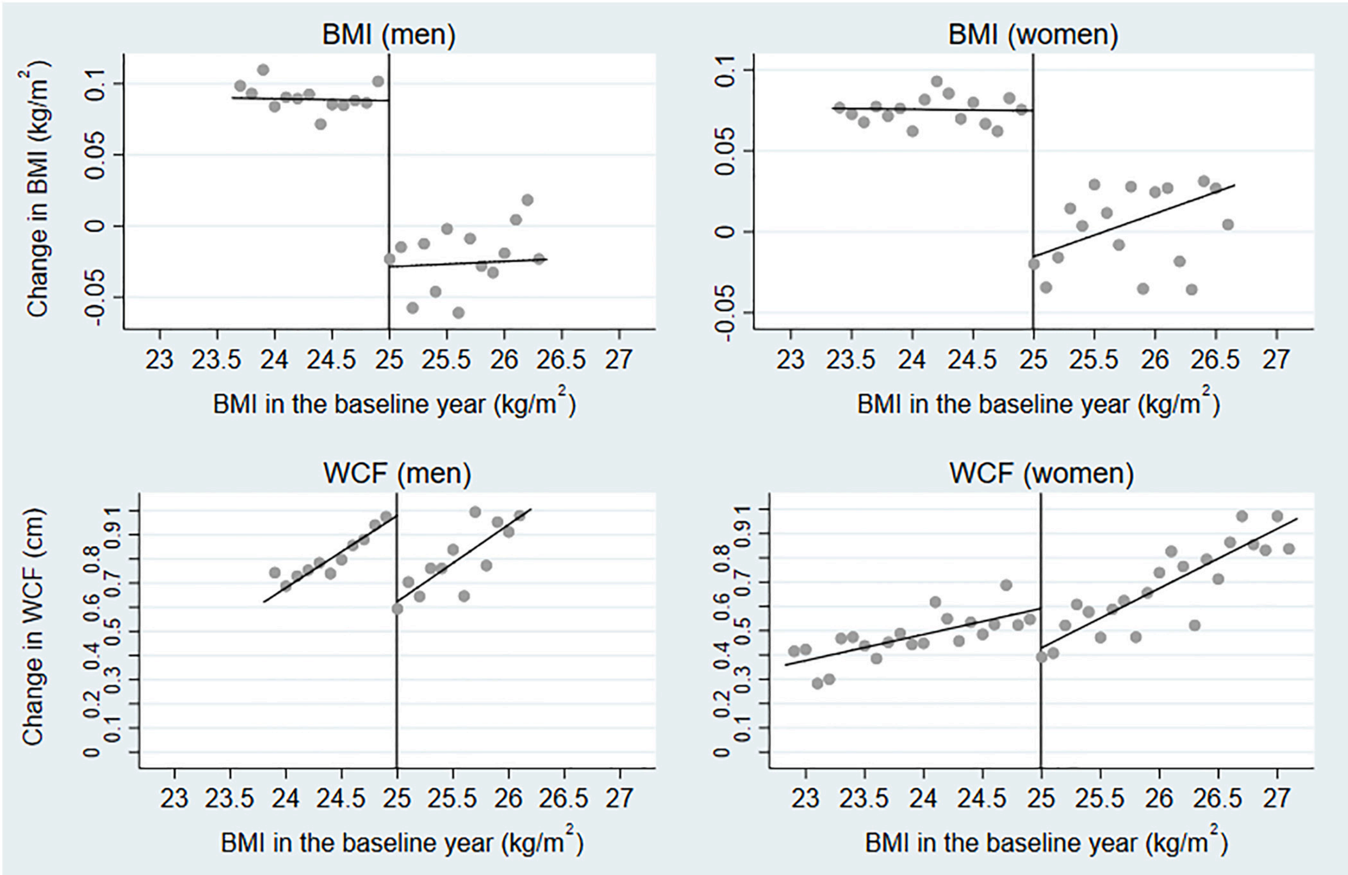

Fig. 3. Changes in BMI and WCF around the cutoff (BMI = 25 kg/m^2): RDD plots.
Note. Each figure is constructed using the "rdplot" (Cattaneo et al., 2019) within the ranges of bandwidths shown in Table 6. Results for the pooled data from 2015 to 2017 as baseline years are shown. BMI, body mass index; WCF, waist circumference; RDD, regression discontinuity design.

modifications and further studies based on the approach implemented herein are warranted.

