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Trends in High Deductible Health Plan Enrollment and Spending Among Commercially Insured Members with and without Chronic Conditions: A Natural Experiments for Translation in Diabetes (NEXT-D2) Study

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Trends in High Deductible Health Plan Enrollment and Spending Among Commercially Insured Members with and without Chronic Conditions: A Natural Experiments for Translation in Diabetes (NEXT-D2) Study

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Abstract:

Objectives: To examine trends in high deductible health plan (HDHP) enrollment among members with diabetes and cardiovascular disease (CVD) compared to healthy members and compare out-of-pocket (OOP) and total spending for members with chronic conditions in HDHPs vs. low deductible plans.
Design: Descriptive study with time trends.
Setting: A large national commercial insurance database.
Participants: 1.2 million members with diabetes, 4.5 million members with CVD (without diabetes) and 18.0 million healthy members (defined by a low comorbidity score) under the age of 65 and insured between 2005 to 2013.
Outcome measures: Proportion of members in a HDHP (i.e., annual deductible ≥$1000) by year, annual mean OOP and total spending, adjusted for member sociodemographic and employer characteristics.
Results: Rates of enrollment in HDHPs among members in all disease categories increased by 6 percentage points a year and were over 50% at the end of the study period. But, on average over the study period, HDHP enrollment among members with diabetes and CVD was 3.06 (95% CI: 2.99, 3.13) and 2.17 (95% CI:2.13, 2.22) percentage points lower, respectively, than among healthier members. On average over the study period, members in HDHP had higher annual OOP costs ($636 [95% CI: 630, 642], $539 [95% CI: 537, 542], and $113 [95% CI: 112, 113]) and lower total costs (-$529 [95% CI: -597, -461], -$364 [95% CI: -385, -342], and -$79 [95% CI: -81, -76]) than low-deductible members with diabetes, CVD and healthy members, respectively. Members with chronic diseases had yearly OOP expenditures that were 5 to 7 times higher than healthier members.
Conclusions: The higher rate of HDHP enrollment coupled with the high OOP costs associated with HDHPs may be particularly detrimental to the health and financial well-being of people with diabetes and cardiovascular disease, who have more health care needs than healthier populations.

Article Summary

Strengths and limitations of this study

- This is the first study to compare rates of enrollment in high deductible health plans between members with chronic diseases (i.e., diabetes and cardiovascular disease) and healthy members.
- This study uses nine years of claims data from large, national health insurer in the United States.
- The study also examines out-of-pocket and total costs between members in high deductible and low deductible plans.
- The algorithm to assign disease categories relies on accurate and complete claims data and the plan deductible amounts are imputed.

Key Words: health insurance, high deductible health plan, diabetes, cardiovascular disease, out-of-pocket costs

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Introduction

Recent research suggests that high deductible health plans (HDHPs), which provide incentives for patients to manage their own health care costs, are associated with concerning impacts on patients with chronic conditions. However, little is known about differential trends of HDHP enrollment and their associated economic burden among patients with chronic conditions versus healthier populations.

To reduce health care costs and monthly premiums, an increasing number of employers offer HDHPs. These arrangements provide incentives for patients to utilize preventive care and reduce health care costs through inexpensive preventive care and higher annual deductibles.[1] In 2019, 82% of commercially insured Americans had an annual deductible; of these, over two-thirds (69%) had a deductible of over $1000 and over one in ten (14%) had a deductible over $3000.[2] HDHPs paired with a tax-preferred savings account for out-of-pocket (OOP) spending (i.e., Health Savings Accounts [HSA] or Health Reimbursement Arrangements [HRA]) are the most rapidly growing plan type, now covering 30% of commercially insured Americans.[2]

Diabetes and cardiovascular disease (CVD) are the two most prevalent chronic illnesses in the United States. High quality of care for such conditions requires multiple office visits, tests, exams and medications.[3-10] Typically, HDHPs fully cover some preventive services and one annual preventive visit, but require full cost-sharing up to the annual deductible for all other services and often additional cost sharing (i.e., coinsurance or co-payment) after the deductible is met. Our Natural Experiments in Diabetes Translation (NEXT-D1) study used a robust study design by including only employers that mandated HDHP enrollment (reducing member-level selection bias) to examine the impact of HDHPs among members with diabetes. Studies demonstrated decreased utilization of both appropriate and discretionary services, with concerning impacts on vulnerable populations. For example, HDHPs were associated with delays in seeking care for major macrovascular disease symptoms, diagnostic tests, and procedure-based treatments,[11] reductions in specialist visits,[12] delayed outpatient visits for acute preventable complications[12] and higher emergency department visits for acute complications among the poor.[12] The negative impacts of HDHPs are consistently more pronounced in low income HDHP members or members with a HSA-HDHP.[12 13] Other studies have suggested similar impacts of HDHPs on members with cardiovascular disease.[14]

Despite these concerning patterns, trends in the rates of HDHP enrollment and OOP burden among patients with chronic illness versus healthier patients are unknown. Our objective was to assess 2005-2013 trends in HDHP enrollment among members with diabetes and cardiovascular disease in a large national insurer, compared to a cohort of healthy members. We also compared the demographics, comorbidities, and trends in OOP spending and total spending of members with chronic conditions and healthier members in HDHPs (with and without savings accounts) to counterparts in low deductible plans.

Methods

Study Design: This descriptive study assessed annual trends from 2005-2013 and differences in rates of HDHP enrollment between subgroups of members with chronic conditions compared to healthy members and, within disease category, compared differences in OOP spending and total costs between members with HDHPs and low-deductible health plans.

Data: We used a large claims database that included approximately 55.5 million unique commercially-insured members of all ages from 2005-2013. Members with Medicare Advantage were excluded from this study since they were not subject to comparable insurance arrangements. The data included enrollment status and all medical and pharmacy claims. We used the Johns Hopkins ACG® System (version 11.1),[15 16] to assign diagnostic categories and an overall comorbidity score using claims data (i.e., diagnoses, procedures and medications) from the prior 12 months. We also linked individuals to neighborhood-level socioeconomic characteristics from the 2008-2012 American Community Survey (ACS; i.e., 5-year estimates at the census-tract level).[17]

Study Population: We included members under the age of 65 years old with diabetes and cardiovascular disease and a comparison group of healthier members. We created the three mutually exclusive disease categories of members based on ACG diagnostic categories: diabetes (inclusive of Type 1 and Type 2 diabetes) with or without cardiovascular disease (CVD); CVD or risk factors (i.e., lipid disorders or hypertension) without diabetes; and "healthy" (defined as ACG morbidity score ≤1 and excluding members with a diabetes or CVD diagnosis). We included members with at least 12 months of continuous enrollment covered by employers insuring 10 or more members (for whom we could reliably assess HDHP status). We used the ACG diagnosis flag (or score) from the last month of each member's 12-month enrollment period (i.e., "anniversary month"). Each 12-month enrollment period was assigned to the calendar year of each anniversary month.

Outcomes and Covariates: For each annual employer enrollment period, we classified members as being enrolled in an HDHP or non-HDHP plan on the anniversary month. We used actual or imputed deductible levels; the imputations were based on adding actual deductible payments per person per benefit year at the employer then assigning a deductible level to that employer using a regression model that included all enrollees' summed deductible levels and other employer characteristics (see details in Appendix 1). Using a common convention, we defined HDHPs as plans with a deductible level ≥$1000 and low deductible plans as plans with a deductible level ≤$500. Within HDHPs, we identified members with a savings account plan (i.e., HSA or HRA) using flags provided by the data vendor.

For member demographics, we examined age; sex; region (i.e., Midwest, Northeast, South and West); and neighborhood-level income (i.e., low poverty, low-medium poverty, high-medium poverty, and high poverty), education (i.e., low, low-medium, high-medium, and high education level), and race/ethnicity (i.e., white, non-Hispanic vs.

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all other races/ethnicities) using ACS categories (see details in Appendix 2). As a measure of comorbidity, we included the ACG score, measured as a continuous variable. We also measured two employer-level variables: self-insured vs. fully-insured status and employer size (i.e., 0-99, 100-999 and >1000 employees). All covariates were measured on the anniversary month.

We calculated members' annual OOP expenditures, which include all cost-sharing (i.e., deductibles, copayments, and coinsurance) but not premium payments, adjusted for inflation to 2015 USD values, and total medical expenditure (i.e., insurer allowed amount inclusive of OOP costs, commonly referred to as "total cost") using a vendor-provided field that standardizes claims-level prices across geography and time which is inflation-adjusted to 2015.

Statistical Analysis: We first generated descriptive statistics of demographic and employer characteristics for HDHP and low deductible members in each of the three disease categories. We then used generalized estimating equations (GEE) with a logit link (i.e., a logistic regression model), to account for member-level clustering (since a member could contribute to the database for multiple years), to examine member-level predictors of being in a HDHP within each disease category. Predictors in the logistic regression model included the member and employer level characteristics mentioned above (i.e., age, sex, region, income, education, race/ethnicity, ACG score, self-insured status, employer size and study year). Using GEE models, we estimated annual rates and trends in HDHP enrollment for each disease category, controlling for the same variables as the logistic regression model. We also used GEE models to estimate the average difference in rates of HDHP enrollment over the study period between each chronic disease group and healthier members, controlling for the same variables as the logistic regression model, except for ACG score (which is highly collinear with our disease categories).

Within each disease category, we used GEE models, controlling for the same variables as the logistic regression model, to examine the adjusted annual rates of OOP and total costs for members with high and low deductible plans, the average difference between the two groups and the trends in rates over time. For each study year, we also calculated the average percent of total expenditure that HDHP members paid OOP (based on adjusted values), by disease category. And, within each disease category, we examined average comorbidity (i.e., ACG) score over the study period for members in high vs. low deductible plans.

In the models to assess rates and predictors of HDHP enrollment, the denominator was all members in that disease category. The analyses that examined OOP and total costs focused on members in HDHP or low deductible plans only (i.e., excluded members with deductibles of $501-$999).

All analyses were performed in SAS Studio 3.7 or STATA 15. This study was approved by the Harvard Pilgrim Health Care Institutional Review Board.

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Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Our sample included three mutually exclusive disease categories: 1.2 million unique members (2.6 million member-years) with diabetes, 4.5 million unique members (9.4 million member-years) with cardiovascular disease and risk factors (without diabetes) and 18.0 million unique healthy members (40.4 million member-years). Appendix 3 includes demographic and employer characteristics for members in HDHP and low deductible health plans.

Predictors of HDHP Enrollment within Disease Category

In the logistic regression models (Table 1), statistically significant predictors of HDHP enrollment among members with diabetes and cardiovascular disease and healthy members included: higher income; white, non-Hispanic race/ethnicity; lower comorbidity score; living in the West, Midwest or South (compared to the Northeast); being insured through a fully-insured (vs. self-insured) employer; and working for a smaller employer. Sex and age had mixed results across disease categories and were close to the null value. Across all disease categories, the largest predictors of HDHP status were region, fully-insured employer status and smaller employer size. For instance, among members with diabetes, members insured through a smaller employer (i.e., 0-99 employees) had 3.70 (3.66, 3.74) higher odds of being enrolled in a HDHP compared to members insured through a large employer (i.e., >1000 employees).

Rates of HDHP Enrollment Over Time

The rate of enrollment of HDHPs increased markedly over the study period for all disease categories, increasing by approximately 6 percentage points per year when adjusting for the variables in Table 1. HDHP enrollment increased by 6.16 percentage points (95% CI: 6.13, 6.19), 6.16 percentage points (95% CI: 6.14, 6.17), and 5.95 percentage points (95% CI: 5.94, 5.96) per year for members with diabetes, CVD and healthy members, respectively, over the study period. Members with chronic diseases were less likely than healthier members to be in an HDHP throughout most of the study period (Figure 1). On average over the study period, HDHP enrollment among members with diabetes and CVD was 3.06 (95% CI: 2.99, 3.13) and 2.17 (95% CI: 2.13, 2.22) percentage points lower, respectively, than among healthy members. The higher rate of enrollment in HDHPs among healthy members, compared to members with chronic diseases, was associated with higher enrollment in HSA-eligible HDHPs (Appendix 4). However, by the end of the study period, over half of members in each disease category were in a HDHP and the rates were similar. In 2013, 54.18% (95% CI: 54.13, 54.22) of healthy members were in a HDHP compared to 53.25% (95% CI: 53.07, 53.42) of members with diabetes and 54.08% (95% CI: 53.98, 54.17) of members with CVD in the adjusted models.

Out of Pocket Costs

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For all disease categories, HDHP members had higher OOP costs than low deductible plan members (Figure 2). The differences in OOP costs between HDHP and low-deductible plans were, on average over the study period, $636 (95% CI: 630, 642), $539 (95% CI: 537, 542), and $113 (95% CI: 112, 113) for members with diabetes, CVD and healthy members, respectively. In relative terms, compared to LDHP members, average OOP costs for HDHP members were 47.26% (95%: 46.73, 47.78), 56.03% (55.71, 56.63) and 70.41% (95% CI: 70.13, 70.69) higher, respectively. OOP costs decreased slightly over time for both low and high deductible health plan members in all three disease categories, with a greater decrease observed among low deductible health plan members. OOP costs for low deductible plan members decreased, on average, by $20 (95%: 19, 21), $17 (95% CI: 17, 18), and $6 (95%: 6, 6) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $6 (95%: 4, 8), $10 (95% CI: 9, 11), and $3 (95%: 3, 4) per year. Across all disease categories, members in HRA and HSA-eligible HDHPs had higher OOP costs than non-account HDHPs (Appendix 5).

Total Costs

For all disease categories, HDHP members had lower total costs than low deductible plan members (Figure 3). The differences in total costs between HDHP and low-deductible plans were, on average over the study period, -$529 (95% CI: -597, -461), -$364 (95% CI: -385, -342), and -$79 (95% CI: -81, -76) for members with diabetes, cardiovascular disease and healthy members, respectively. In relative terms, compared to low deductible members, average total costs for HDHP members were 5.35% (95%: 4.66, 6.04), 5.60% (5.27, 5.93) and 9.05% (95% CI: 8.77, 9.33) lower for members with diabetes, cardiovascular disease and healthy members, respectively. Our measure of total costs decreased over the study period for both HDHP and low deductible health plan members in all three disease categories, with a greater decrease observed among HDHP members. Total costs for low deductible plan members decreased, on average, by $248 (95%: 229, 267), $449 (95% CI: 434, 464), and $21 (95%: 20, 22) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $348 (95%: 318, 379), $567 (95% CI: 544, 589), and $28 (95%: 26, 29) per year, respectively. Members with chronic diseases in HRA- and HSA-eligible HDHPs had consistently higher total costs than non-account HDHPs (Appendix 6).

Members with chronic diseases in both high and low deductible plans had higher OOP costs and total expenditures than healthy members in similar plans (Figures 2 and 3). While the HDHP members' OOP share of total expenditure was lower for members with chronic diseases (i.e., on average over the study period, OOP share was 21% of total expenditure for members with diabetes, 25% for members with cardiovascular disease and 35% for healthy members), members with chronic diseases had yearly OOP expenditures that were 5 (for CVD members) to 7 (for diabetes members) times higher than healthy members (Appendix 7).

Within each disease category, HDHP members had lower comorbidity scores than low deductible plan members and the comorbidity scores remained relatively stable over

time (Appendix 8).

Discussion

HDHP enrollment increased rapidly among both chronically ill and healthy commercially-insured individuals from 2005-2013. Members with diabetes and CVD were slightly less likely than healthy members to be in HDHPs throughout the study period. However, by the end of the study period in 2013, over half (53-54%) of members with chronic conditions and healthy members were in HDHPs. Across all disease categories, members insured through larger and self-insured employers were significantly less likely to be in a HDHP, suggesting that these employers may offer more generous benefit packages to their employees.

Members with chronic diseases in both high and low deductible plans have higher OOP costs and total expenditures than healthy members in similar plans, which is not surprising given the increased health care needs of people with chronic conditions. However, the OOP cost burden was 5-7 times higher for HDHP members with chronic diseases compared to healthy members in HDHPs. These findings are concerning because our previous studies have shown that HDHPs are associated with avoided or delayed care and adverse health outcomes among diabetes patients[11,12] [13] and other studies suggest similar impacts of HDHPs among members with cardiovascular disease.[14] Higher OOP costs combined with stagnant incomes[18] and increasing HDHP enrollment among patients with chronic conditions suggests increasing financial burden on this vulnerable population.

Within each disease category, members in HDHPs had higher OOP costs but lower total medical expenditures than those in low deductible plans. The lower total costs among HDHP members could indicate that HDHP members are different or healthier than low-deductible members in ways not captured by our adjusting covariates. However, it could also reflect less utilization among HDHP members in response to increased cost sharing. We observed decreasing trends in total costs over time for both HDHP and low deductible health plan members across all disease categories. Since our measure of total cost is based on standardized prices over time, and expenditure is price times quantity, this suggests that utilization is decreasing over time among all members. The larger downward trend in total cost among HDHP members, compared to low deductible plan members, suggests a greater decrease in utilization among HDHP members. HSA- and HRA-eligible HDHP members with chronic diseases consistently had higher OOP and higher total costs than members in non-account based HDHPs, possibly because the accounts provide funds that lower barriers to utilization and reduce the effective OOP cost of care through use of pre-tax dollars.

Our study has multiple limitations. The ACG codes and scores rely on the appearance of diagnoses in medical claims. There may be increased provider coding of chronic conditions over time as risk-adjustment payment became more prominent, or reduced coding among HDHP members if they were less likely to seek routine care. However, we found that ACG scores among each disease category remained relatively stable

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over our study period (Appendix 8), past analyses have shown minimal reductions in outpatient visits among members who were forced to switch into a HDHP,[12] and we control for ACG score in our models. Members may make health care decisions based on their total expected costs, which include OOP costs and premiums, minus contributions to savings accounts. While we have data on OOP costs, we do not have data on premium amounts or on employer and employee contributions to savings accounts, so total member expenditure is unknown. Increased OOP costs in HDHPs may be offset by the lower premiums or employer contributions to accounts. Our study includes data from mostly large and mid-size employers with commercial health insurance; therefore, our study results may not be generalizable to regional plans, very small employers (<10 members), or members insured in the non-group market. Although we used imputed deductibles, the algorithm has high sensitivity and specificity (Appendix 1). Finally, our data combined HDHP members whose employers offered only a HDHP with members who were offered a choice by their employer to enroll in a HDHP or a lower-deductible plan. Future research should examine rates of HDHP enrollment among members who have plan choice to better understand factors associated with selecting HDHPs.

Conclusion

HDHP enrollment has increased rapidly among both healthy and chronically ill populations and by 2013 over half of members with chronic conditions in one large national insurer had HDHPs. HDHP members pay significantly more for their health care out of pocket than low deductible plan members, and HDHP members with chronic diseases have OOP spending that is 4-5 times higher than that of healthy members. Policymakers should consider options for protecting clinically vulnerable patients enrolled in HDHPs such as funding HSAs or facilitating enrollment in more generous plan designs.[19]

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Table 1. Predictors of HDHP Enrollment by Disease Category from Logistic Regression Models

	Diabetes n= 1,211,925 unique members			Cardiovascular Disease n= 4,495,831 unique members			Healthy n= 18,035,883 unique members		
	Odds Ratio	**95% CI lower bound**	**95% CI upper bound**	**Odds Ratio**	**95% CI lower bound**	**95% CI upper bound**	**Odds Ratio**	**95% CI lower bound**	**95% CI upper bound**
Female (ref: male)	1.0008	0.9927	1.0089	1.0042	1.0000	1.0084	1.0023	1.0003	1.0043
Age	0.9979	0.9976	0.9983	1.0007	1.0005	1.0008	1.0032	1.0032	1.0033
Neighborhood income level (ref: high) **									
Medium-high	0.9107	0.8997	0.9217	0.9137	0.9075	0.9200	0.9253	0.9221	0.9285
Medium-low	0.8274	0.8157	0.8393	0.8430	0.8365	0.8495	0.8672	0.8638	0.8706
Low	0.7550	0.7434	0.7668	0.7855	0.7791	1.2627	0.8082	0.8050	0.8114
Neighborhood education level (ref: high) **									
Medium-high	0.9800	0.8997	0.9217	1.0175	0.9995	1.0357	0.9663	0.9585	0.9741
Medium-low	0.9658	0.8157	0.8393	0.9904	0.9735	1.0076	0.9456	0.9383	0.9530
Low	0.9287	0.7434	0.7668	0.9503	0.9338	0.9669	0.9131	0.9059	0.9203
Non-white race/ethnicity (ref: white, not hispanic) **	0.8426	0.8351	0.8502	0.8390	0.8350	0.8430	0.8094	0.8076	0.8111
Region (ref: northeast)									
West	1.7034	1.6701	1.7373	1.8466	1.8284	1.8650	1.9311	1.9223	1.9399
Midwest	1.7936	1.7619	1.8259	1.9517	1.9345	1.9690	1.9812	1.9728	1.9895
South	2.1234	2.0874	2.1600	2.2269	2.2081	2.2459	2.1865	2.1775	2.1954
ACG score	0.9912	0.9903	0.9921	0.9860	0.9854	0.9866	0.8135	0.8114	0.8156
Self-insured Employer (ref: fully insured)	0.4526	0.4487	0.4565	0.4435	0.4415	0.4455	0.5001	0.4990	0.5014
Employer size (ref: >1000 employees)									
100-999	1.6844	1.6688	1.7002	1.6466	1.6385	1.6548	1.6523	1.6482	1.6565
0-99	3.6964	3.6562	3.7370	3.6033	3.5827	3.6240	3.3917	3.3818	3.4015

*Models control for study year as a categorical variable. The denominator of the models includes all members (as unique member-years), not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999). All Odds Ratios are statistically significantly different from 1 at p<0.05, except medium-high (vs. high) income for members with cardiovascular disease and sex for healthy members.

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** Income level, education level and race were determined at the neighborhood level using the American Community Survey. See Appendix 2 for a detailed description of each category.

Figures (in excel file):
Figure 1. Rate of Enrollment in HDHPs among Members, by Disease Category (adjusted)
Figure 2. Mean Annual OOP Costs by Disease Category, HDHP vs. LDHP (adjusted)
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)

Appendices (in separate word and excel files):
Appendix 1. Deductible Level Imputation
Appendix 2. Definition of Covariates
Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health Plans and Low Deductible Health Plans, by Disease Category
Appendix 4. HDHP Enrollment by HDHP Type by Disease Category
Appendix 5. Mean Annual OOP Costs by Deductible Type by Disease Category
Appendix 6. Mean Annual Total Costs by Deductible Type by Disease Category
Appendix 7. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plans, by Disease Category (unadjusted)
Appendix 8. ACG Score by Disease Category

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Data Statement: The data for this study cannot be made available in a public data repository.

Reporting Checklist: This study meets all criteria for STROBE cohort studies.