Ethics approval

Since this study used only anonymous data obtained from the JMDC on a fee-paying basis, ethical approval was not required according to the Ethical Guidelines for Medical and Biological Research Involving Human Subjects of the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Health, Labor and Welfare, and the Ministry of Economy, Trade, and Industry, Japan.

Credit author statement

YS designed the study, drafted the manuscript, performed the analysis, and interpreted the results.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgments

This study was planned and organized by the author as part of a research project at the Research Institute of Economy, Trade, and Industry, Japan. Although this study was funded by the institute, it had no role in the study design, data analyses, decision to publish, or manuscript preparation. The author would like to thank Dr. Yoko Konishi and Dr. Ying Ting for valuable advice on technical matters.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2023.107520.

References

Barreca, A.I., Lindo, J.M., Waddell, G.R., 2016. Heaping-induced bias in regression-discontinuity designs. Econ. Inq. 54, 268–293.
Calonico, S., Cattaneo, M.D., Titiunik, R., 2014. Robust nonparametric confidence intervals for regression-discontinuity designs. Econometrica 82, 2295–2326.
Calonico, S., Cattaneo, M.D., Farrell, M.H., Titiunik, R., 2017. rdrobust: software for regression-discontinuity designs. Stata J. 17, 372–404.
Cattaneo, M.D., Jansson, M., Ma, X., 2018. Manipulation testing based on density discontinuity. Stata J. 18, 234–261.
Cattaneo, M.D., Idrobo, N., Titiunik, R., 2019. A Practical Introduction to Regression Discontinuity Designs: Foundations. Cambridge University Press.
Cattaneo, M.D., Jansson, M., Ma, X., 2020. Simple local polynomial density estimators. J. Am. Stat. Assoc. 115, 1449–1455.
Cellini, S.R., Ferreira, F., Rothstein, J., 2010. The value of school facility investments: evidence from a dynamic regression discontinuity design. Q. J. Econ. 125, 215–261.
Chen, S., Sudharsanan, N., Huang, F., Liu, Y., Geldsetzer, P., Bärnighausen, T., 2019. Impact of community based screening for hypertension on blood pressure after two