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References:

1. The Kaiser Family Foundation and Health Research & Educational Trust. Employer Health BenefitsL 2017 Annual Survey. Menlo Park, California: The Kaiser Family Foundation and Health Research & Educational Trust, 2017.
2. The Kaiser Family Foundation. Employer Health Benefits 2019 Annual Survey San Francisco, California: The Kaiser Family Foundation, 2019.
3. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. *Lancet* 1998;352(9131):837-53.
4. Holman RR, Paul SK, Bethel MA, et al. 10-year follow-up of intensive glucose control in type 2 diabetes. *N Engl J Med* 2008;359(15):1577-89. doi: 10.1056/NEJMoa0806470
5. Capewell S, Morrison CE, McMurray JJ. Contribution of modern cardiovascular treatment and risk factor changes to the decline in coronary heart disease mortality in Scotland between 1975 and 1994. *Heart* 1999;81(4):380-6. doi: 10.1136/hrt.81.4.380
6. Standards of medical care in diabetes--2015: summary of revisions. *Diabetes Care* 2015;38 Suppl:S4. doi: 10.2337/dc15-S003
7. American Diabetes A. Standards of Medical Care in Diabetes-2019 Abridged for Primary Care Providers. *Clin Diabetes* 2019;37(1):11-34. doi: 10.2337/cd18-0105
8. Centers for Disease Control and Prevention. Get Active! Atlanta, GA: Centers for Disease Control and Prevention 2018 [Available from: https://www.cdc.gov/diabetes/managing/active.html accessed June 30 20120.
9. American Diabetes A. 10. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes-2020. *Diabetes Care* 2020;43(Suppl 1):S111-S34. doi: 10.2337/dc20-S010
10. American College of Cardiology. Guidelines and Clinical Documents: American College of Cardiology; 2020 [Available from: https://www.acc.org/guidelines accessed June 30 2020.
11. Wharam JF, Lu CY, Zhang F, et al. High-Deductible Insurance and Delay in Care for the Macrovascular Complications of Diabetes. *Ann Intern Med* 2018;169(12):845-54. doi: 10.7326/M17-3365
12. Wharam JF, Zhang F, Eggleston EM, et al. Diabetes Outpatient Care and Acute Complications Before and After High-Deductible Insurance Enrollment: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. *JAMA Intern Med* 2017;177(3):358-68. doi: 10.1001/jamainternmed.2016.8411
13. Wharam JF, Zhang F, Eggleston EM, et al. Effect of High-Deductible Insurance on High-Acuity Outcomes in Diabetes: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. *Diabetes Care* 2018;41(5):940-48. doi: 10.2337/dc17-1183

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14. Lewey J, Gagne JJ, Franklin J, et al. Impact of High Deductible Health Plans on Cardiovascular Medication Adherence and Health Disparities. *Circ Cardiovasc Qual Outcomes* 2018;11(11):e004632. doi: 10.1161/CIRCOUTCOMES.118.004632
15. Reid RJ, Roos NP, MacWilliam L, et al. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. *Health Serv Res* 2002;37(5):1345-64. doi: 10.1111/1475-6773.01029
16. The Johns Hopkins University. The Johns Hopkins ACG System Baltimore, MD: The Johns Hopkins University; 2020 [Available from: https://www.hopkinsacg.org/advantage/ accessed June 30 2020.
17. United States Census Bureau. American Community Survey (ACS) Washington, D.C.: United States Census Bureau; **2020** [Available from: https://www.census.gov/programs-surveys/acs/ accessed June 30 2020.
18. Desilver D. For most U.S. workers, real wages have barely budged in decades Washington, D.C.: Rew Research Center: ; 2018 [Available from: https://www.pewresearch.org/fact-tank/2018/08/07/for-most-us-workers-real-wages-have-barely-budged-for-decades/ accessed August 20 2020.
19. Wharam JF, Ross-Degnan D, Rosenthal MB. The ACA and high-deductible insurance--strategies for sharpening a blunt instrument. *N Engl J Med* 2013;369(16):1481-4. doi: 10.1056/NEJMp1309490

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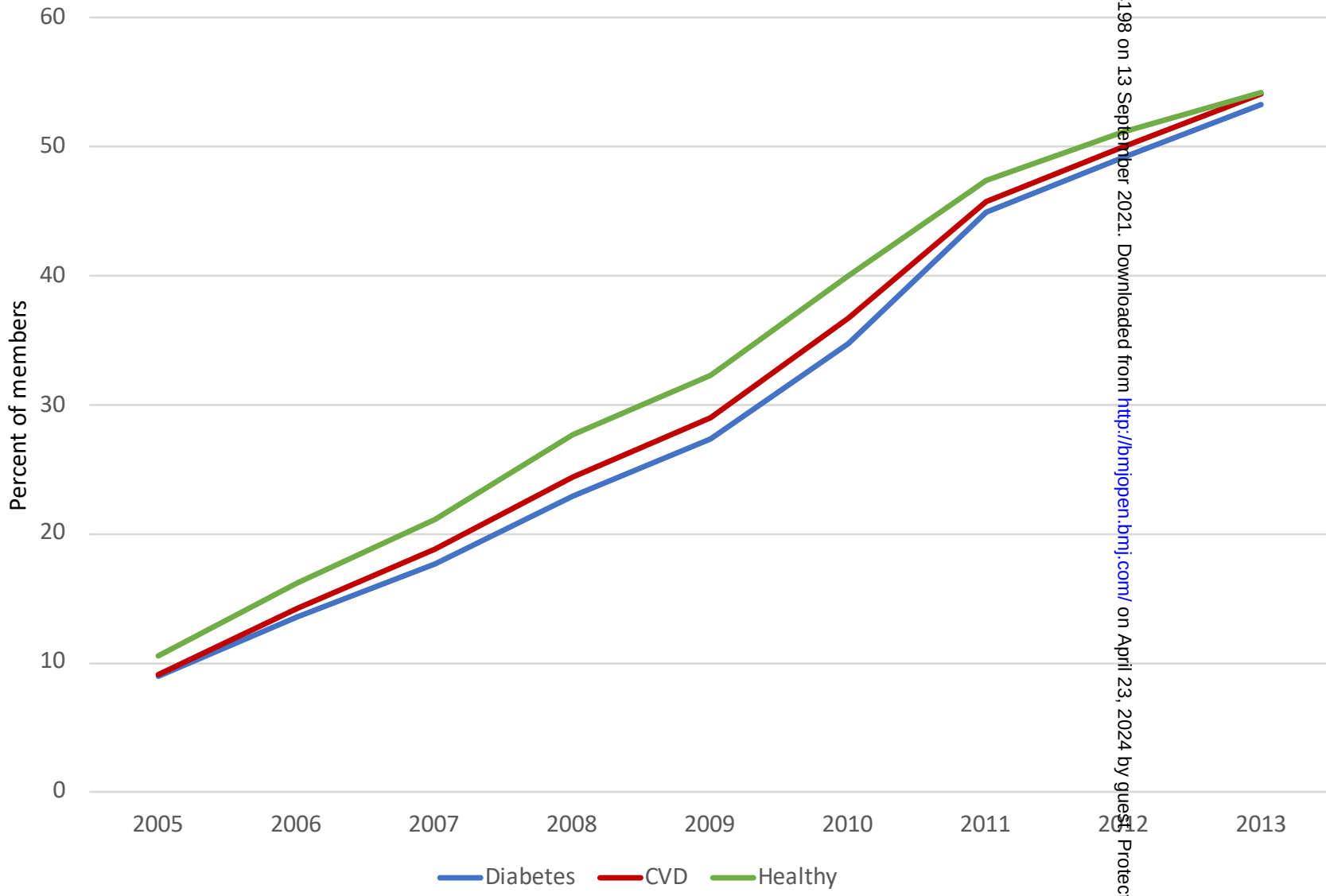

*The denominator includes all members, not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999). Prevalence estimates are adjusted for variables in Table 1.

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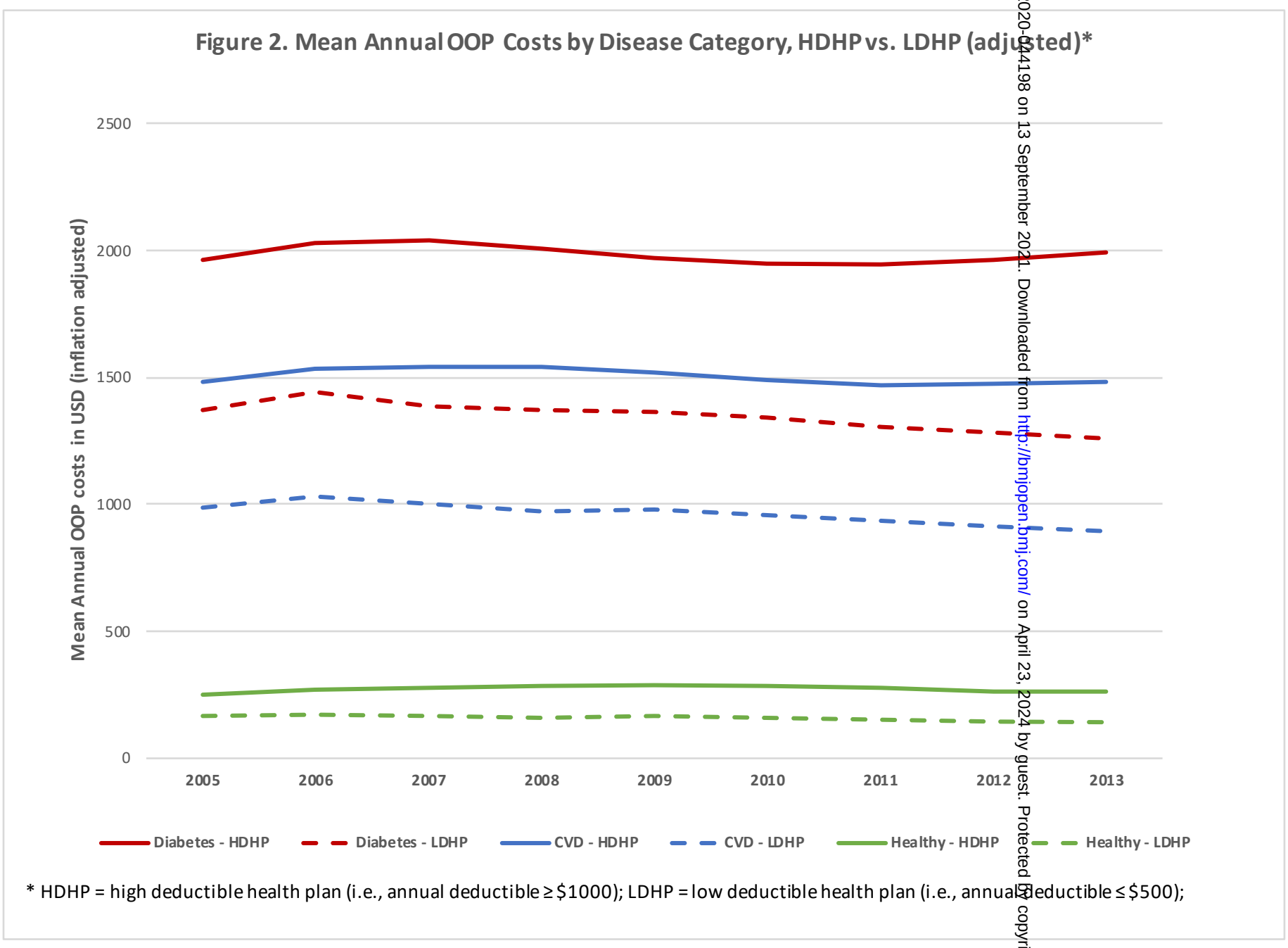

* HDHP = high deductible health plan (i.e., annual deductible ≥ $1000); LDHP = low deductible health plan (i.e., annual deductible ≤ $500);

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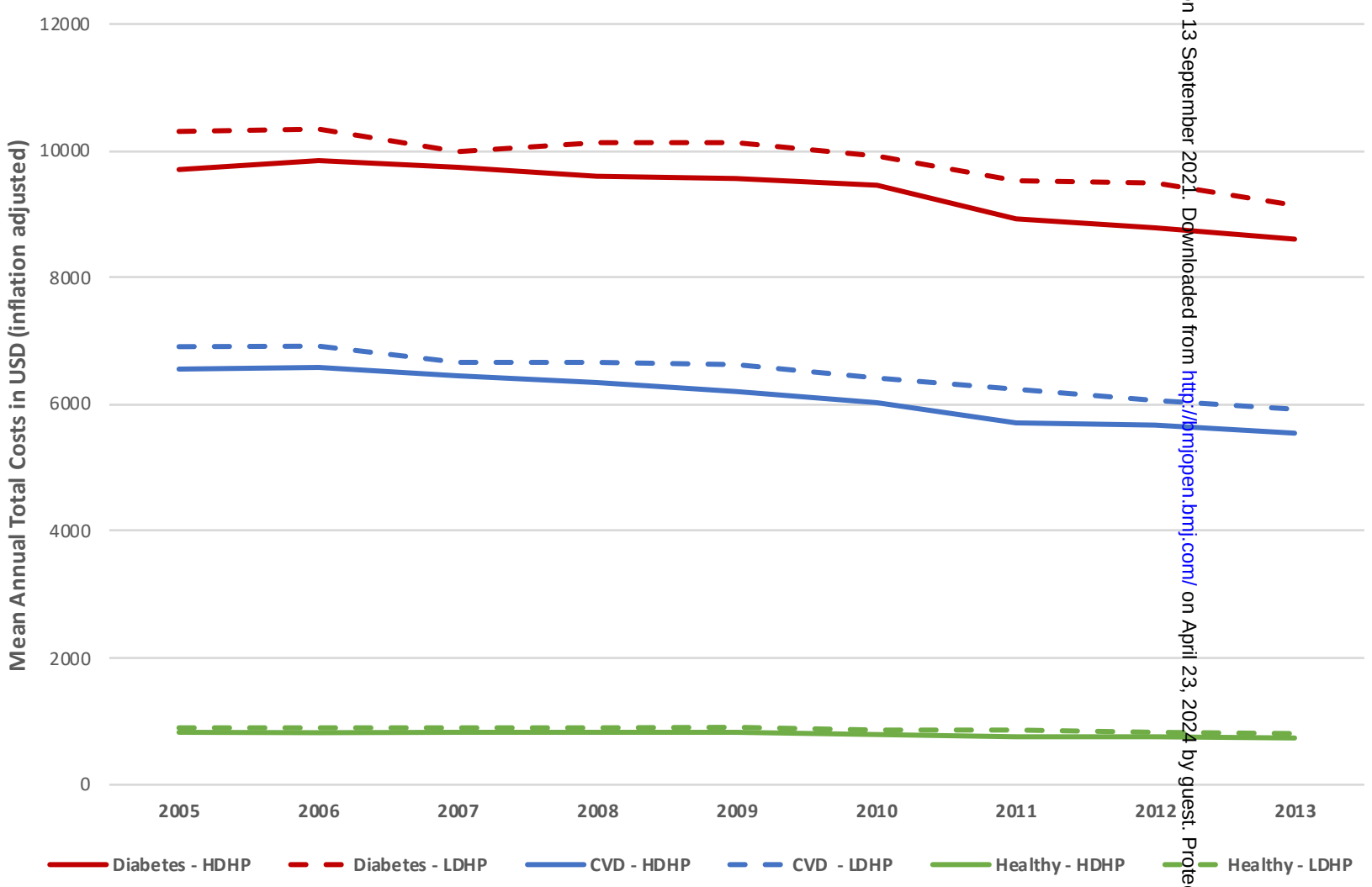
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)*



* HDHP = high deductible health plan (i.e., annual deductible ≥ $1000); LDHP = low deductible health plan (i.e., annual deductible ≤ $500); CVD = cardiovascular disease. Total cost estimates are adjusted for variables in Table 1.

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Appendix 1: Deductible Level Imputation

To determine employer deductible levels, we used a benefits type variable that we had for most smaller employers (with approximately 100 or fewer employees). For larger employers, we took advantage of the fact that health insurance claims data are the most accurate source for assessing out-of-pocket obligations among patients who utilize health services. Our claims data contained an in-network/out-of-network individual deductible payment field. For patients who use expensive or frequent services, the sum of their yearly deductible payments adds up to clearly identifiable exact amounts such as $500.00, $1000.00, $2000.00, etc. When even several members have these same amounts, it provides strong evidence that the employer offered such an annual deductible level. It is also possible to detect employers that offer choices of deductible levels when multiple employees have deductibles at two or more levels, such as 20 employees with an exact annual amount of $1000.00 and 12 employees with $500.00. For employer accounts with at least 10 enrollees, we therefore summed each member's in-network (individual-level) deductible payments and number of claims over the enrollment year and assessed other key characteristics such as percentage with Health Savings Accounts. We randomly selected half of the employer account data set that contained both our calculated employer characteristics (independent variables, below) and actual annual deductible levels from the benefits table (dependent variable, after categorization; below). We then used a multinomial logistic model that predicted the 4-level outcome of individual-level deductible ≤$500/$501-$999/$1000-$2499/≥$2500 (again, dependent variable) based on multiple aggregate employer characteristics (independent variables) such as the percentage with Health Savings Accounts and Health Reimbursement Arrangements, the deductible payment per employer in the 75 percentile of payments, the percentage of employees reaching exact deductible levels or with deductible payments but not reaching an exact deductible level, the employer account size, the percentage of enrollees per account with summed whole dollar annual deductible amounts (from claims data) between $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, ≥$2500, etc.

The statistical model was as follows:

$$\text{Logit}(\Pr=Y_i) = \beta_0 + \sum \beta_k X_{ki}$$

Where:

Y_i = dependent variable (4-level deductible category)
X_{ki}= k^{th} characteristics for i^{th} employer
$\beta_{0=}$ intercept
$\beta_{k=}$ coefficient for k^{th} characteristic

The SAS code we used to implement this model was:

```
proc logistic data=csn_impute_PLUS_to_be_imputed descending;
class
        d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat
        d_wusd1perc_500_1000_cat d_wusd1perc_1000_2500_cat
        d_wusd1perc_ge2500_cat
        d_wusd2perc_0_100_cat d_wusd2perc_100_500_cat
        d_wusd2perc_500_1000_cat d_wusd2perc_1000_2500_cat
        d_wusd2perc_ge2500_cat
```

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```
        d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat
        d_wusd3perc_500_1000_cat d_wusd3perc_1000_2500_cat
        d_wusd3perc_ge2500_cat
        d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat
        d_wusd4perc_500_1000_cat d_wusd4perc_1000_2500_cat
        d_wusd4perc_ge2500_cat;

    model real_dduct_cat =
        pyr sampletot hsa_cnt_over_total cdhp_cnt_over_total perc_grp2 perc_grp3
        perc_grp4 perc_grp5 d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat
        d_wusd1perc_500_1000_cat d_wusd1perc_1000_2500_cat
        d_wusd1perc_ge2500_cat d_wusd2perc_0_100_cat d_wusd2perc_100_500_cat
        d_wusd2perc_500_1000_cat d_wusd2perc_1000_2500_cat
        d_wusd2perc_ge2500_cat d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat
        d_wusd3perc_500_1000_cat d_wusd3perc_1000_2500_cat
        d_wusd3perc_ge2500_cat d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat
        d_wusd4perc_500_1000_cat d_wusd4perc_1000_2500_cat
        d_wusd4perc_ge2500_cat
        p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct
        p75_1000_2500_dduct p75_gt2500_dduct
    output out=prob_of_dduct_cat&IOS. p=p_dduct_cat predprobs=i;
    run;
```

Further explanation of this code is below. Note that all values described are calculated over the benefit year per employer account, and a given employer account could be present for multiple years.

- csn_impute_PLUS_to_be_imputed = name of dataset that contains, at the employer account and benefit year level, accounts with missing deductible levels as well as a random half of the accounts that have actual deductible levels. The other random half is also present in the dataset but with actual deductible levels "hidden" so that they can later be used to validate the predictive algorithm.
- real_dduct_cat = dependent variable; category of actual deductible level from the gold standard source (<=$500, $500-$999, $1000-$2499, ≥$2500)
- pyr = benefit year of account's information and tied to the calendar year. An employer could have multiple benefit years represented in separate records per account-benefit year.
- sampletot = total enrollees per account during the benefit year
- hsa_cnt_over_total = percent of members per account listed as having a health savings account
- cdhp_cnt_over_total = percent of members per account listed as having a health savings account or health reimbursement arrangement
- perc_grp1. Percentage of enrollees per employer-year who have claims but $0 deductible amounts for all annual claims.
- perc_grp2. Percentage of enrollees per employer-year who have reached their annual deductible, evidenced by the sum of their deductible payments ending in $*0.00. Members must have at least one month after the month of the $*0.00 summation where the deductible field is blank, and all subsequent months must have blank deductible fields, indicating that the member reached his or her annual deductible amount.

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- perc_grp3. Percentage of enrollees per employer-year who have an annual deductible amount that does not end in $*0.00.
- perc_grp4. Percentage of enrollees per employer-year who have enrollment during the benefit year where all months show no evidence of utilization (no health insurance claims).
- perc_grp5. Percentage of enrollees per employer-year who might have reached their deductible, as evidenced by having the last month of enrollment of the benefit year with a summed annual deductible amount that ends in $*0.00.
- d_wusd1perc_0_100_cat, d_wusd1perc_100_500_cat, d_wusd1perc_500_1000_cat, d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat. Category of percentage of enrollees with an employer's most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd2perc_0_100_cat, d_wusd2perc_100_500_cat, d_wusd2perc_500_1000_cat, d_wusd2perc_1000_2500_cat d_wusd2perc_ge2500_cat. Category of percentage of enrollees with an employer's second most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd3perc_0_100_cat, d_wusd3perc_100_500_cat, d_wusd3perc_500_1000_cat, d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat. Category of percentage of enrollees with an employer's third most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd4perc_0_100_cat, d_wusd4perc_100_500_cat, d_wusd4perc_500_1000_cat, d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat. Category of percentage of enrollees with an employer's fourth most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct p75_1000_2500_dduct p75_gt2500_dduct. Category of 75th percentile of deductible payments per employer benefit year, categorized as $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.

This predictive model outputs the probability that employers had deductibles in the four categories (summing to 1.0) and we assigned the employer to the level that had the highest probability. We overwrote this assignment with the most common whole number deductible amount per year if it was not zero, and with the second most common whole number deductible amount if the most common amount was zero and at least 10 members had the value of the second most common whole number deductible amount. If an employer had members with both enrollment and evidence of utilization, but never had any amounts in the deductible field, we assigned that employer to <$500 deductible level. If an employer had only members that reached a whole number annual deductible amount such as $1000.00 or $2000.00, we assigned the most common deductible amount as the employer's deductible if that amount was greater than or equal to $1000 and to the 95% percentile value if that number was less than $1000. If at least 99% of employees had Health Savings Accounts or Health Reimbursement Arrangements, we also overwrote any previous assignment to classify the employer as a high-deductible employer. We assigned employers to have a choice between deductible levels of $1000 to $2499 and ≥$2500 when both were common and one accounted for at least 85% of

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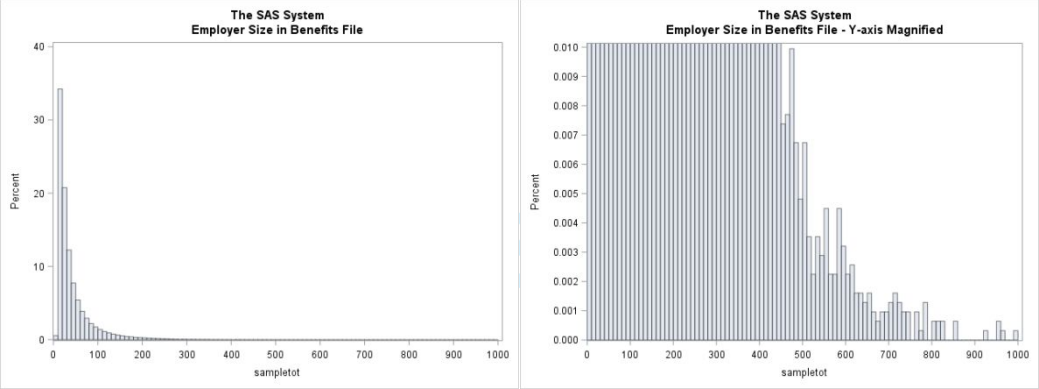
$1000-$2499 or ≥$2500 deductible levels reached per employer. If we detected employers that had sufficient enrollees with whole number deductible levels both above and below $1000 (e.g. $250.00 and $1500.00), we assigned the employers' category as "choice," applying a similar 85% rule. Finally, for any employer that had gold standard deductible level information in our benefits file, we overwrote any previous imputed deductible level.

Our file that contains actual deductible amounts per employer covers the “small employer” segment of the insurer’s business, a segment that generally includes employers with fewer than 100 or so enrollees. However, it does include a modest number of employers with more than 100 enrollees, even up to approximately 1000 enrollees. The histograms below, where the x-axis represents employer size and the y-axis shows the percentage of employers that are that size, demonstrate the distribution of employer sizes. The second plot “magnifies” the y-axis to demonstrate the smaller number of large employers.



To demonstrate the robustness of our imputation algorithm, and its predictive value as employer size increases (given that we do not have benefits information on most large employers), we took advantage of the fact that although this file mostly covers employers with 100 enrollees or fewer, there is some overlap with larger employers (i.e., those with ~100 to 1000 enrollees). A random half of our imputation sample had the actual deductible levels of employers of all sizes “hidden” from the imputation. Thus, this random half included a modest number of employers with 75 to 1000 enrollees. We tested the sensitivity and specificity of the imputation in this overlap zone, categorizing employer sizes as 75-100, 101-400, 401-700, and 701-1000 enrollees (Exhibit 1). At employers with 75-100 enrollees, we found sensitivity of 95.4% and specificity of 98.3% (Exhibit 1a). Sensitivity and specificity increased across employer size to 100%, and Exhibits 1b-1d display these for employers of sizes 101-400, 401-700, and 701-1000.

We used an employer ID and an algorithm that determined linked employer subaccounts to identify an employer’s subaccounts per benefit year, and removed benefit years when employers offered both low and high deductible levels.

Rationale for High-Deductible Cutoffs: When Health Savings Account-eligible high-deductible health plans came to market in 2005-2006, the Internal Revenue Service set the minimum deductible level for qualifying high-deductible health plans at $1050 (which could be adjusted upward for inflation annually). The range of this minimum deductible during our study period was $1050-$1250. For these reasons, we defined high-deductible health plans as annual individual deductibles of at least $1000 (otherwise some health savings account plans would be excluded). In addition, choosing this cutoff (as opposed to, e.g., $2000) improves the sensitivity

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and specificity of the imputation because this is common deductible level and more enrollees per employer meet this threshold. This cutoff is also a "real-world" deductible minimum that allows the most generalizable results. It should also be noted that $1000 was the *minimum* annual deductible level we included and not the mean deductible level. We cannot precisely calculate the mean deductible level of the high-deductible health plan group, but we estimate, using the most common non-zero deductible levels per employer account, an approximate mean deductible of $1900. We defined traditional plans as having deductible levels of ≤$500 after determining that a threshold of ≤$250 would lead to an inadequate sample size for the control group. Again, the mean deductible level of the control group members would be lower than $500.

Appendix 2: Definition of Covariates

Comorbidity score: We used version 11.1 of the Johns Hopkins ACG® System[1,2] to calculate members' baseline period morbidity score. The algorithm uses age, gender, and ICD-9-CM codes to calculate a morbidity score and the average of the reference population is 1.0.[2] Researchers have validated the index against premature mortality.[1]

Demographic characteristics: To derive proxy demographic measures, the data vendor linked members' most recent residential street addresses to their 2010 US Census tract.[3] Census-based measures of socioeconomic status have been validated [4,5] and used in multiple studies to examine the impact of policy changes on disadvantaged populations.[6-8] Using 2008-2012 American Community Survey[9] census tract-level data and validated cut-points,[4,5] we created categories that defined residence in neighborhoods with below-poverty levels of <5%, 5%-9.9%, 10%-19.9%, and ≥20%. Similarly, we defined categories of residence in neighborhoods with below-high-school education levels of <15%, 15%-24.9%, 25%-39.9%, ≥40%.[4,5] We classified members as from predominantly white, black, or Hispanic neighborhoods if they lived in a census tract with at least 75% of members of the respective race/ethnicity. We then applied a superseding ethnicity assignment using flags created by the E-Tech system (Ethnic Technologies), which analyzes full names and geographic locations of individuals.[10] We classified remaining members as from mixed race/ethnicity neighborhoods. This validated approach of combining surname analysis and census data has positive and negative predictive values of approximately 80 and 90 percent, respectively.[11]

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References:

1. Reid RJ, Roos NP, MacWilliam L, Frohlich N, Black C. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. *Health services research.* 2002;37(5):1345-1364.
2. ACG. The Johns Hopkins ACG System. https://www.hopkinsacg.org/advantage/. Accessed 2 June, 2018.
3. USCensus. Census 2000 Gateway. 2000; https://www.census.gov/main/www/cen2000.html. Accessed 2 June, 2018.
4. Krieger N. Overcoming the absence of socioeconomic data in medical records: validation and application of a census-based methodology. *American Journal of Public Health.* 1992;82(5):703-710.
5. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures--the public health disparities geocoding project. *American Journal of Public Health.* 2003;93(10):1655-1671.
6. Trivedi AN, Zaslavsky AM, Schneider EC, Ayanian JZ. Relationship between quality of care and racial disparities in Medicare health plans. *Jama.* 2006;296(16):1998-2004.
7. Trivedi AN, Rakowski W, Ayanian JZ. Effect of cost sharing on screening mammography in medicare health plans. *The New England journal of medicine.* 2008;358(4):375-383.
8. Selby JV, Fireman BH, Swain BE. Effect of a copayment on use of the emergency department in a health maintenance organization. *New England Journal of Medicine.* 1996;334(10):635-641.
9. American Community Survey. https://www.census.gov/programs-surveys/acs/. Accessed 28 September, 2017.
10. Ethnic Technologies. Frequently Asked Questions. www.ethnictechnologies.com/faq. Accessed 24 October, 2018.
11. Fiscella K, Fremont AM. Use of geocoding and surname analysis to estimate race and ethnicity. *Health services research.* 2006;41(4 Pt 1):1482-1500.

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Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health P

	Healthy (no cardiovascular disease or diabete n=40,354,443 member years, 18,035,883 mem w/ LDHP or HDHP *		
	HDHP	HDHP %	Low Deductible
Sample Size	14,701,292		25,653,151
Female	6,962,858	47.36	12,443,275
No. (%) by age category			
Age 0 le 10	2,525,030	17.18	5,140,849
Age 11 to 20	2,937,945	19.98	5,514,822
Age 21 to 30	2,355,574	16.02	3,796,997
Age 31 to 40	2,561,703	17.43	4,454,282
Age 41 to 50	2,480,463	16.87	4,075,686
Age 51 to 60	1,551,032	10.55	2,272,663
Age 61 to 64	289,545	1.97	397,852
Mean Age (std)	29	16.84	27
No. (%) living in neighborhoods with below- poverty levels of			
<5%[1]	3,881,683	26.40	7,683,966
5%-9.9%[1]	4,083,917	27.78	7,177,138
10%-19.9%[2]	4,309,315	29.31	6,956,071
>=20%3[2]	2,426,377	16.50	3,835,976
No. (%) living in neighborhoods with below-high-school education levels of			
<15%[3]	10,937,448	74.40	19,471,646
15%-24.9%[3]	2,450,190	16.67	4,031,237
25%-39.9%[4]	1,033,349	7.03	1,709,914
>=40%[4]	280,305	1.91	440,354
Race/ethnicity, No. (%)[5]			
Hispanic	1,518,148	10.33	2,822,783
Asian	575,277	3.91	1,362,086
Black neighborhood	258,590	1.76	615,995
Mixed neighborhood	2,934,009	19.96	5,582,773
White neighborhood	9,415,268	64.04	15,269,514
Region			
Midwest	4,644,040	31.59	6,936,478
Northeast	916,338	6.23	3,191,361
South	6,760,826	45.99	11,169,713
West	2,380,088	16.19	4,355,599
Median Household Income	66,322	29,601.01	70,858
Mean Patient ACG	0	0.24	0
Mean Count Patids	14,097	49,233.70	12,956
Employer insurance type			
Self-insured	5,043,356	34.31	14,793,332
Fully-insured	9,657,936	65.69	10,859,819
Employersizecategory			
1-99 members	4,119,500	28.02	14,022,246
100-999 members	4,896,008	33.30	7,726,310
1000+ members	5,685,784	38.68	3,904,595
Year			
2005	630,747	4.29	4,006,074

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2006	931,303	6.33	3,644,738
2007	1,209,833	8.23	3,445,104
2008	1,496,575	10.18	3,200,633
2009	1,670,261	11.36	3,019,628
2010	1,879,274	12.78	2,403,893
2011	2,186,945	14.88	2,202,115
2012	2,304,290	15.67	1,924,830
2013	2,392,064	16.27	1,806,136

* Denominator for each disease category is member-years. The denominator includes just HDHI

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Plans and Low Deductible Health Plans, by Disease Category

s; ACG score ≤1)			**Diabetes**		**Ca**
bers, 17,461,997	**n=2,591,414 member years, 1,211,925 members, 1,166,030 w/HDHP or LDHP ***				**n=9,400,823 n**
Low Deductible %	**HDHP**	**HDHP %**	**Low Deductible**	**Low Deductible %**	**HDHP**
	890,420		1,700,994		3,259,616
48.51	427,499	48.01	829,650	48.77	1,538,068
20.04	3,342	0.38	7,508	0.44	20,658
21.50	18,403	2.07	35,092	2.06	45,947
14.80	39,138	4.40	71,982	4.23	102,922
17.36	103,136	11.58	199,799	11.75	375,306
15.89	223,882	25.14	414,944	24.39	923,857
8.86	362,006	40.66	696,366	40.94	1,335,969
1.55	140,513	15.78	275,303	16.18	454,957
16.77	50	11.18	50	11.25	50
29.95	163,429	18.35	369,889	21.75	777,485
27.98	217,208	24.39	434,446	25.54	877,522
27.12	296,408	33.29	530,169	31.17	1,014,427
14.95	213,375	23.96	366,490	21.55	590,182
75.90	559,306	62.81	1,120,370	65.87	2,311,430
15.71	207,634	23.32	365,358	21.48	635,437
6.67	97,651	10.97	172,883	10.16	262,101
1.72	25,829	2.90	42,383	2.49	50,648
11.00	104,640	11.75	200,071	11.76	230,559
5.31	25,876	2.91	65,952	3.88	72,645
2.40	29,938	3.36	75,437	4.43	77,460
21.76	217,086	24.38	434,835	25.56	730,467
59.52	512,880	57.60	924,699	54.36	2,148,485
27.04	253,338	28.45	440,857	25.92	953,263
12.44	45,255	5.08	165,986	9.76	184,069
43.54	489,626	54.99	865,144	50.86	1,734,588
16.98	102,201	11.48	229,007	13.46	387,696
32,504.34	57,895	25,589.44	61,577	27,963.25	63,516
0.24	2	2.77	2	2.88	1
32,855.74	18,618	62,993.80	15,192	40,794.33	16,872
57.67	299,256	33.61	1,007,620	59.24	1,049,576
42.33	591,164	66.39	693,374	40.76	2,210,040
54.66	236,789	26.59	939,469	55.23	866,218
30.12	297,680	33.43	518,619	30.49	1,053,371
15.22	355,951	39.98	242,906	14.28	1,340,027
15.62	29,110	3.27	212,093	12.47	119,408

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14.21	46,520	5.22	217,464	12.78	188,209
13.43	64,017	7.19	224,959	13.23	253,065
12.48	81,780	9.18	223,858	13.16	319,345
11.77	95,412	10.72	221,882	13.04	366,366
9.37	114,898	12.90	173,309	10.19	425,374
8.58	144,049	16.18	160,851	9.46	507,040
7.50	152,708	17.15	137,300	8.07	531,421
7.04	161,926	18.19	129,278	7.60	549,388

P (i.e., deductible ≥$1000) or low-deductible (i.e., deductible ≤ $500) members in the respective columns; †

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ırdiovascular Diesase (no diabetes)
nember years, 4,495,831 members, 4,336,794 w/HDHP or LDHP *

HDHP %	Low Deductible	Low Deductible %
	6,141,207	
47.19	2,958,931	48.18
0.63	37,974	0.62
1.41	84,577	1.38
3.16	191,312	3.12
11.51	744,238	12.12
28.34	1,774,058	28.89
40.99	2,475,473	40.31
13.96	833,575	13.57
10.59	50	10.56
23.85	1,666,412	27.13
26.92	1,706,353	27.79
31.12	1,774,635	28.90
18.11	993,807	16.18
70.91	4,500,556	73.28
19.49	1,101,320	17.93
8.04	452,356	7.37
1.55	86,975	1.42
7.07	495,571	8.07
2.23	185,613	3.02
2.38	190,872	3.11
22.41	1,433,947	23.35
65.91	3,835,204	62.45
29.24	1,596,434	26.00
5.65	704,924	11.48
53.21	2,992,920	48.74
11.89	846,929	13.79
28,840.52	67,271	30,793.56
2.09	2	2.14
58,779.22	14,426	38,380.82
32.20	3,573,083	58.18
67.80	2,568,124	41.82
26.57	3,353,679	54.61
32.32	1,858,301	30.26
41.11	929,227	15.13
3.66	851,959	13.87

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5.77	833,415	13.57
7.76	818,952	13.34
9.80	800,222	13.03
11.24	777,666	12.66
13.05	605,291	9.86
15.56	554,797	9.03
16.30	467,660	7.62
16.85	431,245	7.02

this analysis excludes members with deductibles of $501-$9

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Appendix 4. HDHP Prevalence by Type by Disease Category

DM

	HRA HDHP	HSA HDHP	non Account H LDHP		(choice, other,
2005	1.113559535	0.267838664	10.43191014	86.07076622	2.115925443
2006	1.632677119	1.69346045	13.81107804	80.11022044	2.752563951
2007	3.054379004	2.648915637	15.74839825	75.3823419	3.165965204
2008	4.791947238	3.94425495	16.99663944	70.43901272	3.82814565
2009	6.000570083	4.617969606	18.00921134	66.57425327	4.797995709
2010	8.521426928	5.685492172	20.57566327	52.46509572	12.75232191
2011	8.931959555	6.783930158	27.52960108	48.28968225	8.464826957
2012	8.74638017	8.345438314	30.40781603	42.70699518	9.793370307
2013	9.778268229	10.03419651	30.66432248	40.29950778	9.223705006

CVD

	1	2	3	4	5
2005	0.951260975	0.367706705	10.7136775	85.85120223	2.116152593
2006	1.4956943	2.16200494	14.29072773	79.47807097	2.573502065
2007	2.96171277	3.49198404	16.41103297	73.99330678	3.14196344
2008	4.959011071	4.923660215	17.58477109	68.82854491	3.704012709
2009	6.167859521	5.712716378	18.60927097	64.71920772	4.790945406
2010	8.806415359	7.015638556	20.75481595	52.04749265	11.37563749
2011	8.697616509	8.280659867	27.07542145	48.20302026	7.743281907
2012	8.539476476	10.19013956	29.6701315	42.59264488	9.007607586
2013	9.707545471	11.94801389	29.61642232	40.24621168	8.481806635

Healthy

	1	2	3	4	5
2005	1.773352076	0.542475333	10.99279527	84.52727843	2.164098894
2006	2.469559683	2.800287949	14.54157748	77.53379291	2.654781977
2007	4.220184248	4.308501093	16.5708293	71.4730366	3.427448759
2008	6.681771489	6.138596724	17.87138493	65.63856668	3.66968018
2009	7.148442203	7.601080094	19.16351836	61.31063775	4.776321595
2010	9.577953146	9.276929577	21.06226145	51.06043263	9.022423197
2011	8.714846333	10.85871908	26.94795415	46.84422153	6.634258909
2012	7.905851237	13.23606857	28.96155781	41.85266474	8.043857639
2013	8.443297075	15.2556489	28.56331353	39.46079551	8.276944986

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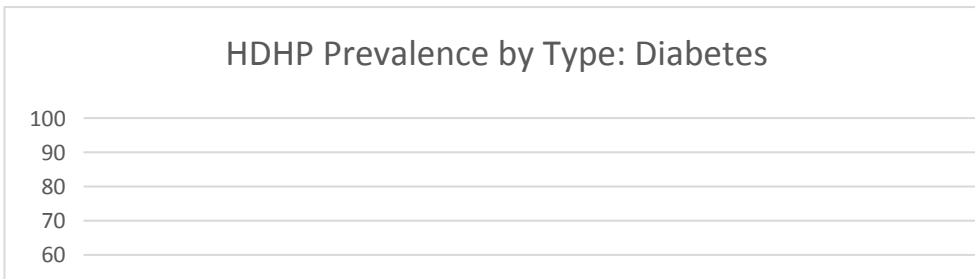
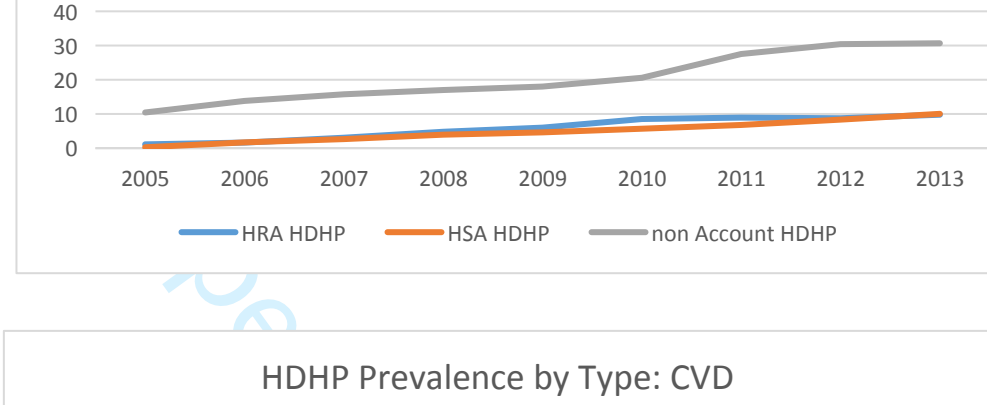
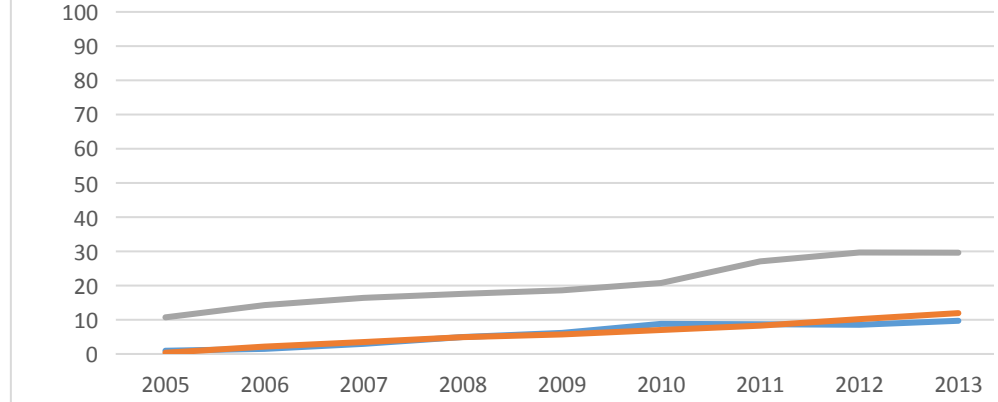
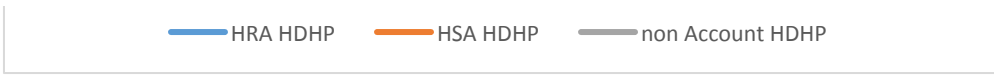
500-999)


HDHP Prevalence by Type: Diabetes
100
90
80
70
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
HRA HDHP
HSA HDHP
non Account HDHP


HDHP Prevalence by Type: CVD
100
90
80
70
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
HRA HDHP
HSA HDHP
non Account HDHP


HDHP Prevlance by Type: Healthy
100
90
80
70
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
2010
2011
2012
2013



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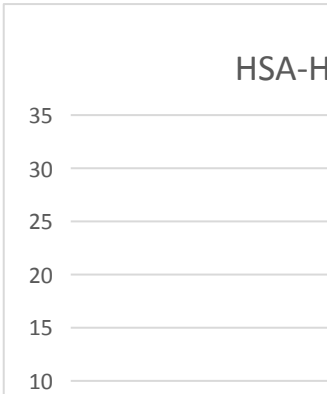
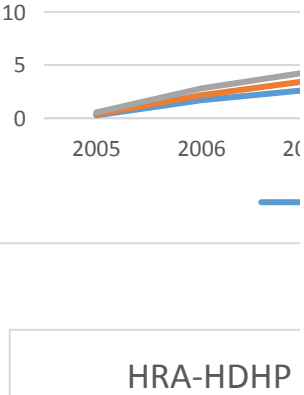
HSA-HDHP

	Diabetes	CVD	Healthy
2005	0.267839	0.367707	0.542475
2006	1.69346	2.162005	2.800288
2007	2.648916	3.491984	4.308501
2008	3.944255	4.92366	6.138597
2009	4.61797	5.712716	7.60108
2010	5.685492	7.015639	9.27693
2011	6.78393	8.28066	10.85872
2012	8.345438	10.19014	13.23607
2013	10.0342	11.94801	15.25565



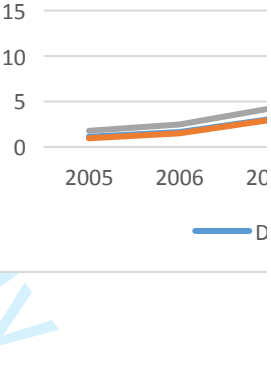
HRA-HDHP

	Diabetes	CVD	Healthy
2005	1.11356	0.951261	1.773352
2006	1.632677	1.495694	2.46956
2007	3.054379	2.961713	4.220184
2008	4.791947	4.959011	6.681771
2009	6.00057	6.16786	7.148442
2010	8.521427	8.806415	9.577953
2011	8.93196	8.697617	8.714846
2012	8.74638	8.539476	7.905851
2013	9.778268	9.707545	8.443297



Non Account-HDHP

	Diabetes	CVD	Healthy
2005	10.43191	10.71368	10.9928
2006	13.81108	14.29073	14.54158
2007	15.7484	16.41103	16.57083
2008	16.99664	17.58477	17.87138
2009	18.00921	18.60927	19.16352
2010	20.57566	20.75482	21.06226
2011	27.5296	27.07542	26.94795
2012	30.40782	29.67013	28.96156



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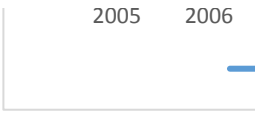
2013	30.66432	29.61642	28.56331



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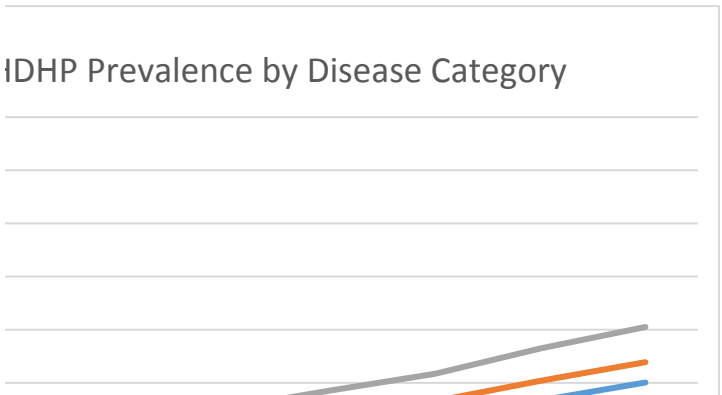

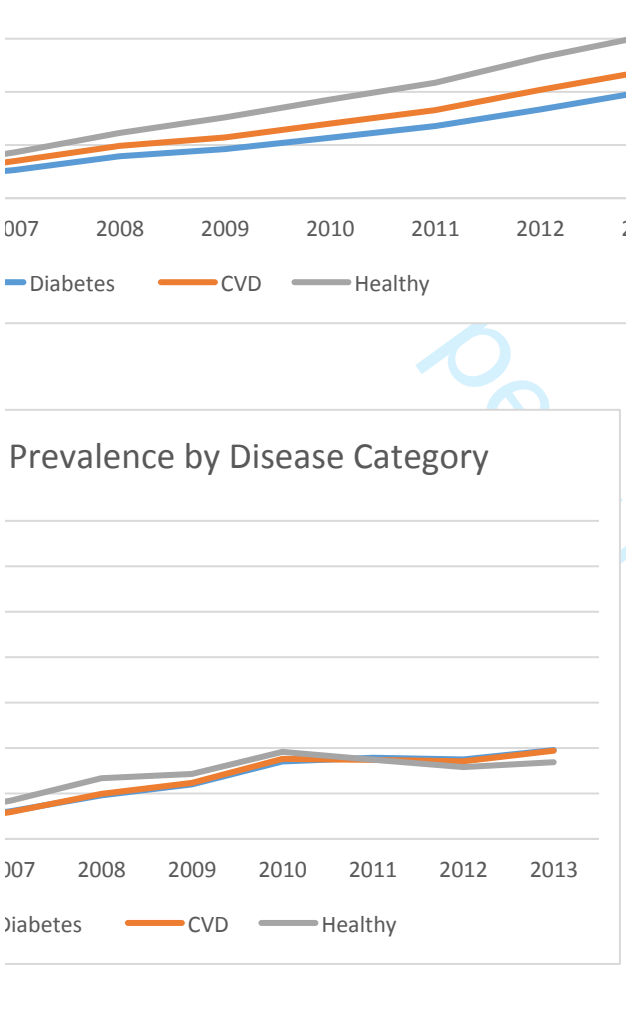

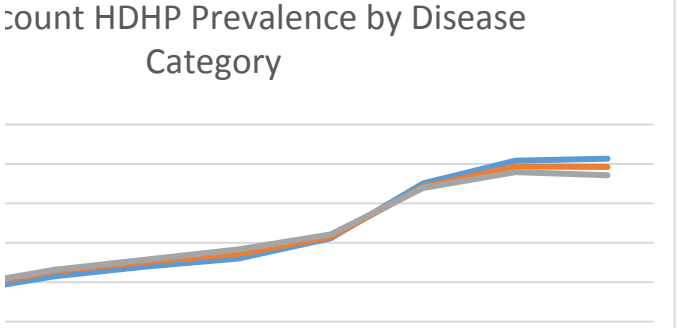

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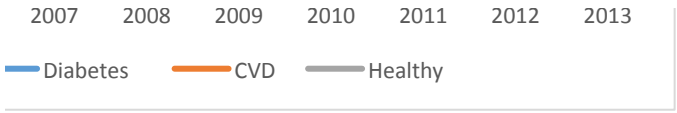

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Appendix 5. Mean Annual OOP Costs by Deductible Type by Disease Category

DM

	HRA-HDHP	HAS- HDHF	Non-accou	Low Deduc	HRA minus	HSA minus non-account
2005	2393.916	2881.905	2003.091	1516.98	390.8251	878.814
2006	2559.193	2631.365	1988.599	1595.349	570.594	642.7656
2007	2590.896	2526.562	1938.282	1582.098	652.6135	588.28
2008	2296.826	2436.601	1926.693	1556.628	370.1324	509.9076
2009	2194.634	2431.91	1885.599	1565.047	309.0354	546.3113
2010	2238.621	2420.992	1865.441	1497.35	373.1802	555.5506
2011	2321.375	2440.716	1903.518	1447.1	417.8574	537.1983
2012	2574.192	2373.463	1850.834	1422.535	723.3575	522.6287
2013	2687.706	2353.21	1874.342	1388.097	813.3646	478.8685

CVD (no DM)

	1	2	3	4	HRA minus	HSA minus non-account
2005	1920.443	2326.151	1479.539	1090.894	440.9041	846.6121
2006	1986.084	2028.731	1485.003	1146.635	501.0815	543.7286
2007	2007.072	1961.689	1450.305	1140.393	556.7679	511.3849
2008	1790.413	1900.173	1474.796	1117.401	315.6174	425.3775
2009	1735.514	1840.534	1483.046	1130.698	252.4678	357.4885
2010	1734.52	1836.894	1459.298	1085.333	275.2217	377.5953
2011	1800.884	1867.053	1460.313	1059.419	340.5712	406.7393
2012	1934.948	1843.689	1427.32	1033.656	507.6274	416.3687
2013	2027.645	1817.272	1444.648	1020.506	582.9969	372.6236

Healthy (no CVD/DM)

	1	2	3	4	HRA minus	HSA minus non-account
2005	347.3469	551.8989	322.074	247.2184	25.2729	229.8249
2006	427.0065	544.3314	330.4697	261.703	96.53675	213.8617
2007	486.1821	533.8033	330.1245	266.8136	156.0576	203.6789
2008	474.593	527.5781	336.9341	257.3514	137.6588	190.644
2009	516.8504	502.2568	343.9218	263.8786	172.9286	158.335
2010	517.5078	494.6837	340.2603	254.0303	177.2475	154.4234
2011	539.9028	511.0485	335.8207	251.1227	204.082	175.2278
2012	552.2777	507.3392	327.0786	241.9559	225.1992	180.2607
2013	551.6646	495.3605	320.5448	235.7487	231.1198	174.8157

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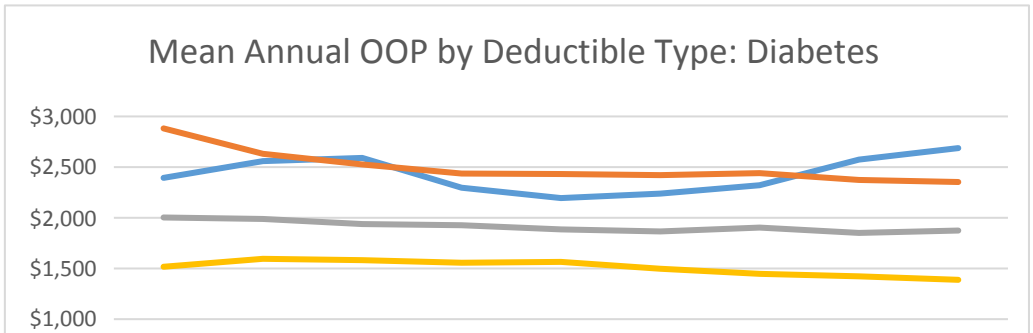
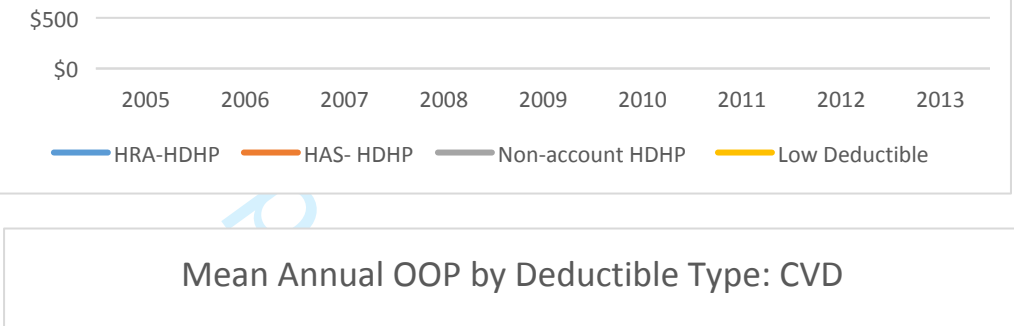
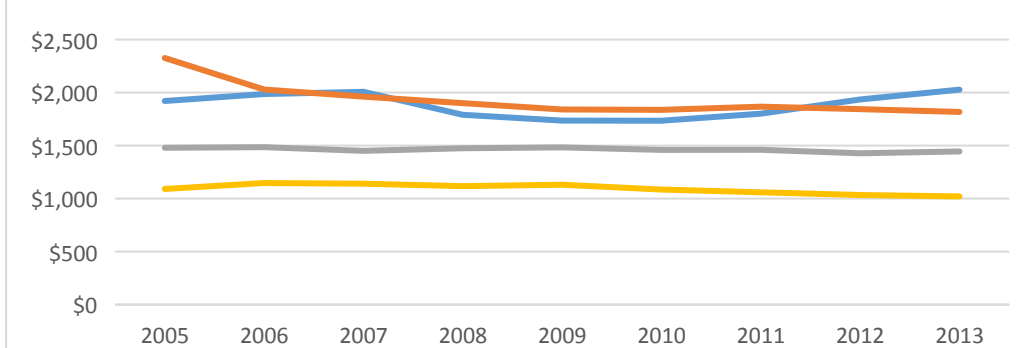

Mean Annual OOP by Deductible Type: Diabetes
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
2005 2006 2007 2008 2009 2010 2011 2012 2013
HRA-HDHP
HAS- HDHP
Non-account HDHP
Low Deductible


Mean Annual OOP by Deductible Type: CVD
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
2005 2006 2007 2008 2009 2010 2011 2012 2013
HRA-HDHP
HAS- HDHP
Non-account HDHP
Low Deductible


Mean Annual OOP by Deductible Type: Healthy
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
2005 2006 2007 2008 2009 2010 2011 2012 2013
HRA-HDHP
HAS- HDHP
Non-account HDHP
Low Deductible

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Appendix 6. Mean Annual Total Costs by Deductible Type by Disease Category (unadjusted)

DM

	HRA	HSA	Non-account H	Low Deductibl
2005	14295.15901	14546.6128	12233.7601	14554.59815
2006	13405.63135	14868.81695	11846.05042	14426.92738