years: regression discontinuity analysis in a national cohort of older adults in China. BMJ 366, l4064.
Cook, W., 2019. The effect of personalised weight feedback on weight loss and health behaviours: evidence from a regression discontinuity design. Health Econ. 28, 161–172.
Dansinger, M.L., Tatsioni, A., Wong, J.B., Chung, M., Balk, E.M., 2007. Meta-analysis: the effect of dietary counseling for weight loss. Ann. Intern. Med. 147, 41–50.
Fukuma, S., Iizuka, T., Ikenoue, T., Tsugawa, Y., 2020. Association of the national health guidance intervention for obesity and cardiovascular risks with health outcomes among Japanese men. JAMA Intern. Med. 180 (12), 1630–1637.
Hippisley-Cox, J., Coupland, C., Brindle, P., 2017. Development and validation of QRISK3 risk prediction algorithms to estimate future risk of cardiovascular disease: prospective cohort study. BMJ 357, j2099.
Iizuka, T., Nishiyama, K., Chen, B., Eggleston, K., 2021. False alarm? Estimating the marginal value of health signals. J. Public Econ. 195, 104368.
Jorgensen, T., Jacobsen, R.K., Toft, U., Aadahl, M., Glumer, C., Pisinger, C., 2014. Effect of screening and lifestyle counselling on incidence of ischaemic heart disease in general population: Inter99 randomised trial. Bmj 348 g3617-g17.
Keogh-Brown, M.R., Bachmann, M.O., Shepstone, L., Hewitt, C., Howe, A., Ramsay, C.R., Song, F., Miles, J.N., Torgerson, D.J., et al., 2007. Contamination in trials of educational interventions. Health Technol. Assess. 11 (iii), ix–107.
Kim, H.B., Lee, S.A., Lim, W., 2019. Knowing is not half the battle: impacts of information from the National Health Screening Program in Korea. J. Health Econ. 65, 1–14.
Kohro, T., Furui, Y., Mitsutake, N., Fujii, R., Morita, H., Oku, S., Ohe, K., Nagai, R., 2008. The Japanese national health screening and intervention program aimed at preventing worsening of the metabolic syndrome. Int. Heart J. 49, 193–203.
Kolesár, M., Rothe, C., 2018. Inference in regression discontinuity designs with a discrete running variable. Am. Econ. Rev. 108, 2277–2304.
Krogsbøll, L.T., Jørgensen, K.J., Gøtzsche, P.C., 2019. General health checks in adults for reducing morbidity and mortality from disease. Cochrane Database Syst. Rev. 2019 (1), CD009009.
Liss, D.T., Uchida, T., Wilkes, C.L., Radakrishnan, A., Linder, J.A., 2021. General health checks in adult primary care: a review. JAMA 325, 2294–2306.
Ministry of Health, Labor & Welfare, 2019. 2018 nendo tokuteikenkoushinsa tokuteihokenshidou no jisshi joukyou nitsuite (Report of Specific Health Checkup and Guidance in 2018). (In Japanese).
Ministry of Health, Labor, and Welfare, 2013. Hyoujuntekina kenshin hoken shidou programme – heisei 25 nendo ban (Standard health checkup and health guidance programme – 2013). (In Japanese).
Nagai, K., Tanaka, T., Kodaira, N., Kimura, S., Takahashi, Y., Nakayama, T., 2021. Data resource profile: JMDC claims database sourced from health insurance societies. J. General Family Med. 22, 118–127.
Nakao, Y.M., Miyamoto, Y., Ueshima, K., Nakao, K., Nakai, M., Nishimura, K., Yasuno, S., Hosoda, K., Ogawa, Y., et al., 2018. Effectiveness of nationwide screening and lifestyle intervention for abdominal obesity and cardiometabolic risks in Japan: the metabolic syndrome and comprehensive lifestyle intervention study on nationwide database in Japan (MetS ACTION-J study). PLoS One 13, e0190862.
Narisada, A., Shibata, E., Hasegawa, T., Wakayama, R., Suzuki, K., 2022. The impact of the National Health Program on diabetes incidence among working-age men with prediabetes: a regression discontinuity analysis of a nation-wide database in Japan. Diabetes Res. Clin. Pract. 189, 109946.
Porter, K.E., Reardon, S.F., Unlu, F., Bloom, H.S., Cimpian, J.R., 2017. Estimating causal effects of education interventions using a two-rating regression discontinuity design: lessons from a simulation study and an application. J. Res.Educ. Effect. 10, 138–167.
Reardon, S.F., Robinson, J.P., 2012. Regression discontinuity designs with multiple rating-score variables. J. Res. Educ. Effect. 5, 83–104.
Sekizawa, Y., Kimura, M., Nawata, K., 2020. Was being notified of eligibility for “aggressive health guidance” under Japan’s specific health checkup system effective in reducing risk factors of cardiovascular diseases for male members of a health insurance society?: examination using regression discontinuity design. Jpn. J. Health Econ. Policy 32, 44–60 (In Japanese).
Takeuchi, Y., Kashiwabara, K., Hosoi, H., Imai, H., Matsuyama, Y., 2020. Longitudinal effects of a nationwide lifestyle intervention program on cardiometabolic outcomes in Japan: an observational cohort study. Prev. Med. 141, 106301.
Teramoto, T., Sasaki, J., Ueshima, H., Egusa, G., Kinoshita, M., Shimamoto, K., Daida, H., Biro, S., Hirobe, K., et al., 2008. Metabolic syndrome. J. Atheroscler. Thromb. 15, 1–5.
Tsushita, K., Hosler, A.S., Miura, K., Ito, Y., Fukuda, T., Kitamura, A., Tatara, K., 2018. Rationale and descriptive analysis of specific health guidance: the nationwide lifestyle intervention program targeting metabolic syndrome in Japan. J. Atheroscler. Thromb. 25, 308–322.
Venkataramani, A.S., Bor, J., Jena, A.B., 2016. Regression discontinuity designs in healthcare research. BMJ 352, i1216.
Wadden, T.A., Neiberg, R.H., Wing, R.R., Clark, J.M., Delahanty, L.M., Hill, J.O., Krakoff, J., Otto, A., Ryan, D.H., et al., 2011. Four-year weight losses in the look AHEAD study: factors associated with long-term success. Obesity 19, 1987–1998.
Wong, V.C., Steiner, P.M., Cook, T.D., 2013. Analyzing regression-discontinuity designs with multiple assignment variables: a comparative study of four estimation methods. J. Educ. Behav. Stat. 38, 107–141.
Yerevanian, A., Soukas, A.A., 2019. Metformin: mechanisms in human obesity and weight loss. Curr. Obes. Rep. 8, 156–164.