2007	13720.22153	13642.25951	11639.91124	14526.02864
2008	14131.75479	13994.31617	11534.83607	14877.3287
2009	14322.29938	14503.04544	11411.71708	15028.2057
2010	14027.56971	14109.11982	11402.7128	14406.14894
2011	13582.10935	13337.52968	11132.93139	13854.35939
2012	13080.23284	12669.93664	10893.35848	13685.20298
2013	13691.86599	12726.6443	10815.17043	13456.14811

CVD, no DM

	HRA	HSA	Non-account H	Low Deductibl
2005	8850.256505	9598.062586	7866.036401	9271.997354
2006	8915.313118	8876.553784	7631.195185	9320.588567
2007	8848.853019	8493.630408	7573.834261	9384.138362
2008	8580.592785	8784.496764	7512.799245	9526.765184
2009	8720.503012	8711.905936	7616.054761	9658.355955
2010	8648.269763	8540.065897	7448.820658	9277.827305
2011	8573.48888	8220.636208	7255.241166	9070.624837
2012	8320.183574	8280.958581	7230.308001	9028.639503
2013	8477.33171	8152.846695	7339.746457	8988.416795

Healhty, no CVD, no DM

	HRA	HSA	Non-account H	Low Deductibl
2005	886.9861308	1213.842657	1224.830341	1495.335946
2006	1008.234675	1209.061845	1225.083036	1506.232586
2007	1147.217313	1223.599031	1221.549034	1515.32876
2008	1199.469737	1217.558335	1201.53683	1530.071192
2009	1285.869673	1162.702343	1206.441497	1561.344602
2010	1324.598342	1141.728807	1171.974055	1489.797593
2011	1275.707557	1111.261067	1156.502128	1466.704303
2012	1290.420283	1111.124486	1154.080793	1434.908082
2013	1292.016802	1109.158634	1140.75247	1421.652668

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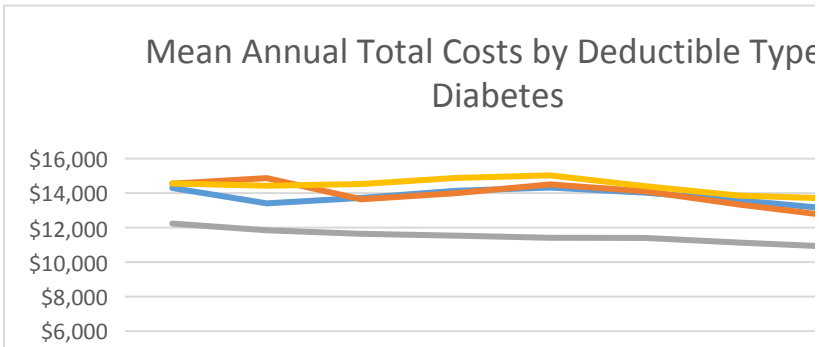
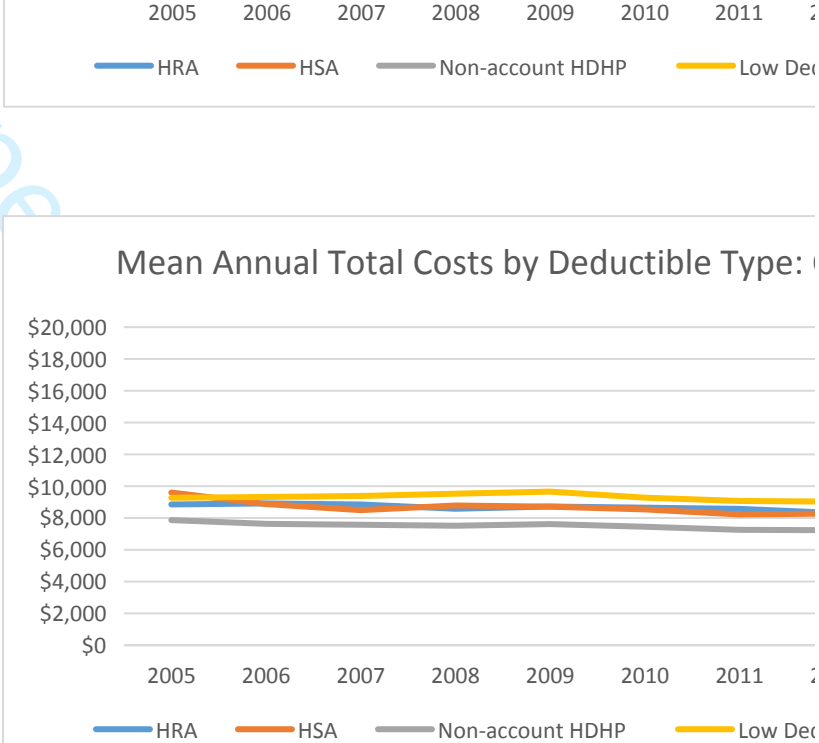
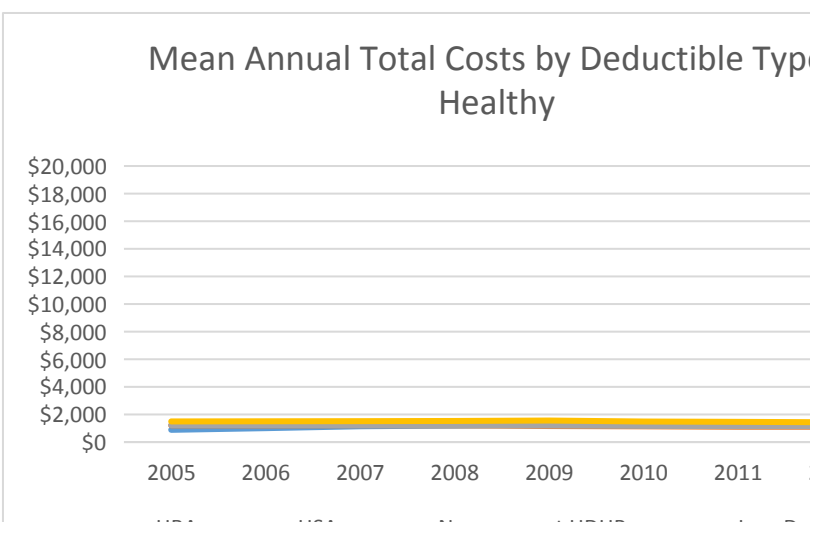
HRA - non-acc	HSA-non-account
2061.39891	2312.8527
1559.58093	3022.76653
2080.31029	2002.34827
2596.91872	2459.4801
2910.5823	3091.32836
2624.85691	2706.40702
2449.17796	2204.59829
2186.87436	1776.57816
2876.69556	1911.47387

HRA - non-acc	HSA-non-account
984.220104	1732.026185
1284.117933	1245.358599
1275.018758	919.796147
1067.79354	1271.697519
1104.448251	1095.851175
1199.449105	1091.245239
1318.247714	965.395042
1089.875573	1050.65058
1137.585253	813.100238

HRA - non-acc	HSA-non-account
-337.84421	-10.987684
-216.848361	-16.021191
-74.331721	2.049997
-2.067093	16.021505
79.428176	-43.739154
152.624287	-30.245248
119.205429	-45.241061
136.33949	-42.956307
151.264332	-31.593836







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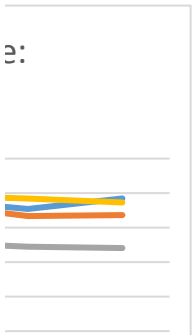

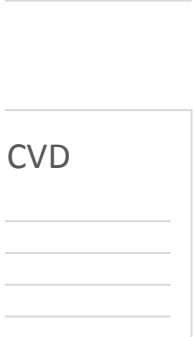

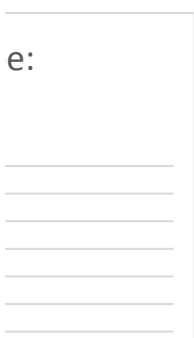

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Appendix 7. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plan

OOP Costs

DM

	Low Deductibl	HDHP	HDHP-LDHP
2005	1368.324	1959.252	590.928
2006	1441.811	2029.778	587.967
2007	1388.378	2038.749	650.371
2008	1368.538	2006.348	637.81
2009	1362.979	1965.911	602.932
2010	1338.029	1945.981	607.952
2011	1303.13	1943.895	640.765
2012	1284.478	1960.074	675.596
2013	1258.84	1989.25	730.41
Mean	1346.056333	1982.137556	

CVD (no DM)

	0	1	
2005	987.0506	1479.058	492.0074
2006	1030.623	1530.359	499.736
2007	1000.954	1540.841	539.887
2008	975.2969	1537.254	561.9571
2009	976.0373	1515.611	539.5737
2010	954.6136	1486.501	531.8874
2011	933.4627	1468.28	534.8173
2012	911.3351	1473.901	562.5659
2013	893.9074	1485.194	591.2866
Mean	962.5867333	1501.888778	

Healthy (no CVD/DM)

	0	1	
2005	166.4346	250.436	84.0014
2006	171.8132	272.3515	100.5383
2007	169.8192	279.7187	109.8995
2008	162.8924	285.4981	122.6057
2009	165.9155	287.9714	122.0559
2010	160.5264	281.4719	120.9455
2011	155.5968	274.167	118.5702
2012	147.853	266.1062	118.2532
2013	142.2151	261.422	119.2069
Mean	160.3406889	273.2380889	

Relative costs	LDHP	HDHP
vs. DM	8.394976613	7.254250546
vs. CVD	6.003384044	5.496630371

Total Costs

DM

	Low Deductibl
2005	10308.47
2006	10341.91
2007	9992.148
2008	10114.71
2009	10133.87
2010	9926.813
2011	9529.334
2012	9488.913
2013	9138.999
Mean	

CVD, no DM

	0
2005	6903.557
2006	6918.276
2007	6663.636
2008	6680.236
2009	6626.569
2010	6400.159
2011	6221.113
2012	6064.94
2013	5922.871
Mean	

Healthy, no CVD, no DM

	0
2005	899.2028
2006	895.8246
2007	889.7641
2008	892.4623
2009	906.1254
2010	876.4865
2011	851.6796
2012	824.5298
2013	807.2234
Mean	

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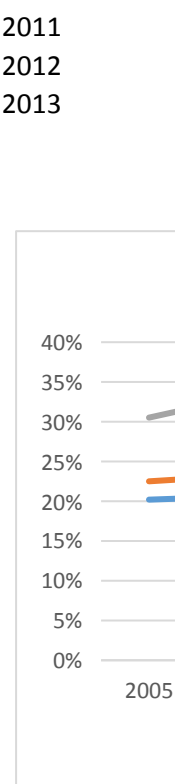
ıs, by Disease Category (unadjusted)

HDHP	HDHP-LDHP		HDHP - OOP/T	LDHP - OOP/Total costs	
9699.435	-609.035		20.20%	13.27%	2005
9845.497	-496.413		20.62%	13.94%	2006
9743.071	-249.077		20.93%	13.89%	2007
9606.592	-508.118		20.89%	13.53%	2008
9549.384	-584.486		20.59%	13.45%	2009
9458.704	-468.109		20.57%	13.48%	2010
8935.642	-593.692		21.75%	13.67%	2011
8769.875	-719.038		22.35%	13.54%	2012
8606.055	-532.944		23.11%	13.77%	2013
9357.139444		**Mean**	**21.22%**	**13.62%**	
1					
6572.213	-331.344		22.50%	14.30%	
6582.855	-335.421		23.25%	14.90%	
6458.677	-204.959		23.86%	15.02%	
6350.276	-329.96		24.21%	14.60%	
6201.896	-424.673		24.44%	14.73%	
6034.349	-365.81		24.63%	14.92%	
5721.829	-499.284		25.66%	15.00%	
5662.128	-402.812		26.03%	15.03%	
5545.22	-377.651		26.78%	15.09%	
6125.493667		**Mean**	**24.60%**	**14.84%**	
1					
820.705	-78.4978		30.51%	18.51%	
821.0606	-74.764		33.17%	19.18%	
818.8746	-70.8895		34.16%	19.09%	
813.7006	-78.7617		35.09%	18.25%	
811.5594	-94.566		35.48%	18.31%	
796.0561	-80.4304		35.36%	18.31%	
761.3796	-90.3		36.01%	18.27%	
752.7057	-71.8241		35.35%	17.93%	
737.2551	-69.9683		35.46%	17.62%	
792.5885222		**Mean**	**34.51%**	**18.39%**	



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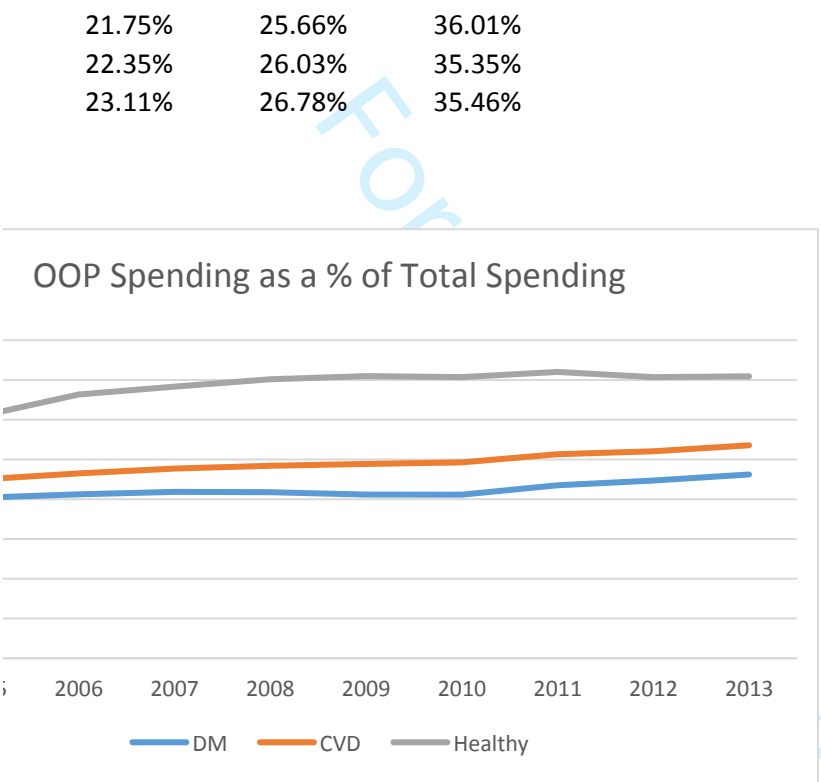
DM	CVD	Healthy
20.20%	22.50%	30.51%
20.62%	23.25%	33.17%
20.93%	23.86%	34.16%
20.89%	24.21%	35.09%
20.59%	24.44%	35.48%
20.57%	24.63%	35.36%
21.75%	25.66%	36.01%
22.35%	26.03%	35.35%
23.11%	26.78%	35.46%



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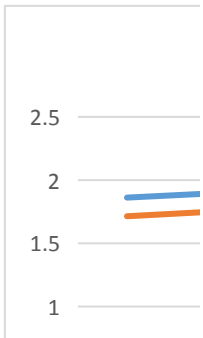
Appendix 8. Average ACG score over time by Deductible Type by Disease Category (unadjusted)

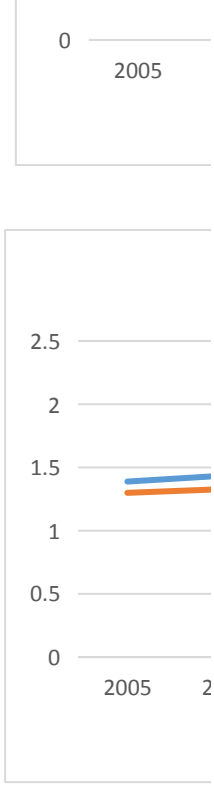
DM

	Low Deductible	HDHP
2005	1.861649017	1.714135177
2006	1.900161553	1.755773667
2007	1.97781806	1.770965478
2008	2.012055696	1.828904806
2009	2.044269382	1.848417882
2010	2.037977855	1.864763712
2011	2.057163586	1.865177058
2012	2.057682309	1.866217048
2013	2.05615462	1.891463564



CVD

	0	1
2005	1.388339763	1.299303003
2006	1.436105621	1.329121657
2007	1.491629805	1.350587912
2008	1.514304403	1.383810136
2009	1.551069175	1.419532189
2010	1.560214495	1.429574365
2011	1.578042255	1.442374895
2012	1.599309203	1.455452532
2013	1.609740152	1.469366178



Healthy

	0	1
2005	0.255855261	0.22290789
2006	0.263268967	0.229830085
2007	0.267363128	0.235275946
2008	0.269366642	0.238672036
2009	0.273416246	0.242011671
2010	0.268782921	0.244339555
2011	0.27245572	0.246896724
2012	0.271553431	0.248249108
2013	0.271018578	0.248220379

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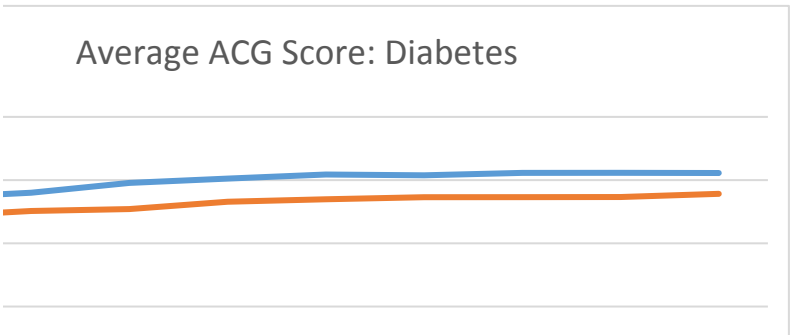
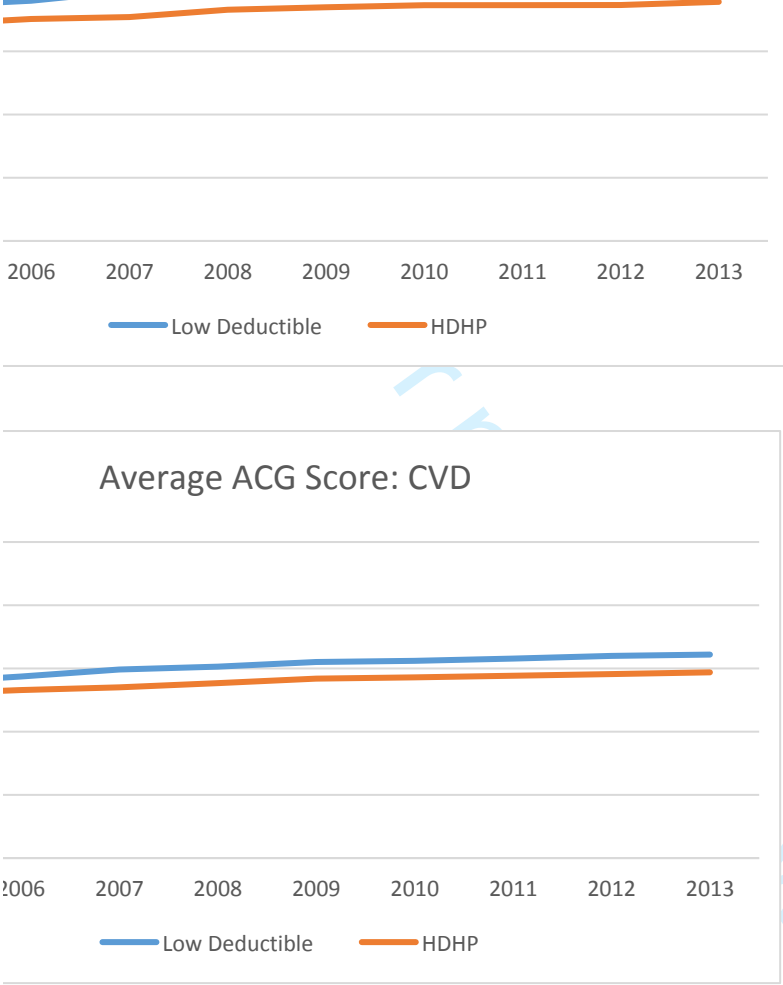
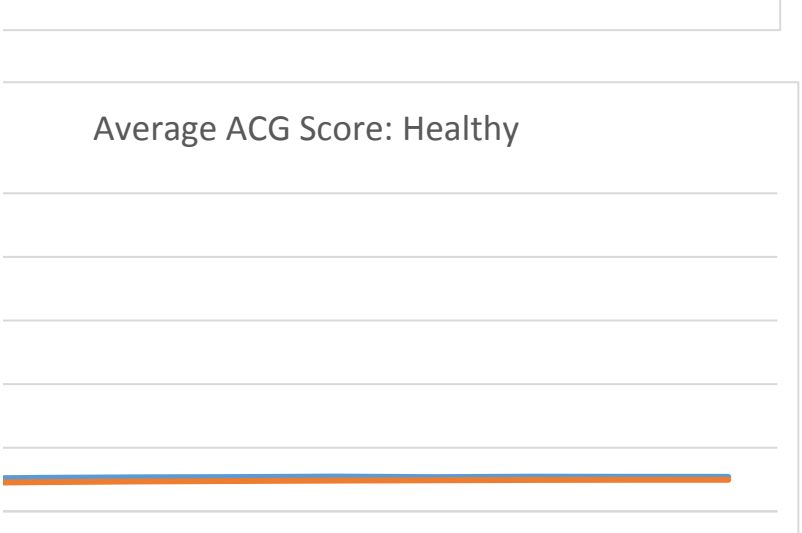

Average ACG Score: Diabetes
2006
2007
2008
2009
2010
2011
2012
2013
Low Deductible
HDHP


Average ACG Score: CVD
2006
2007
2008
2009
2010
2011
2012
2013
Low Deductible
HDHP


Average ACG Score: Healthy
2006
2007
2008
2009
2010
2011
2012
2013
Low Deductible
HDHP

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	p2 1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	p3 2	Explain the scientific background and rationale for the investigation being reported
Objectives	p3 3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	p4 4	Present key elements of study design early in the paper
Setting	p4 5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	p4 6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	p4/5 7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	p4 8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	p5 9	Describe any efforts to address potential sources of bias
Study size	p4/6 10	Explain how the study size was arrived at
Quantitative variables	p4/5 11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	p5 12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	p6 13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	p6 14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	p6/7 15*	Report numbers of outcome events or summary measures over time
Main results	p6/7 16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

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Other analyses	p7	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	p5	18	Summarise key results with reference to study objectives
Limitations	p8/9	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	p8/9	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	p9	21	Discuss the generalisability (external validity) of the study results
Other information			
Funding	p11	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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BMJ Open

Trends in High Deductible Health Plan Enrollment and Spending Among Commercially Insured Members with and without Chronic Conditions: A Natural Experiments for Translation in Diabetes (NEXT-D2) Study

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Keywords:	Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, DIABETES & ENDOCRINOLOGY, Health economics < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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Trends in High Deductible Health Plan Enrollment and Spending among Commercially Insured Members with and without Chronic Conditions: A Natural Experiments for Translation in Diabetes (NEXT-D2) Study

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Word Count: 3812

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Abstract:

Objectives: To examine trends in high deductible health plan (HDHP) enrollment among members with diabetes and cardiovascular disease (CVD) compared to healthy members and compare out-of-pocket (OOP) and total spending for members with chronic conditions in HDHPs vs. low deductible plans.
Design: Descriptive study with time trends.
Setting: A large national commercial insurance database.
Participants: 1.2 million members with diabetes, 4.5 million members with CVD (without diabetes) and 18.0 million healthy members (defined by a low comorbidity score) under the age of 65 and insured between 2005 to 2013.
Outcome measures: Percentage of members in a HDHP (i.e., annual deductible ≥$1000) by year, annual mean OOP and total spending, adjusted for member sociodemographic and employer characteristics.
Results: Enrollment in HDHPs among members in all disease categories increased by 5 percentage points a year and was over 50% by 2013. On average over the study period, HDHP enrollment among members with diabetes and CVD was 2.84 (95% CI: 2.78, 2.90) and 2.02 (95% CI: 1.98, 2.05) percentage points lower, respectively, than among healthy members. HDHP members with diabetes, CVD, and low morbidity had higher annual OOP costs ($636 [95% CI: 630, 642], $539 [95% CI: 537, 542], and $113 [95% CI: 112, 113]) and lower total costs (-$529 [95% CI: -597, -461], -$364 [95% CI: -385, -342], and -$79 [95% CI: -81, -76]), respectively, than corresponding low-deductible members when averaged over the study period. Members with chronic diseases had yearly OOP expenditures that were 5 to 7 times higher than healthier members.
Conclusions: High HDHP enrollment coupled with the high OOP costs associated with HDHPs may be particularly detrimental to the financial well-being of people with diabetes and cardiovascular disease, who have more health care needs than healthier populations.

Article Summary

Strengths and limitations of this study

- This is the first study to compare enrollment in high deductible health plans between members with chronic diseases (i.e., diabetes and cardiovascular disease) and healthy members.
- This study uses nine years of claims data from large, national health insurer in the United States.
- The study also examines out-of-pocket and total costs between members in high deductible and low deductible plans.
- The study is descriptive and we cannot infer causal relationships.
- The algorithm to assign disease categories relies on accurate and complete claims data and the plan deductible amounts are imputed.
- The data do not include insurance premium information, so we cannot assess the full financial burden on members.

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Key Words: health insurance, high deductible health plan, diabetes, cardiovascular disease, out-of-pocket costs

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Introduction

Recent research suggests that high deductible health plans (HDHPs), which provide incentives for patients to manage their own health care costs, are associated with concerning impacts on patients with chronic conditions. However, little is known about trends in HDHP enrollment among patients with chronic conditions versus healthier populations and the associated economic burden.

To reduce health care costs and monthly premiums, an increasing number of employers offer HDHPs. These arrangements provide incentives for patients to utilize select high-value services and reduce health care costs through inexpensive preventive care and higher annual deductibles.[1] In 2019, 82% of commercially insured Americans had an annual deductible; of these, over two-thirds (69%) had a deductible of over $1000 and over one in ten (14%) had a deductible over $3000.[2] HDHPs paired with a tax-preferred savings account for out-of-pocket (OOP) spending (i.e., Health Savings Accounts [HSA] or Health Reimbursement Arrangements [HRA]) are the most rapidly growing plan type, now covering 30% of commercially insured Americans.[2] HDHPs have been shown to reduce health care spending, but also reduce preventive care[3] and cause members to delay care because of costs.[4] If given a choice in plans by their employer, employees who choose HDHPs tend to be younger and healthier and more likely to live in neighborhoods with a higher proportion of individuals of higher income, higher education and white race.[5]

Diabetes and cardiovascular disease (CVD) are the two most prevalent chronic illnesses in the United States. High quality of care for such conditions requires multiple office visits, tests, exams and medications.[6-13] Typically, HDHPs fully cover some preventive services and one annual preventive visit, but require full cost-sharing up to the annual deductible for all other services and often additional cost sharing (i.e., coinsurance or co-payment) after the deductible is met. Our Natural Experiments in Diabetes Translation (NEXT-D1) study used a robust study design to examine the impact of HDHPs among members with diabetes. Studies demonstrated decreased utilization of both appropriate and discretionary services, with concerning impacts on vulnerable populations. For example, HDHPs were associated with delays in seeking care for major macrovascular disease symptoms, diagnostic tests, and procedure-based treatments,[14] reductions in specialist visits,[15] delayed outpatient visits for acute preventable complications[15] and higher emergency department visits for acute complications among the poor.[15] The negative impacts of HDHPs are consistently more pronounced in low income HDHP members or members with a HSA-HDHP. [15,16] Other studies have suggested similar impacts of HDHPs on members with cardiovascular disease.[17]

Despite these concerning effects, trends in HDHP enrollment and OOP burden among patients with chronic illness versus healthier patients are unknown. Our objective was to assess 2005-2013 trends in HDHP enrollment among members with diabetes and cardiovascular disease in a large national insurer, compared to a cohort of healthy members. We also compared the demographics, comorbidities, and trends in OOP

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spending and total spending of members with chronic conditions and healthier members in HDHPs (with and without savings accounts) to counterparts in low deductible plans.

Methods

Study Design: This descriptive study assessed annual trends from 2005-2013 and differences in HDHP enrollment between subgroups of members with chronic conditions compared to healthy members and, within disease category, assessed member-level and employer-level characteristics associated with HDHP enrollment and compared differences in OOP spending and total costs between members with HDHPs and low-deductible health plans.

Data: We used a large claims database that included approximately 55.5 million unique commercially-insured members of all ages from 2005-2013. Members with Medicare Advantage were excluded from this study since they were not subject to comparable insurance arrangements. The data included enrollment status and all medical and pharmacy claims. We used the Johns Hopkins ACG® System (version 11.1),[18,19] to assign diagnostic categories and an overall comorbidity score using claims data (i.e., diagnoses, procedures and medications) from the prior 12 months. We also linked individuals to neighborhood-level socioeconomic characteristics from the 2008-2012 American Community Survey (ACS; i.e., 5-year estimates at the census-tract level).[20]

Study Population: We included members under the age of 65 years old with diabetes and cardiovascular disease and a comparison group of healthier members. We created the three mutually exclusive categories of members based on ACG diagnostic categories: diabetes (inclusive of Type 1 and Type 2 diabetes) with or without cardiovascular disease (CVD); CVD or risk factors (i.e., lipid disorders or hypertension) without diabetes; and "healthy" (defined as ACG morbidity score ≤1 and excluding members with a diabetes or CVD diagnosis). We included members with at least 12 months of continuous enrollment covered by employers insuring 10 or more members (for whom we could reliably assess HDHP status). We used the ACG diagnosis flag (or score) from the last month of each member's 12-month enrollment period (i.e., "anniversary month"). Measures calculated over each 12-month enrollment period were assigned to the calendar year of each anniversary month.

Outcomes and Covariates: For each annual employer enrollment period, we classified members as being enrolled in a HDHP or non-HDHP plan on the anniversary month. We used actual or imputed deductible levels; the imputations were based on adding actual deductible payments per person per benefit year at the employer then assigning a deductible level to that employer using a regression model that included all enrollees' summed deductible levels and other employer characteristics (see details in Appendix 1). Using a common convention, we defined HDHPs as plans with a deductible level ≥$1000 and low deductible plans as plans with a deductible level ≤$500. Within HDHPs, we examined two levels of HDHP (i.e., $1000-2499 and ≥$2500) and identified HDHP members with a savings account plan (i.e., HSA or HRA) using flags provided by the data vendor.

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For member demographics, we examined age; sex; region (i.e., Midwest, Northeast, South and West); and neighborhood-level income (i.e., low poverty, low-medium poverty, high-medium poverty, and high poverty), education (i.e., low, low-medium, high-medium, and high education level), and race/ethnicity (i.e., white, non-Hispanic vs. all other races/ethnicities) using ACS categories (see details in Appendix 2). As a measure of comorbidity, we included the ACG score, measured as a continuous variable. We also measured two employer-level variables: self-insured vs. fully-insured status and employer size (i.e., 10-99, 100-999 and ≥ 1000 employees). All covariates were measured on the anniversary month.

We calculated members' annual OOP expenditures, which include all cost-sharing (i.e., deductibles, copayments, and coinsurance) but not premium payments, adjusted for inflation to 2015 USD values using the Consumer Price Index for medical care, and total medical expenditure (i.e., insurer allowed amount inclusive of OOP costs, commonly referred to as "total cost") using a vendor-provided field that standardizes claims-level prices across geography and time which is inflation-adjusted to 2015.

Using employer-level data, we determined which members had a choice of a HDHP or a plan with a lower deductible from their employer. As a secondary analysis, we examined HDHP enrollment in the subset of members with employer-level plan choice.

Statistical Analysis: We first generated descriptive statistics of demographic and employer characteristics for HDHP and low deductible members in each of the three disease categories. We then used generalized estimating equations (GEE), applying the robust sandwich estimator and assuming an exchangeable working correlation structure to account for member-level clustering (since a member could contribute to the database for multiple years), with marginal models to assess all outcomes.[21] We used average adjusted predictions[22] to examine member-level predictors of being in a HDHP within each disease category, controlling for study year. Predictors in the model included the member and employer level characteristics mentioned above (i.e., age, sex, region, income, education, race/ethnicity, ACG score, self-insured status, employer size and study year). We also used average adjusted prediction models to estimate annual percentage of members enrolled in a HDHP and trends (i.e., slope) in HDHP enrollment for each disease category, controlling for the same variables as the enrollment prediction model. We calculated average marginal effects on the GEE models[22] to estimate the average difference in the percentage of members enrolled in a HDHP over the study period between each chronic disease group and healthier members, controlling for the same variables as the prediction model, except for ACG score (which is highly collinear with our disease categories).

Within each disease category, we used GEE models and adjusted prediction at the means,[22] controlling for the same variables as the HDHP enrollment prediction model, to examine the adjusted annual OOP and total costs for members with high and low deductible plans and the trends in costs over time for each disease category. Within each disease category, we used marginal effects at the means to estimate the absolute

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and relative differences in OOP and total costs between HDHP and low deductible health plan members. For each study year, we also calculated the average percent of total expenditure that HDHP members paid OOP (based on adjusted values), by disease category. And, within each disease category, we examined average comorbidity (i.e., ACG) score over the study period for members in high vs. low deductible plans.

In the models to assess percentage of members enrolled in a HDHP and predictors of HDHP enrollment, the denominator was all members in that disease category. The analyses that examined OOP and total costs compared members in HDHP (≥ $1000) to members in low deductible plans (≤$500) and therefore excluded members with deductibles of $501-$999.

All analyses were performed in SAS Studio 3.7 or STATA 15. This study was approved by the Harvard Pilgrim Health Care Institutional Review Board.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Our sample included three mutually exclusive disease categories: 1.2 million unique members (2.6 million member-years) with diabetes, 4.5 million unique members (9.4 million member-years) with cardiovascular disease and risk factors (without diabetes) and 18.0 million unique healthy members (40.4 million member-years). Appendix 3 includes demographic and employer characteristics for members in HDHP and low deductible health plans.

Predictors of HDHP Enrollment within Disease Category

In the predicted probability models (Table 1), HDHP enrollment among members with diabetes and cardiovascular disease and healthy members was statistically significantly higher for members with the following characteristics: higher income; white, non-Hispanic race/ethnicity; lower comorbidity score; living in the West, Midwest or South (compared to the Northeast); being insured through a fully-insured (vs. self-insured) employer; and working for a smaller employer. Age had mixed results across disease categories. Across all disease categories, the largest absolute predictors of HDHP status were region, fully-insured employer status and smaller employer size. For instance, on average over the study period, 49.30% (95% CI:49.13, 49.47) of members with diabetes insured through a smaller employer (i.e., 10-99 enrollees) were enrolled in a HDHP compared to 23.93% (95% CI: 23.72, 23.94) of members with diabetes insured through a large employer (i.e., ≥ 1000 enrollees).

Percentage of Members Enrolled in a HDHP Over Time

Enrollment in HDHPs increased markedly over the study period for all disease

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categories, increasing by approximately 5 percentage points per year across all groups when adjusting for the variables in Table 1. HDHP enrollment increased by 5.29 percentage points (95% CI: 5.27, 5.31), 5.27 percentage points (95% CI: 5.26, 5.28), and 5.11 percentage points (95% CI: 5.10, 5.12) per year for members with diabetes, CVD and healthy members, respectively, over the study period. Members with chronic diseases were less likely than healthier members to be in a HDHP throughout the entire study period (Figure 1). On average over the study period, HDHP enrollment among members with diabetes and CVD was 2.84 (95% CI: 2.78, 2.90) and 2.02 (95% CI: 1.98, 2.05) percentage points lower, respectively, than among healthy members. However, by the end of the study period, over half of members in each disease category were in a HDHP. In 2013, 53.43% (95% CI: 53.39, 53.47) of healthy members were in a HDHP compared to 52.48% (95% CI: 52.33, 52.63) of members with diabetes and 53.21% (95% CI: 53.12, 53.29) of members with CVD in the adjusted models. While non-account HDHPs were the most common HDHP type for HDHP members in all three disease categories (Appendix 4a), the higher percentage of enrollment in HDHPs among healthy members, compared to members with chronic diseases, was driven by higher enrollment in HSA-eligible HDHPs (Appendix 4b). The percentage of members enrolled in a very high deductible health plan (≥$2500) increased over the study period for all disease categories, from less than 1% in 2005 to 14-15% in 2015 (Appendix 5). In the last three years of the study period, the percentage of members in a HDHP with a deductible between $1000 and $2499 remained relatively flat, and the increase observed in HDHP plan enrollment overall was driven by enrollment in very high deductible health plans.

During the study period, the percent of members with an employer that offered both HDHPs and a lower deductible plans increased from 10-11% in 2005 to 33-34% in 2013 in all disease areas. (Appendix 6) The percentage of members with employer-level plan choice that enrolled in a HDHP increased over the study period, but was 12-13 percentage points lower than the percentage of all members (i.e., with and without plan choice). In 2013, among members with employer-level plan choice, 41.25% (95% CI: 41.18, 41.32) of healthy members, 39.10% (95% CI: 38.83, 39.37) of members with diabetes and 40.58% (95% CI: 40.43, 40.73) with cardiovascular disease were in a HDHP. On average, over the study period, members with plan choice that had a chronic disease were 4-5 percentage points less likely than healthier members with plan choice to enroll in a HDHP.

Out of Pocket Costs

For all disease categories, HDHP members had higher OOP costs than low deductible plan members (Figure 2). The differences in OOP costs between HDHP and low-deductible plans were, on average over the study period, $636 (95% CI: 630, 642), $539 (95% CI: 537, 542), and $113 (95% CI: 112, 113) for members with diabetes, CVD and healthy members, respectively. In relative terms, compared to LDHP members, average OOP costs for HDHP members were 47.26% (95%: 46.73, 47.78), 56.03% (55.71, 56.63) and 70.41% (95% CI: 70.13, 70.69) higher, respectively. Inflation-adjusted OOP costs decreased slightly over time for both low and high deductible health plan members in all three disease categories, with a steeper decline observed among

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low deductible health plan members. OOP costs for low deductible plan members decreased, on average, by $20 (95%: 19, 21), $17 (95% CI: 17, 18), and $6 (95%: 6, 6) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $6 (95%: 4, 8), $10 (95% CI: 9, 11), and $3 (95%: 3, 4) per year. Across all disease categories, members in HRA and HSA-eligible HDHPs had higher OOP costs than non-account HDHPs (Appendix 7).

Total Costs

For all disease categories, HDHP members had lower total costs than low deductible plan members (Figure 3). The differences in total costs between HDHP and low-deductible plans were, on average over the study period, -$529 (95% CI: -597, -461), -$364 (95% CI: -385, -342), and -$79 (95% CI: -81, -76) for members with diabetes, cardiovascular disease and healthy members, respectively. In relative terms, compared to low deductible members, average total costs for HDHP members were 5.35% (95%: 4.66, 6.04), 5.60% (5.27, 5.93) and 9.05% (95% CI: 8.77, 9.33) lower for members with diabetes, cardiovascular disease and healthy members, respectively. Our measure of total costs decreased over the study period for both HDHP and low deductible health plan members in all three disease categories, with a steeper decrease observed among HDHP members. Total costs for low deductible plan members decreased, on average, by $248 (95%: 229, 267), $449 (95% CI: 434, 464), and $21 (95%: 20, 22) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $348 (95%: 318, 379), $567 (95% CI: 544, 589), and $28 (95%: 26, 29) per year, respectively. Members with chronic diseases in HRA- and HSA-eligible HDHPs had consistently higher total costs than non-account HDHPs (Appendix 8).

Members with chronic diseases in both high and low deductible plans had higher OOP costs and total expenditures than healthy members in similar plans (Figures 2 and 3). While HDHP members' OOP share of total expenditure was lower for members with chronic diseases (i.e., on average over the study period, OOP share was 21% of total expenditure for members with diabetes, 25% for members with cardiovascular disease and 35% for healthy members), members with chronic diseases had yearly OOP expenditures that were 5 (for CVD members) to 7 (for diabetes members) times higher than healthy members (Appendix 9).

Within each disease category, HDHP members had lower comorbidity scores than low deductible plan members and the comorbidity scores remained relatively stable over time (Appendix 10).

Discussion

HDHP enrollment increased rapidly among both chronically ill and healthy commercially-insured individuals from 2005-2013. Members with diabetes and CVD were slightly less likely than healthy members to be in HDHPs throughout the study period. However, by the end of the study period in 2013, over half (52-53%) of members

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with chronic conditions and healthy members were in HDHPs. Similar to previous research, we found that members who were healthier and lived in neighborhoods with higher income and education and a higher proportion of white, non-Hispanic individuals were more likely to be in a HDHP.[5] Across all disease categories, members insured through larger and self-insured employers were significantly less likely to be in a HDHP, suggesting that these employers may offer more generous benefit packages to their employees. Among the subset of members who were offered a choice of a HDHP or lower deductible plan from their employer, most members opted for a lower deductible health plan and members with chronic diseases were less likely to choose a HDHP than healthier members.

As expected, members with chronic diseases in both high and low deductible plans have higher OOP costs and total expenditures than healthy members in similar plans. However, the OOP cost burden was 5-7 times higher for HDHP members with chronic diseases compared to healthy members in HDHPs. These findings are concerning because our previous studies have shown that HDHPs are associated with avoided or delayed care and adverse health outcomes among diabetes patients[14-16] and other studies suggest similar impacts of HDHPs among members with cardiovascular disease.[17] Higher OOP costs combined with stagnant incomes[23] and increasing HDHP enrollment among patients with chronic conditions suggests increasing financial burden on this vulnerable population.

Within each disease category, members in HDHPs had higher OOP costs but lower total medical expenditures than those in low deductible plans. Lower total medical costs among HDHP members has been demonstrated in other studies.[3] The lower total costs among HDHP members in our study could indicate that HDHP members are different or healthier than low-deductible members in ways not captured by our adjusting covariates. However, it could also reflect less utilization among HDHP members in response to increased cost sharing. We observed decreasing trends in total costs over time for both HDHP and low deductible health plan members across all disease categories. Since our measure of total cost is based on standardized prices over time, and expenditure is price times quantity, this suggests that utilization is decreasing over time among all members. The larger downward trend in total cost among HDHP members compared to low deductible plan members suggests a greater decrease in utilization among HDHP members. HSA- and HRA-eligible HDHP members with chronic diseases consistently had higher OOP and higher total costs than members in non-account based HDHPs, (Appendix 7) possibly because the accounts provide funds that lower barriers to utilization and reduce the effective OOP cost of care through use of pre-tax dollars. However, another study found that more than half of members with HSA-eligible HDHPs do not contribute money to their HSA,[24] suggesting that HSA accounts may not actually reduce the OOP burden for the majority of HDHP members. Our finding that members with chronic diseases paid OOP for a lower share of total costs than healthier members is because members with chronic diseases have much higher total costs and many high costs members hit their deductible and OOP max limits.[25]

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Our study has multiple limitations. The ACG codes and scores rely on the appearance of diagnoses in medical claims. There may be increased provider coding of chronic conditions over time as risk-adjustment payment became more prominent, or reduced coding among HDHP members if they were less likely to seek routine care. However, we found that ACG scores among each disease category remained relatively stable over our study period (Appendix 10) and past analyses have shown minimal reductions in outpatient visits among members who were forced to switch into a HDHP.[15] Members may make health care decisions based on their total expected costs, which include OOP costs and premiums, minus contributions to savings accounts. While we have data on OOP costs, we do not have data on premium amounts or on employer and employee contributions to savings accounts, so total member expenditure is unknown. Increased OOP costs in HDHPs may be offset by the lower premiums or employer contributions to accounts or by increased wages. Our study includes data from large, mid-size and small employers with commercial health insurance plans offered by a large, national insurer; therefore, our study results may not be generalizable to regional plans, very small employers (<10 members), or members insured in the non-group market. Although we knew the exact deductible level of most smaller employers, we had to infer it from claims at large employers. However, the sensitivity and specificity of our algorithm was high and increased across employer size category, ranging 96% to 100% (Appendix 1). We expect adjustment for the uncertainty of the imputation process would have a negligible effect on confidence bounds. We were missing neighborhood-level socioeconomic variables for a small proportion of members (≤3% across the disease and deductible level categories, Appendix 3) and these members were excluded from the GEE models. Finally, since our study aimed to examine overall trends in HDHP enrollment and costs, our main analyses combined HDHP members whose employers offered only a HDHP with members who were offered a choice by their employer to enroll in a HDHP or a lower-deductible plan. Future research should examine HDHP enrollment among members who have plan choice to better understand factors associated with selecting HDHPs.

Conclusion

HDHP enrollment has increased rapidly among both healthy and chronically ill populations and by 2013 over half of members with chronic conditions in one large national insurer had HDHPs. HDHP members pay significantly more for their health care out of pocket than low deductible plan members, and HDHP members with chronic diseases have OOP spending that is 4-5 times higher than that of healthy members. Policymakers should consider options for protecting clinically vulnerable patients enrolled in HDHPs such as funding HSAs or facilitating enrollment in more generous plan designs.[26]

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Table 1. Predicted Probability of HDHP Enrollment by Disease Category

	Diabetes			Cardio-vascular Disease			Healthy		
	Predicted Probability (%)	95% CI lower bound	95% CI upper bound	Predicted Probability (%)	95% CI lower bound	95% CI upper bound	Predicted Probability (%)	95% CI lower bound	95% CI upper bound
Number of unique members	1,211,925			4,495,831			18,035,883		
Sex									
Female	32.72	32.61	32.82	33.00	32.95	33.06	34.40	34.37	34.43
Male	32.73	32.63	32.83	33.08	33.03	33.13	34.44	34.42	34.47
Neighborhood income level**									
High	35.10	34.92	35.28	35.45	35.35	35.56	36.67	36.61	36.73
Medium-high	33.41	33.29	33.54	33.82	33.75	33.89	35.22	35.18	35.25
Medium-low	31.72	31.57	31.87	32.39	32.32	32.47	34.02	33.98	34.06
Low	30.14	29.97	30.31	31.16	31.08	31.24	32.74	32.70	32.78
Neighborhood education level **									
High	33.74	33.29	34.18	33.70	33.40	34.00	35.90	35.75	36.04
Medium-high	33.38	33.14	33.62	34.01	33.86	34.16	35.26	35.18	35.34
Medium-low	33.12	32.96	33.28	33.53	33.43	33.62	34.86	34.81	34.91
Low	32.43	32.33	32.52	32.79	32.75	32.84	34.21	34.19	34.23
Race/ethnicity **									
White, not hispanic	34.09	33.99	34.19	34.18	34.14	34.23	35.94	35.91	35.96
Non-white race/ethnicity	31.06	31.06	31.06	31.09	31.03	31.16	32.06	32.03	32.10
Region	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northeast	22.54	22.30	22.77	22.09	21.98	22.20	23.17	23.12	23.23
West	31.03	30.83	31.23	31.91	31.80	32.02	34.30	34.25	34.34
Midwest	31.93	31.80	32.07	32.89	32.82	32.96	34.77	34.25	34.81
South	34.96	34.86	35.06	35.28	35.22	35.33	36.63	36.60	36.66
Employer insurance model									
Fully insured	40.09	39.98	40.21	40.39	40.33	40.45	40.83	40.80	40.86
Self insured	25.46	25.35	25.56	25.37	25.31	25.42	27.62	27.59	27.64
Employer size (ref: >1000 employees)									
≥ 1000 employees	23.83	23.72	23.94	24.16	24.10	24.22	25.61	25.58	25.64
100-999 employees	33.11	32.99	33.23	33.03	32.97	33.10	34.92	34.89	34.95
10-99 employees	49.30	49.13	49.47	49.10	49.01	49.19	49.99	49.95	50.04

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*Models control for study year as a categorical variable and age and ACG (i.e., comorbidity) score as continuous variables. Higher ACG score was associated with lower probability of HDHP enrollment in all disease categories. The results for age were mixed: higher age was associated with higher probability of HDHP enrollment for members with CVD and healthy members and lower probability of enrollment for members with diabetes. The denominator of the models includes all members (as unique member-years), not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999).

** Income level, education level and race were determined at the neighborhood level using the American Community Survey. See Appendix 2 for a detailed description of each category.

Figures (in excel file):

Figure 1. Percentage of Members Enrolled in a HDHP, by Disease Category (adjusted)
Figure 2. Mean Annual OOP Costs by Disease Category, HDHP vs. LDHP (adjusted)
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)

Appendices (in separate word and excel files):

Appendix 1. Deductible Level Imputation
Appendix 2. Definition of Covariates
Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health Plans and Low Deductible Health Plans, by Disease Category
Appendix 4a. Percentage of Members Enrolled in a HDHP by HDHP Type (i.e. HSA, HRA or non-account HDHP) for Each Disease Category (unadjusted)
Appendix 4b. Percentage of Members Enrolled in a HSA, HRA or non-account HDHP by Disease Category (unadjusted)
Appendix 5. Percentage of Members Enrolled in a HDHP by HDHP level (i.e., $1000-$2499 or ≥$2500) (adjusted)
Appendix 6. Percentage of Members with Employer-level Choice of HDHP and non-HDHP, by Disease Category (adjusted) and Percentage of Members with Employer-level Plan Choice that Enrolled in a HDHP, by Disease Category (adjusted)
Appendix 7. Mean Annual OOP Costs by Deductible Type by Disease Category (unadjusted)
Appendix 8. Mean Annual Total Costs by Deductible Type by Disease Category (unadjusted)
Appendix 9. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plans, by Disease Category (unadjusted)
Appendix 10. ACG Score by Disease Category

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Competing Interests: The authors declare no conflict of interests.

Author Contributions: LFG, DRD and JFW contributed to the conception and design of the project. LFG, FZ, RL, JW, DRD, and JFW contributed to the acquisition, analysis and interpretation of the data. LFG, FZ, RL, JW, DRD, and JFW contributed to drafts of the manuscript. LFG provided final approval of the version to be published and is accountable for the accuracy and integrity of the work.

Data Statement: Data are not shareable because of our data use agreement with the data vendor, but we are happy to share programming code upon request.

Reporting Checklist: This study meets all criteria for STROBE cohort studies.

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References:

1. The Kaiser Family Foundation and Health Research & Educational Trust. Employer Health BenefitsL 2017 Annual Survey. Menlo Park, California: The Kaiser Family Foundation and Health Research & Educational Trust, 2017.

2. The Kaiser Family Foundation. Employer Health Benefits 2019 Annual Survey San Francisco, California: The Kaiser Family Foundation, 2019.

3. Buntin MB, Haviland AM, McDevitt R. Health care spending and preventive care in high-deductible and consumer-directed health plans. Am J Manag Care. 2011;17(3):222-230.

4. Frostin P, Dretzka E. Consumer Engagement in Health Care: Findings From the 2018 EBRI/Greenwald & Associates Consumer Engagement in Health Care Survey. EBRI Issue Brief, no. 468. Employee Benefit Research Institute, December 13, 2018. [Available from: https://www.ebri.org/crawler/view/high-deductible-health-plan-enrollees-are-more-engaged-in-their-health-care]

5. Lave JR, Men A, Day, BT, Wang W, Zhang Y. Employee choice of a high-deductible health plan across multiple employers. Health Services Research. 2011;46:138-54.

6. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. Lancet 1998;352(9131):837-53.

7. Holman RR, Paul SK, Bethel MA, et al. 10-year follow-up of intensive glucose control in type 2 diabetes. N Engl J Med 2008;359(15):1577-89. doi: 10.1056/NEJMoa0806470

8. Capewell S, Morrison CE, McMurray JJ. Contribution of modern cardiovascular treatment and risk factor changes to the decline in coronary heart disease mortality in Scotland between 1975 and 1994. Heart 1999;81(4):380-6. doi: 10.1136/hrt.81.4.380

9. Standards of medical care in diabetes--2015: summary of revisions. Diabetes Care 2015;38 Suppl:S4. doi: 10.2337/dc15-S003

10. American Diabetes A. Standards of Medical Care in Diabetes-2019 Abridged for Primary Care Providers. Clin Diabetes 2019;37(1):11-34. doi: 10.2337/cd18-0105

11. Centers for Disease Control and Prevention. Get Active! Atlanta, GA: Centers for Disease Control and Prevention, 2018. [Available from: https://www.cdc.gov/diabetes/managing/active.html]

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12. American Diabetes A. 10. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes-2020. Diabetes Care 2020;43(Suppl 1):S111-S34. doi: 10.2337/dc20-S010

13. American College of Cardiology. Guidelines and Clinical Documents: American College of Cardiology; 2020 [Available from: https://www.acc.org/guidelines accessed June 30 2020.

14. Wharam JF, Lu CY, Zhang F, et al. High-Deductible Insurance and Delay in Care for the Macrovascular Complications of Diabetes. Ann Intern Med 2018;169(12):845-54. doi: 10.7326/M17-3365

15. Wharam JF, Zhang F, Eggleston EM, et al. Diabetes Outpatient Care and Acute Complications Before and After High-Deductible Insurance Enrollment: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. JAMA Intern Med 2017;177(3):358-68. doi: 10.1001/jamainternmed.2016.8411

16. Wharam JF, Zhang F, Eggleston EM, et al. Effect of High-Deductible Insurance on High-Acuity Outcomes in Diabetes: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. Diabetes Care 2018;41(5):940-48. doi: 10.2337/dc17-1183

17. Lewey J, Gagne JJ, Franklin J, et al. Impact of High Deductible Health Plans on Cardiovascular Medication Adherence and Health Disparities. Circ Cardiovasc Qual Outcomes 2018;11(11):e004632. doi: 10.1161/CIRCOUTCOMES.118.004632

18. Reid RJ, Roos NP, MacWilliam L, et al. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. Health Serv Res 2002;37(5):1345-64. doi: 10.1111/1475-6773.01029

19. The Johns Hopkins University. The Johns Hopkins ACG System. Baltimore, MD: The Johns Hopkins University; 2020 [Available from: https://www.hopkinsacg.org/advantage/ accessed June 30 2020.

20. United States Census Bureau. American Community Survey (ACS) Washington, D.C.: United States Census Bureau, 2020 [Available from: https://www.census.gov/programs-surveys/acs/ accessed June 30 2020.

21. STATA. Marginal means, adjusted predictions, and marginal effects. Accessed January 27, 2021. [Available at: https://www.stata.com/features/overview/marginal-analysis/]

22. Williams R. Using the margins command to estimate and interpret adjusted predictions and marginal effects. Stata Journal. 2012;2:308-331.

23. Desilver D. For most U.S. workers, real wages have barely budged in decades Washington, D.C.: Pew Research Center. 2018 [Available from:

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https://www.pewresearch.org/fact-tank/2018/08/07/for-most-us-workers-real-wages-have-barely-budged-for-decades/ accessed August 20 2020.

24. Kullgren JT, Cliff EQ, Krenz C, et al. Use of health savings accounts among US adults enrolled in high-deductible health plans. JAMA Network Open. 2020;3(7):e2011014.

25. Fronstin P, Roebuck MC. Persistency in high-cost health care claims: "It's where the spending is, stupid." EBRI Issue Brief, no. 493. Employee Benefit Research Institute, October 24, 2019. [Available from: https://www.ebri.org/crawler/view/persistency-in-high-cost-health-care-claims-it-s-where-the-spending-is-stupid]

26. Wharam JF, Ross-Degnan D, Rosenthal MB. The ACA and high-deductible insurance--strategies for sharpening a blunt instrument. N Engl J Med 2013;369(16):1481-4. doi: 10.1056/NEJMp1309490

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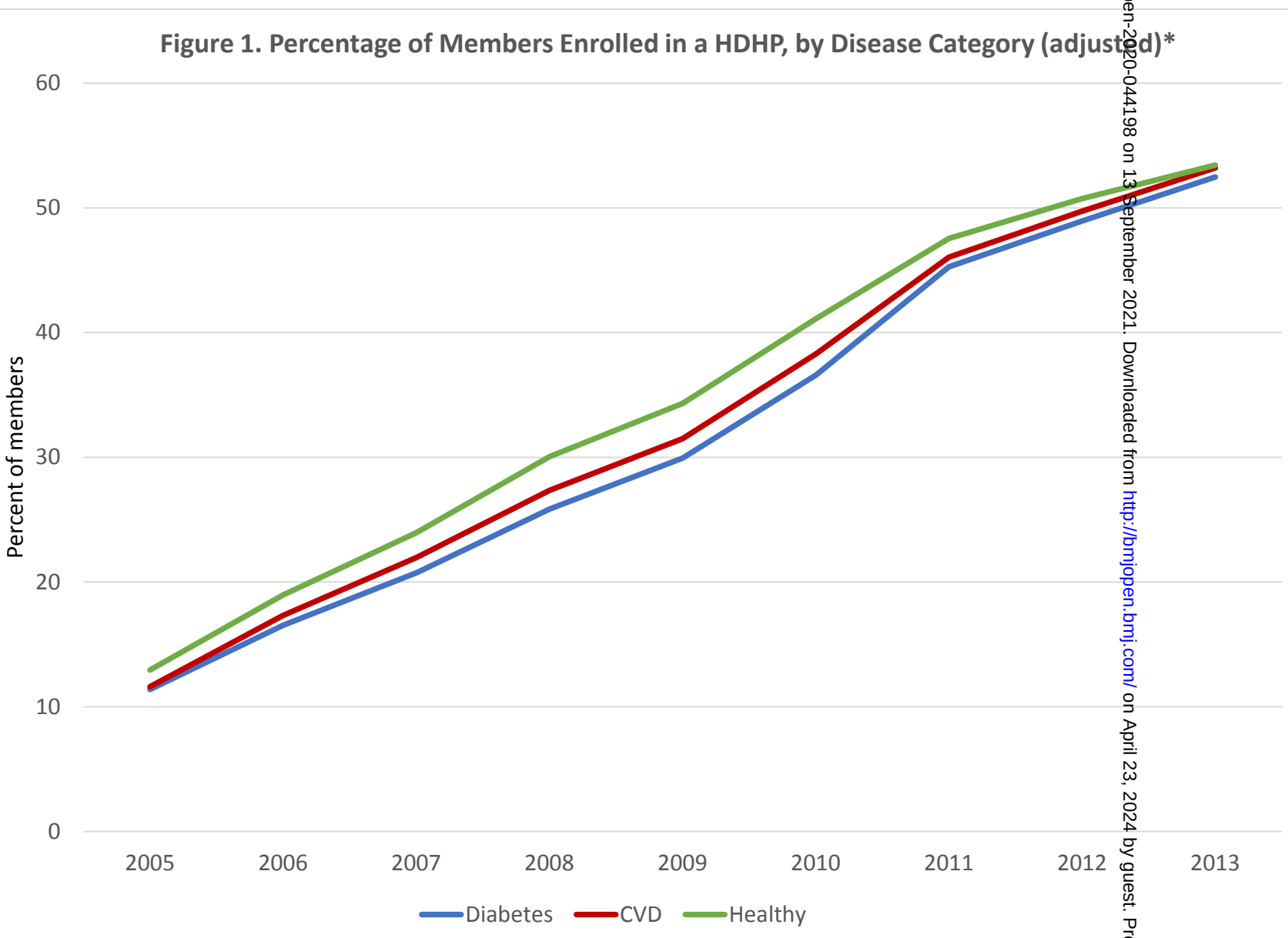

*The denominator includes all members, not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999). Estimates are adjusted for variables in Table 1.

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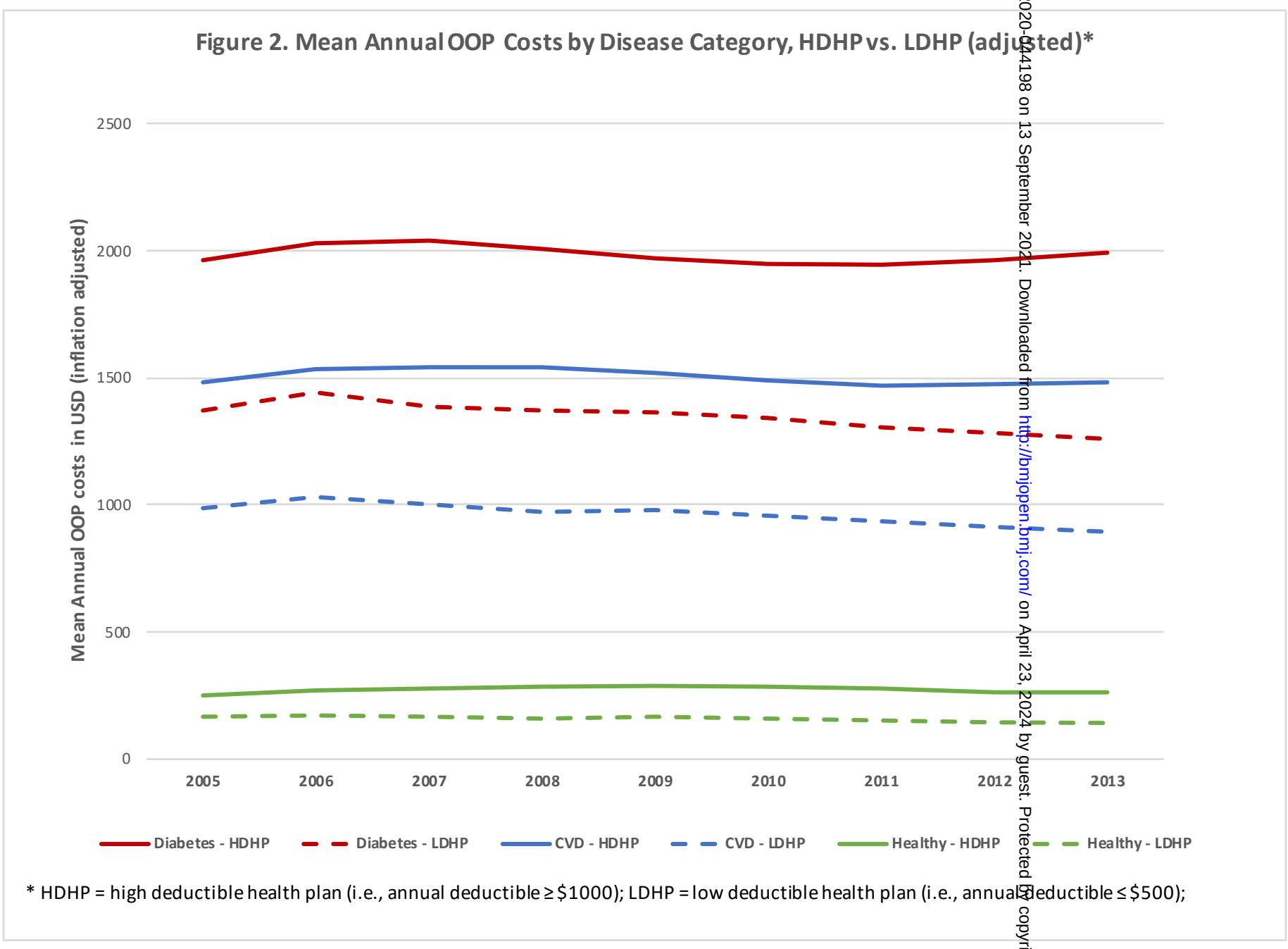

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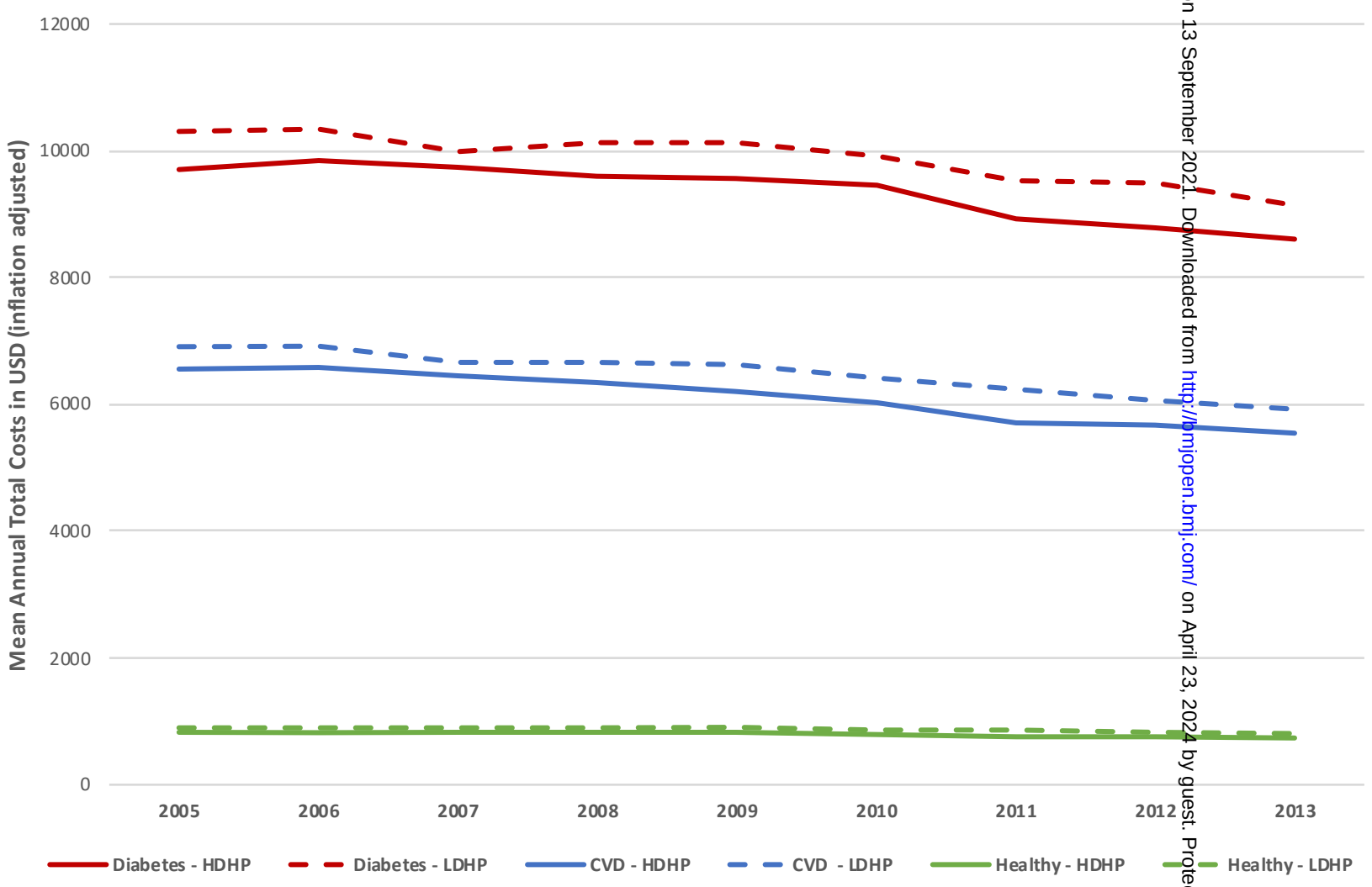
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)*



* HDHP = high deductible health plan (i.e., annual deductible ≥ $1000); LDHP = low deductible health plan (i.e., annual deductible ≤ $500); CVD = cardiovascular disease. Total cost estimates are adjusted for variables in Table 1.

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Appendix 1: Deductible Level Imputation

To determine employer deductible levels, we used a benefits type variable that we had for most smaller employers (with approximately 100 or fewer employees). For larger employers, we took advantage of the fact that health insurance claims data are the most accurate source for assessing out-of-pocket obligations among patients who utilize health services. Our claims data contained an in-network/out-of-network individual deductible payment field. For patients who use expensive or frequent services, the sum of their yearly deductible payments adds up to clearly identifiable exact amounts such as $500.00, $1000.00, $2000.00, etc. When even several members have these same amounts, it provides strong evidence that the employer offered such an annual deductible level. It is also possible to detect employers that offer choices of deductible levels when multiple employees have deductibles at two or more levels, such as 20 employees with an exact annual amount of $1000.00 and 12 employees with $500.00. For employer accounts with at least 10 enrollees, we therefore summed each member's in-network (individual-level) deductible payments and number of claims over the enrollment year and assessed other key characteristics such as percentage with Health Savings Accounts. We randomly selected half of the employer account data set that contained both our calculated employer characteristics (independent variables, below) and actual annual deductible levels from the benefits table (dependent variable, after categorization; below). We then used a multinomial logistic model that predicted the 4-level outcome of individual-level deductible ≤$500/$501-$999/$1000-$2499/≥$2500 (again, dependent variable) based on multiple aggregate employer characteristics (independent variables) such as the percentage with Health Savings Accounts and Health Reimbursement Arrangements, the deductible payment per employer in the 75 percentile of payments, the percentage of employees reaching exact deductible levels or with deductible payments but not reaching an exact deductible level, the employer account size, the percentage of enrollees per account with summed whole dollar annual deductible amounts (from claims data) between $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, ≥$2500, etc.

The statistical model was as follows:

$$\text{Logit}(\Pr=Y_i) = \beta_0 + \sum \beta_k X_{ki}$$

Where:

Y_i = dependent variable (4-level deductible category)

X_{ki}= k^{th} characteristics for i^{th} employer

$\beta_{0=}$ intercept

$\beta_{k=}$ coefficient for k^{th} characteristic

The SAS code we used to implement this model was:

```
proc logistic data=csn_impute_PLUS_to_be_imputed descending;
class
        d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat d_wusd1perc_500_1000_cat
        d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat
        d_wusd2perc_0_100_cat d_wusd2perc_100_500_cat d_wusd2perc_500_1000_cat
        d_wusd2perc_1000_2500_cat d_wusd2perc_ge2500_cat
        d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat d_wusd3perc_500_1000_cat
        d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat
        d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat d_wusd4perc_500_1000_cat
        d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat;

model real_dduct_cat =
        pyr sampletot hsa_cnt_over_total cdhp_cnt_over_total perc_grp2 perc_grp3 perc_grp4
        perc_grp5 d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat d_wusd1perc_500_1000_cat
        d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat d_wusd2perc_0_100_cat
        d_wusd2perc_100_500_cat d_wusd2perc_500_1000_cat d_wusd2perc_1000_2500_cat
        d_wusd2perc_ge2500_cat d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat
        d_wusd3perc_500_1000_cat d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat
```

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```
        d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat d_wusd4perc_500_1000_cat
        d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat
        p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct p75_1000_2500_dduct
        p75_gt2500_dduct
    output out=prob_of_dduct_cat&IOS. p=p_dduct_cat predprobs=i;
    run;
```

Further explanation of this code is below. Note that all values described are calculated over the benefit year per employer account, and a given employer account could be present for multiple years.

- csn_impute_PLUS_to_be_imputed = name of dataset that contains, at the employer account and benefit year level, accounts with missing deductible levels as well as a random half of the accounts that have actual deductible levels. The other random half is also present in the dataset but with actual deductible levels "hidden" so that they can later be used to validate the predictive algorithm.
- real_dduct_cat = dependent variable; category of actual deductible level from the gold standard source (<=$500, $500-$999, $1000-$2499, ≥$2500)
- pyr = benefit year of account's information and tied to the calendar year. An employer could have multiple benefit years represented in separate records per account-benefit year.
- sampletot = total enrollees per account during the benefit year
- hsa_cnt_over_total = percent of members per account listed as having a health savings account
- cdhp_cnt_over_total = percent of members per account listed as having a health savings account or health reimbursement arrangement
- perc_grp1. Percentage of enrollees per employer-year who have claims but $0 deductible amounts for all annual claims.
- perc_grp2. Percentage of enrollees per employer-year who have reached their annual deductible, evidenced by the sum of their deductible payments ending in $*0.00. Members must have at least one month after the month of the $*0.00 summation where the deductible field is blank, and all subsequent months must have blank deductible fields, indicating that the member reached his or her annual deductible amount.
- perc_grp3. Percentage of enrollees per employer-year who have an annual deductible amount that does not end in $*0.00.
- perc_grp4. Percentage of enrollees per employer-year who have enrollment during the benefit year where all months show no evidence of utilization (no health insurance claims).
- perc_grp5. Percentage of enrollees per employer-year who might have reached their deductible, as evidenced by having the last month of enrollment of the benefit year with a summed annual deductible amount that ends in $*0.00.
- d_wusd1perc_0_100_cat, d_wusd1perc_100_500_cat, d_wusd1perc_500_1000_cat, d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat. Category of percentage of enrollees with an employer's most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd2perc_0_100_cat, d_wusd2perc_100_500_cat, d_wusd2perc_500_1000_cat, d_wusd2perc_1000_2500_cat d_wusd2perc_ge2500_cat. Category of percentage of enrollees with an employer's second most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd3perc_0_100_cat, d_wusd3perc_100_500_cat, d_wusd3perc_500_1000_cat, d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat. Category of percentage of enrollees with an employer's third most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.

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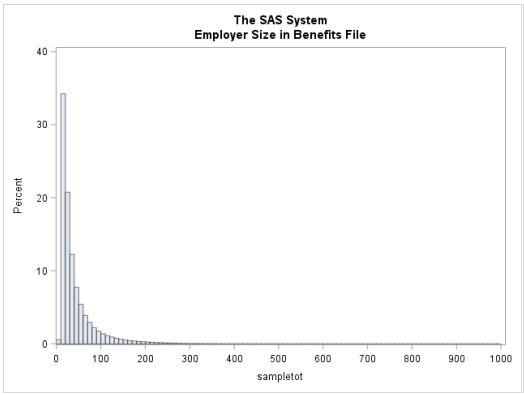
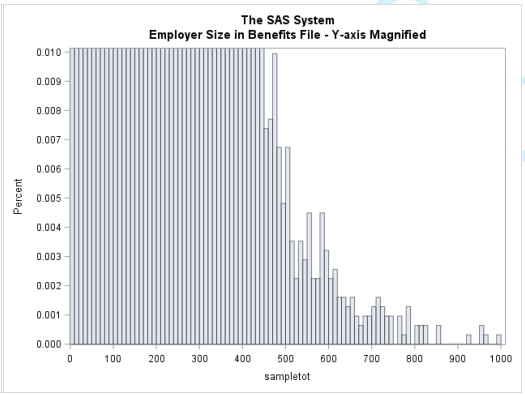
- d_wusd4perc_0_100_cat, d_wusd4perc_100_500_cat, d_wusd4perc_500_1000_cat, d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat. Category of percentage of enrollees with an employer's fourth most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct p75_1000_2500_dduct p75_gt2500_dduct. Category of 75th percentile of deductible payments per employer benefit year, categorized as $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.

This predictive model outputs the probability that employers had deductibles in the four categories (summing to 1.0) and we assigned the employer to the level that had the highest probability. We overwrote this assignment with the most common whole number deductible amount per year if it was not zero, and with the second most common whole number deductible amount if the most common amount was zero and at least 10 members had the value of the second most common whole number deductible amount. If an employer had members with both enrollment and evidence of utilization, but never had any amounts in the deductible field, we assigned that employer to <$500 deductible level. If an employer had only members that reached a whole number annual deductible amount such as $1000.00 or $2000.00, we assigned the most common deductible amount as the employer's deductible if that amount was greater than or equal to $1000 and to the 95% percentile value if that number was less than $1000. If at least 99% of employees had Health Savings Accounts or Health Reimbursement Arrangements, we also overwrote any previous assignment to classify the employer as a high-deductible employer. We assigned employers to have a choice between deductible levels of $1000 to $2499 and ≥$2500 when both were common and one accounted for at least 85% of $1000-$2499 or ≥$2500 deductible levels reached per employer. If we detected employers that had sufficient enrollees with whole number deductible levels both above and below $1000 (e.g. $250.00 and $1500.00), we assigned the employers' category as "choice," applying a similar 85% rule. Finally, for any employer that had gold standard deductible level information in our benefits file, we overwrote any previous imputed deductible level.

Our file that contains actual deductible amounts per employer covers the "small employer" segment of the insurer's business, a segment that generally includes employers with fewer than 100 or so enrollees. However, it does include a modest number of employers with more than 100 enrollees, even up to approximately 1000 enrollees. The histograms below, where the x-axis represents employer size and the y-axis shows the percentage of employers that are that size, demonstrate the distribution of employer sizes. The second plot "magnifies" the y-axis to demonstrate the smaller number of large employers.





To demonstrate the robustness of our imputation algorithm, and its predictive value as employer size increases (given that we do not have benefits information on most large employers), we took advantage of the fact that although this file mostly covers employers with 100 enrollees or fewer, there is some overlap with larger employers (i.e., those with ~100 to 1000 enrollees). A random half of our imputation sample had the actual deductible levels of employers of all sizes "hidden" from the imputation. Thus, this random half included a modest number of employers with 75 to 1000 enrollees. We tested the sensitivity and specificity of the imputation in this overlap zone, categorizing employer sizes as 75-100, 101-400, 401-700, and 701-1000 enrollees (Exhibit 1). At employers with 75-100 enrollees, we found sensitivity of 95.4% and specificity of

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98.3% (Exhibit 1a). Sensitivity and specificity increased across employer size to 100%, and Exhibits 1b-1d display these for employers of sizes 101-400, 401-700, and 701-1000.

We used an employer ID and an algorithm that determined linked employer subaccounts to identify an employer's subaccounts per benefit year, and removed benefit years when employers offered both low and high deductible levels.

Rationale for High-Deductible Cutoffs: When Health Savings Account-eligible high-deductible health plans came to market in 2005-2006, the Internal Revenue Service set the minimum deductible level for qualifying high-deductible health plans at $1050 (which could be adjusted upward for inflation annually). The range of this minimum deductible during our study period was $1050-$1250. For these reasons, we defined high-deductible health plans as annual individual deductibles of at least $1000 (otherwise some health savings account plans would be excluded). In addition, choosing this cutoff (as opposed to, e.g., $2000) improves the sensitivity and specificity of the imputation because this is common deductible level and more enrollees per employer meet this threshold. This cutoff is also a "real-world" deductible minimum that allows the most generalizable results. It should also be noted that $1000 was the *minimum* annual deductible level we included and not the mean deductible level. We cannot precisely calculate the mean deductible level of the high-deductible health plan group, but we estimate, using the most common non-zero deductible levels per employer account, an approximate mean deductible of $1900. We defined traditional plans as having deductible levels of ≤$500 after determining that a threshold of ≤$250 would lead to an inadequate sample size for the control group. Again, the mean deductible level of the control group members would be lower than $500.

Appendix Exhibit 1. Validation of Deductible Imputation Algorithm, Stratified by Employer Size

Exhibit 1a. Validation of deductible imputation algorithm, using employer accounts of size 75-100 enrollees.

	Gold Standard[a]=high-deductible (n)	**Gold Standard=low-deductible (n)**
We imputed high-deductible	882,588	24,786
We imputed low-deductible	15,612	511,770

	High-deductible	**Low-deductible**
Sensitivity	98.3%	95.4%
Specificity	95.4%	98.3%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

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Exhibit 1b. Validation of deductible imputation algorithm, using employer accounts of size 101-400 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	1,998,885	42,655
We imputed low-deductible	20,302	1,748,826

	High-deductible	Low-deductible
Sensitivity	99.0%	97.6%
Specificity	97.6%	99.0%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

Exhibit 1c. Validation of deductible imputation algorithm, using employer accounts of size 401-700 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	83,393	485
We imputed low-deductible	2,017	122,983

	High-deductible	Low-deductible
Sensitivity	97.6%	99.6%
Specificity	99.6%	97.6%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

Exhibit 1d. Validation of deductible imputation algorithm, using employer accounts of size 701-1000 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	9950	0
We imputed low-deductible	0	19,664

	High-deductible	Low-deductible
Sensitivity	100.0%	100.0%
Specificity	100.0%	100.0%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

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Appendix 2: Definition of Covariates

Comorbidity score: We used version 11.1 of the Johns Hopkins ACG® System[1,2] to calculate members' baseline period morbidity score. The algorithm uses age, gender, and ICD-9-CM codes to calculate a morbidity score and the average of the reference population is 1.0.[2] Researchers have validated the index against premature mortality.[1]

Demographic characteristics: To derive proxy demographic measures, the data vendor linked members' most recent residential street addresses to their 2010 US Census tract.[3] Census-based measures of socioeconomic status have been validated [4,5] and used in multiple studies to examine the impact of policy changes on disadvantaged populations.[6-8] Using 2008-2012 American Community Survey[9] census tract-level data and validated cut-points,[4,5] we created categories that defined residence in neighborhoods with below-poverty levels of <5%, 5%-9.9%, 10%-19.9%, and ≥20%. Similarly, we defined categories of residence in neighborhoods with below-high-school education levels of <15%, 15%-24.9%, 25%-39.9%, ≥40%.[4,5] We classified members as from predominantly white, black, or Hispanic neighborhoods if they lived in a census tract with at least 75% of members of the respective race/ethnicity. We then applied a superseding ethnicity assignment using flags created by the E-Tech system (Ethnic Technologies), which analyzes full names and geographic locations of individuals.[10] We classified remaining members as from mixed race/ethnicity neighborhoods. This validated approach of combining surname analysis and census data has positive and negative predictive values of approximately 80 and 90 percent, respectively.[11]

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References:

1. Reid RJ, Roos NP, MacWilliam L, Frohlich N, Black C. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. *Health services research.* 2002;37(5):1345-1364.
2. ACG. The Johns Hopkins ACG System. https://www.hopkinsacg.org/advantage/. Accessed 2 June, 2018.
3. USCensus. Census 2000 Gateway. 2000; https://www.census.gov/main/www/cen2000.html. Accessed 2 June, 2018.
4. Krieger N. Overcoming the absence of socioeconomic data in medical records: validation and application of a census-based methodology. *American Journal of Public Health.* 1992;82(5):703-710.
5. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures--the public health disparities geocoding project. *American Journal of Public Health.* 2003;93(10):1655-1671.
6. Trivedi AN, Zaslavsky AM, Schneider EC, Ayanian JZ. Relationship between quality of care and racial disparities in Medicare health plans. *Jama.* 2006;296(16):1998-2004.
7. Trivedi AN, Rakowski W, Ayanian JZ. Effect of cost sharing on screening mammography in medicare health plans. *The New England journal of medicine.* 2008;358(4):375-383.
8. Selby JV, Fireman BH, Swain BE. Effect of a copayment on use of the emergency department in a health maintenance organization. *New England Journal of Medicine.* 1996;334(10):635-641.
9. American Community Survey. https://www.census.gov/programs-surveys/acs/. Accessed 28 September, 2017.
10. Ethnic Technologies. Frequently Asked Questions. www.ethnictechnologies.com/faq. Accessed 24 October, 2018.
11. Fiscella K, Fremont AM. Use of geocoding and surname analysis to estimate race and ethnicity. *Health services research.* 2006;41(4 Pt 1):1482-1500.

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Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health Plans and Low Deductible Health Plans, by Disease Category

	Healthy (no cardiovascular disease or diabetes; ACG score ≤1) n=40,901,861 HDHP or LDHP member years, 18,197,003 members, 17,621,767 w/ LDHP or HDHP *				Diabetes n=2,594,613 HDHP or LDHP member years, 1,213,654 members, 1,167,709 w/HDHP or LDHP *				Cardiovascular Disease (no diabetes) n=9,409.979 HDHP or LDHP member years, 4,501,418 members, 4,341,894 w/HDHP or LDHP *			
	HDHP	HDHP %	Low Deductible	Low Deductible %	HDHP	HDHP %	Low Deductible	Low Deductible %	HDHP	HDHP %	Low Deductible	Low Deductible %
Sample Size	15,194,328		25,707,533		891,434		1,703,179		3,262,388		6,147,591	
Female	7,233,322	47.61	12,470,162	48.52	428,005	48.01	830,577	48.78	1,539,370	47.19	2,961,387	48.18
Gender unknown	802	0.01	4,272	0.02	13	0.00	432	0.03	83	0.00	1,164	0.02
No. (%) by age category												
Age 0 le 10	2,624,478	17.27	5,150,580	20.04	3,351	0.38	7,528	0.44	20,685	0.63	37,995	0.62
Age 11 to 20	3,019,754	19.87	5,524,374	21.49	18,420	2.07	35,128	2.06	45,983	1.41	84,679	1.38
Age 21 to 30	2,406,352	15.84	3,806,372	14.81	39,198	4.40	72,079	4.23	103,046	3.16	191,543	3.12
Age 31 to 40	2,648,264	17.43	4,464,680	17.37	103,287	11.59	200,104	11.75	375,710	11.52	745,081	12.12
Age 41 to 50	2,575,536	16.95	4,084,100	15.89	224,167	25.15	415,419	24.39	924,684	28.34	1,775,706	28.88
Age 51 to 60	1,617,095	10.64	2,278,281	8.86	362,355	40.65	697,277	40.94	1,336,975	40.98	2,478,107	40.31
Age 61 to 64	302,849	1.99	399,146	1.55	140,656	15.78	275,644	16.18	455,305	13.96	834,480	13.57
Mean Age (std)	29	16.89	27	16.78	50	11.18	50	11.25	50	10.59	50	10.56
No. (%) living in neighborhoods with below- poverty levels of												
Missing**	492,227	3.24	50,154	0.20	998	0.11	1,765	0.10	2,672	0.08	5,251	0.09
<5%[1]	3,881,960	25.55	7,685,399	29.90	163,434	18.33	370,023	21.73	777,528	23.83	1,666,823	27.11
5%-9.9%[1]	4,084,101	26.88	7,178,347	27.92	217,209	24.37	434,544	25.51	877,539	26.90	1,706,679	27.76
10%-19.9%[2]	4,309,548	28.36	6,957,116	27.06	296,413	33.25	530,286	31.14	1,014,449	31.10	1,774,930	28.87
>=20%3[2]	2,426,492	15.97	3,836,517	14.92	213,380	23.94	366,561	21.52	590,200	18.09	993,908	16.17
No. (%) living in neighborhoods with below-high-school education levels of												
Missing**	491,958	3.24	49,592	0.19	981	0.11	1,745	0.10	2,644	0.08	5,162	0.08
<15%[3]	10,938,154	71.99	19,475,329	75.76	559,322	62.74	1,120,672	65.80	2,311,519	70.85	4,501,490	73.22
15%-24.9%[3]	2,450,320	16.13	4,031,833	15.68	207,641	23.29	365,446	21.46	635,454	19.48	1,101,518	17.92
25%-39.9%[4]	1,033,470	6.80	1,710,228	6.65	97,651	10.95	172,925	10.15	262,115	8.03	452,423	7.36
>=40%[4]	280,426	1.85	440,551	1.71	25,839	2.90	42,391	2.49	50,656	1.55	86,998	1.42
Race/ethnicity, No. (%)[5]												
Missing**	486,320	3.20	40,819	0.16	691	0.08	1,214	0.07	2,178	0.07	3,968	0.06
Hispanic	1,522,483	10.02	2,829,806	11.01	104,893	11.77	200,538	11.77	230,962	7.08	496,619	8.08
Asian	576,755	3.80	1,364,478	5.31	25,916	2.91	66,025	3.88	72,703	2.23	185,792	3.02
Black neighborhood	258,600	1.70	616,188	2.40	29,938	3.36	75,519	4.43	77,462	2.37	190,978	3.11
Mixed neighborhood	2,934,347	19.31	5,584,177	21.72	217,099	24.35	435,009	25.54	730,505	22.39	1,434,429	23.33
White neighborhood	9,415,823	61.97	15,272,065	59.41	512,897	57.54	924,874	54.30	2,148,578	65.86	3,835,805	62.40
Region												
Missing**	490,854	3.23	46,495	0.18	927	0.10	1,532	0.09	2,403	0.07	4,501	0.07
Midwest	4,644,238	30.57	6,937,470	26.99	253,345	28.42	440,965	25.89	953,302	29.22	1,596,631	25.97
Northeast	916,550	6.03	3,192,642	12.42	45,274	5.08	166,038	9.75	184,088	5.64	705,135	11.47
South	6,762,146	44.50	11,174,002	43.47	489,678	54.93	865,579	50.82	1,734,814	53.18	2,994,215	48.71
West	2,380,540	15.67	4,356,924	16.95	102,210	11.47	229,065	13.45	387,781	11.89	847,109	13.78
Median Household Income	66,322	29,600.99	70,859	32,504.73	57,895	25,590.10	61,579	27,965.45	63,516	28,840.57	67,274	30,794.96
Mean Patient ACG	0	0.24	0	0.24	2	2.77	2	2.88	1	2.09	2	2.14
Mean Count Patids	15,897	49,851.85	12,979	32,881.27	18,602	62,964.34	15,192	40,784.14	16,862	58,759.71	14,427	38,373.68
Employer insurance type												
Self-insured	5,511,420	36.27	14,828,244	57.68	299,461	33.59	1,008,395	59.21	1,050,211	32.19	3,575,544	58.16
Fully-insured	9,682,908	63.73	10,879,289	42.32	591,973	66.41	694,784	40.79	2,212,177	67.81	2,572,047	41.84
Employersizecategory												
1000+members	4,584,599	30.17	14,054,462	54.67	236,972	26.58	940,438	55.22	866,806	26.57	3,356,707	54.60
100-999 members	4,913,017	32.33	7,739,251	30.10	298,015	33.43	519,265	30.49	1,054,269	32.32	1,860,104	30.26
10-99 members	5,696,712	37.49	3,913,820	15.22	356,447	39.99	243,476	14.30	1,341,313	41.11	930,780	15.14
Year												
2005	662,755	4.36	4,012,258	15.61	29,130	3.27	212,386	12.47	119,494	3.66	852,827	13.87
2006	969,258	6.38	3,649,884	14.20	46,555	5.22	217,735	12.78	188,338	5.77	834,234	13.57
2007	1,258,017	8.28	3,449,312	13.42	64,057	7.19	225,193	13.22	253,210	7.76	819,673	13.33
2008	1,549,752	10.20	3,204,539	12.47	81,846	9.18	224,104	13.16	319,536	9.79	800,941	13.03
2009	1,730,518	11.39	3,025,704	11.77	95,501	10.71	222,092	13.04	366,645	11.24	778,295	12.66
2010	1,943,724	12.79	2,407,596	9.37	114,999	12.90	173,510	10.19	425,688	13.05	605,860	9.86
2011	2,246,518	14.79	2,208,391	8.59	144,185	16.17	161,072	9.46	507,368	15.55	555,400	9.03
2012	2,369,611	15.60	1,933,232	7.52	152,915	17.15	137,548	8.08	531,926	16.30	468,358	7.62
2013	2,464,175	16.22	1,816,617	7.07	162,246	18.20	129,539	7.61	550,183	16.86	432,003	7.03

* Denominator for each disease category is member-years. The denominator includes just HDHP (i.e., deductible ≥$1000) or low-deductible (i.e., deductible ≤ $500) members in the respective columns; this analysis excludes members with deductibles of $501-$999.

** The neighborhood-level demographic and socioeconomic variables are based on a member's residential address; missingness means that a member did not have a stable address during the study period. Missingness was slightly higher in the healthy HDHP cohort

Appendix 4a. Percentage of Members Enrolled in a HDHP by HDHP Type (i.e. HSA, HRA or non-account HDHP) by Disease Category (unadjusted)
(Note: demonimator of each line is all members in the disease cohort, i.e., diabetes, cardiovascular disease, or healthy)

DM

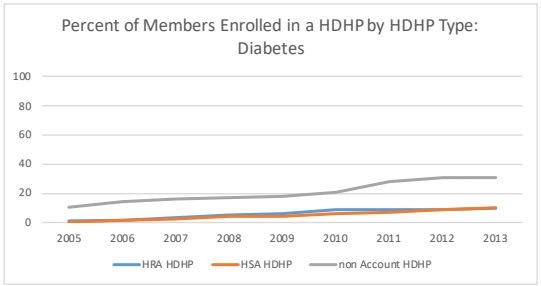
	HRA HDHP	HSA HDHP	non Account HI	LDHP	(choice, other, 500-999)
2005	1.113559535	0.267838664	10.43191014	86.07076622	2.115925443
2006	1.632677119	1.69346045	13.81107804	80.11022044	2.752563951
2007	3.054379004	2.648915637	15.74839825	75.3823419	3.165965204
2008	4.791947238	3.94425495	16.99663944	70.43901272	3.82814565
2009	6.000570083	4.617969606	18.00921134	66.57425327	4.797995709
2010	8.521426928	5.685492172	20.57566327	52.46509572	12.75232191
2011	8.931959555	6.783930158	27.52960108	48.28968225	8.464826957
2012	8.74638017	8.345438314	30.40781603	42.70699518	9.793370307
2013	9.778268229	10.03419651	30.66432248	40.29950778	9.223705006

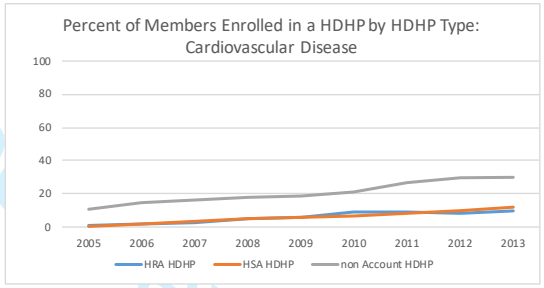
CVD

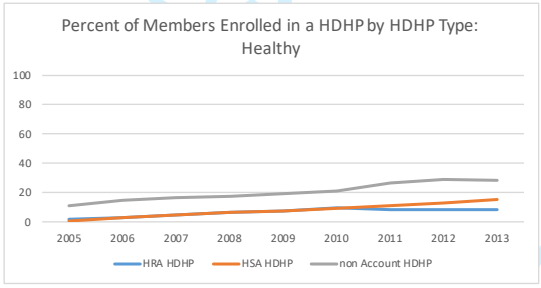
	1	2	3	4	5
2005	0.951260975	0.367706705	10.7136775	85.85120223	2.116152593
2006	1.4956943	2.16200494	14.29072773	79.47807097	2.573502065
2007	2.96171277	3.49198404	16.41103297	73.99330678	3.14196344
2008	4.959011071	4.923660215	17.58477109	68.82854491	3.704012709
2009	6.167859521	5.712716378	18.60927097	64.71920772	4.790945406
2010	8.806415359	7.015638556	20.75481595	52.04749265	11.37563749
2011	8.697616509	8.280659867	27.07542145	48.20302026	7.743281907
2012	8.539476476	10.19013956	29.6701315	42.59264488	9.007607586
2013	9.707545471	11.94801389	29.61642232	40.24621168	8.481806635

Healthy

	1	2	3	4	5
2005	1.773352076	0.542475333	10.99279527	84.52727843	2.164098894
2006	2.469559683	2.800287949	14.54157748	77.53379291	2.654781977
2007	4.220184248	4.308501093	16.5708293	71.4730366	3.427448759
2008	6.681771489	6.138596724	17.87138493	65.63856668	3.66968018
2009	7.148442203	7.601080094	19.16351836	61.31063775	4.776321595
2010	9.577953146	9.276929577	21.06226145	51.06043263	9.022423197
2011	8.714846333	10.85871908	26.94795415	46.84422153	6.634258909
2012	7.905851237	13.23606857	28.96155781	41.85266474	8.043857639
2013	8.443297075	15.2556489	28.56331353	39.46079551	8.276944986







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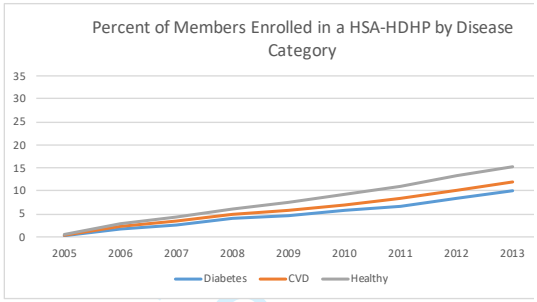
Appendix 4b. Percentage of Members Enrolled in a HSA, HRA or non-account HDHP by Disease Category (unadjusted)
(Note: demonimator of each line is all members in the disease cohort, i.e., diabetes, cardiovascular disease, or healthy)

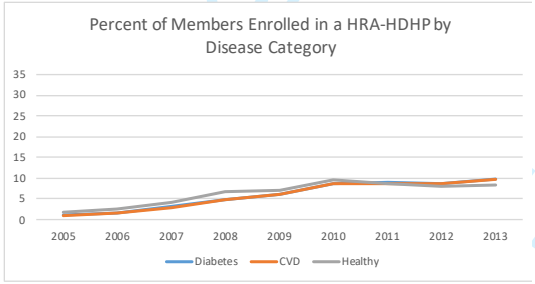
HSA-HDHP

	Diabetes	CVD	Healthy
2005	0.267839	0.367707	0.542475
2006	1.69346	2.162005	2.800288
2007	2.648916	3.491984	4.308501
2008	3.944255	4.92366	6.138597
2009	4.61797	5.712716	7.60108
2010	5.685492	7.015639	9.27693
2011	6.78393	8.28066	10.85872
2012	8.345438	10.19014	13.23607
2013	10.0342	11.94801	15.25565



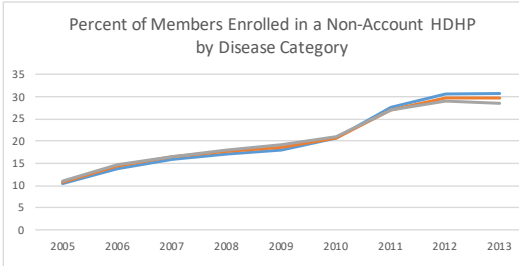
HRA-HDHP

	Diabetes	CVD	Healthy
2005	1.11356	0.951261	1.773352
2006	1.632677	1.495694	2.46956
2007	3.054379	2.961713	4.220184
2008	4.791947	4.959011	6.681771
2009	6.00057	6.16786	7.148442
2010	8.521427	8.806415	9.577953
2011	8.93196	8.697617	8.714846
2012	8.74638	8.539476	7.905851
2013	9.778268	9.707545	8.443297



Non Account-HDHP

	Diabetes	CVD	Healthy
2005	10.43191	10.71368	10.9928
2006	13.81108	14.29073	14.54158
2007	15.7484	16.41103	16.57083
2008	16.99664	17.58477	17.87138
2009	18.00921	18.60927	19.16352
2010	20.57566	20.75482	21.06226
2011	27.5296	27.07542	26.94795
2012	30.40782	29.67013	28.96156
2013	30.66432	29.61642	28.56331



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Appendix 5. Percentage of Members Enrolled in HDHP by Deductible Amount ($1000-$2499 and ≥$2500)

Deductible $1000-2499

	Diabetes	CVD	Healthy
2005	10.91604	11.10743	12.43166
2006	15.45958	16.11428	17.64392
2007	18.2095	19.15216	20.87959
2008	21.16371	22.2593	24.73561
2009	22.60751	23.76169	26.25005
2010	26.45562	27.53338	30.02893
2011	32.77277	32.83255	33.89115
2012	34.3502	34.16569	34.32813
2013	35.05437	34.55724	33.7226

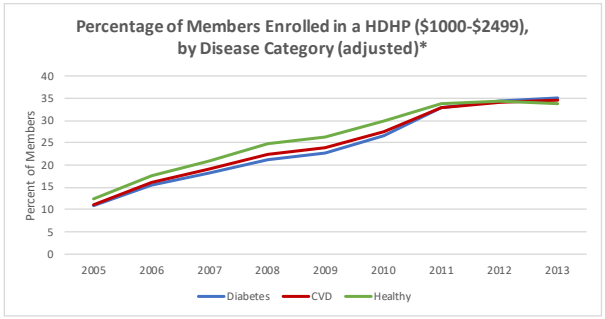
Diabetes	CVD	Healthy
0.1091604	0.1110743	0.1243166
0.1545958	0.1611428	0.1764392
0.182095	0.1915216	0.2087959
0.2116371	0.222593	0.2473561
0.2260751	0.2376169	0.2625005
0.2645562	0.2753338	0.3002893
0.3277277	0.3283255	0.3389115
0.343502	0.3416569	0.3432813
0.3505437	0.3455724	0.337226

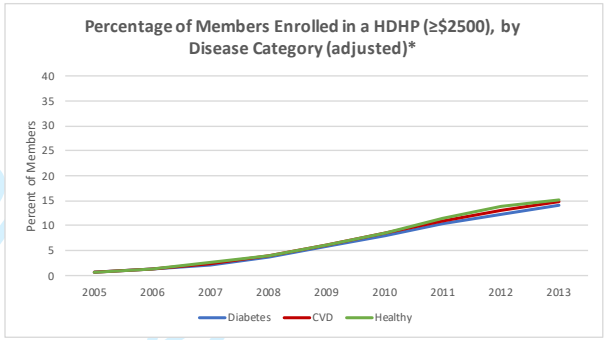
Deductible ≥ $2500

	Diabetes	CVD	Healthy
2005	0.69452	0.68785	0.6662
2006	1.2067	1.26371	1.31815
2007	2.24622	2.40487	2.53268
2008	3.69438	3.97341	4.02361
2009	5.81674	6.12616	6.24586
2010	8.03579	8.44121	8.51678
2011	10.39904	10.94723	11.44764
2012	12.37166	13.09128	13.74244
2013	14.08734	14.80603	15.15463

Diabetes	CVD	Healthy
0.0069452	0.0068785	0.006662
0.012067	0.0126371	0.0131815
0.0224622	0.0240487	0.0253268
0.0369438	0.0397341	0.0402361
0.0581674	0.0612616	0.0624586
0.0803579	0.0844121	0.0851678
0.1039904	0.1094723	0.1144764
0.1237166	0.1309128	0.1374244
0.1408734	0.1480603	0.1515463

*Estimates are adjusted for variables in Table 1.





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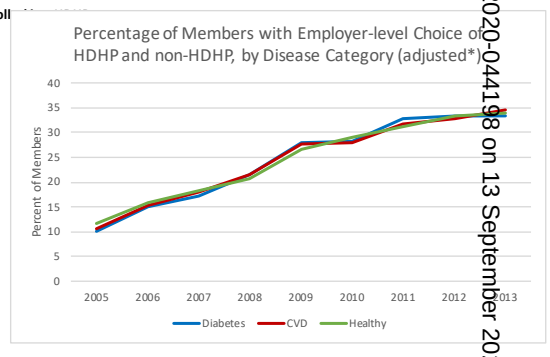
Appendix 6. Percentage of Members with Employer-level Choice of HDHP and non-HDHP and Percentage of Members wit Employer-level Plan Choice that Enroll

Members with Employer-level Plan Choice

	Diabetes	CVD	Healthy
2005	10.08195	10.59967	11.66249
2006	14.98163	15.30981	15.80417
2007	17.22922	17.9922	18.19298
2008	21.58658	21.45532	20.64135
2009	27.99466	27.77114	26.54475
2010	28.21836	27.92916	28.90129
2011	32.83495	31.67371	31.11506
2012	33.25026	32.72252	33.42743
2013	33.34627	34.55724	33.91297

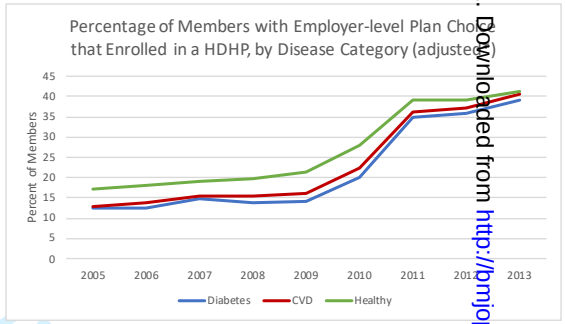
Diabetes	CVD	Healthy
0.1008195	0.1059967	0.1166249
0.1498163	0.1530981	0.1580417
0.1722922	0.179922	0.1819298
0.2158658	0.2145532	0.2064135
0.2799466	0.2777114	0.2654475
0.2821836	0.2792916	0.2890129
0.3283495	0.3167371	0.3111506
0.3325026	0.3272252	0.3342743
0.3334627	0.3455724	0.3391297



HDHP Enrollment

	Diabetes	CVD	Healthy
2005	12.47771	12.84836	17.16191
2006	12.52168	13.68354	18.11788
2007	14.6445	15.28622	19.10159
2008	13.79897	15.45891	19.78912
2009	14.11181	16.1932	21.3451
2010	20.06749	22.40512	27.93875
2011	34.80682	36.11686	39.01214
2012	35.78895	37.22782	39.2702
2013	39.0987	40.57872	41.24586

Diabetes	CVD	Healthy	Healthy vs. Dia	Healthy vs. CVD
0.1247771	0.1284836	0.1716191	0.046842	0.0431355
0.1252168	0.1368354	0.1811788	0.055962	0.0443434
0.146445	0.1528622	0.1910159	0.0445709	0.0381537
0.1379897	0.1545891	0.1978912	0.0599015	0.0433021
0.1411181	0.161932	0.213451	0.0723329	0.051519
0.2006749	0.2240512	0.2793875	0.0787126	0.0553363
0.3480682	0.3611686	0.3901214	0.0420532	0.0289528
0.3578895	0.3722782	0.392702	0.0348125	0.0204238
0.390987	0.4057872	0.4124586	0.0214716	0.0066714
		AVERAGE	0.05073991	0.03687089



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Appendix 7. Mean Annual OOP Costs by Deductible Type by Disease Category

DM

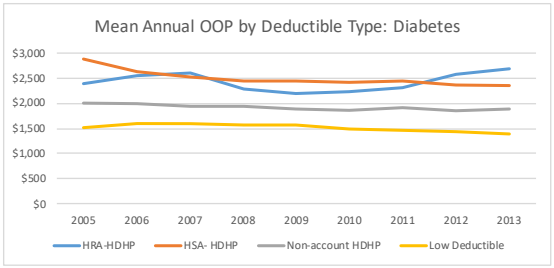
	HRA-HDHP	HSA- HDHP	Non-accou	Low Deduc	HRA minus	HSA minus non-account
2005	2393.916	2881.905	2003.091	1516.98	390.8251	878.814
2006	2559.193	2631.365	1988.599	1595.349	570.594	642.7656
2007	2590.896	2526.562	1938.282	1582.098	652.6135	588.28
2008	2296.826	2436.601	1926.693	1556.628	370.1324	509.9076
2009	2194.634	2431.91	1885.599	1565.047	309.0354	546.3113
2010	2238.621	2420.992	1865.441	1497.35	373.1802	555.5506
2011	2321.375	2440.716	1903.518	1447.1	417.8574	537.1983
2012	2574.192	2373.463	1850.834	1422.535	723.3575	522.6287
2013	2687.706	2353.21	1874.342	1388.097	813.3646	478.8685

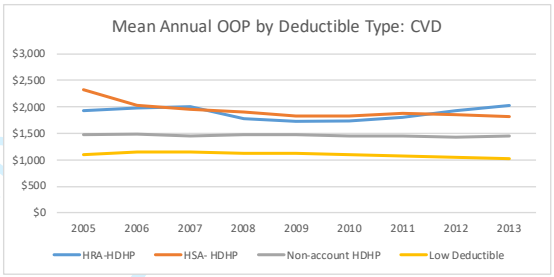
CVD (no DM)

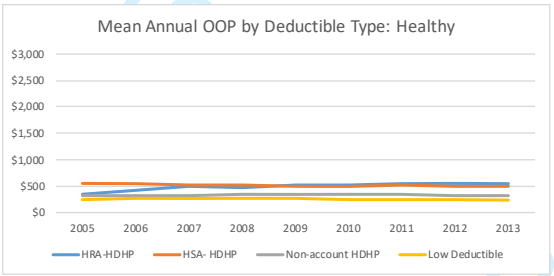
	1	2	3	4	HRA minus	HSA minus non-account
2005	1920.443	2326.151	1479.539	1090.894	440.9041	846.6121
2006	1986.084	2028.731	1485.003	1146.635	501.0815	543.7286
2007	2007.072	1961.689	1450.305	1140.393	556.7679	511.3849
2008	1790.413	1900.173	1474.796	1117.401	315.6174	425.3775
2009	1735.514	1840.534	1483.046	1130.698	252.4678	357.4885
2010	1734.52	1836.894	1459.298	1085.333	275.2217	377.5953
2011	1800.884	1867.053	1460.313	1059.419	340.5712	406.7393
2012	1934.948	1843.689	1427.32	1033.656	507.6274	416.3687
2013	2027.645	1817.272	1444.648	1020.506	582.9969	372.6236

Healthy (no CVD/DM)

	1	2	3	4	HRA minus	HSA minus non-account
2005	347.3469	551.8989	322.074	247.2184	25.2729	229.8249
2006	427.0065	544.3314	330.4697	261.703	96.53675	213.8617
2007	486.1821	533.8033	330.1245	266.8136	156.0576	203.6789
2008	474.593	527.5781	336.9341	257.3514	137.6588	190.644
2009	516.8504	502.2568	343.9218	263.8786	172.9286	158.335
2010	517.5078	494.6837	340.2603	254.0303	177.2475	154.4234
2011	539.9028	511.0485	335.8207	251.1227	204.082	175.2278
2012	552.2777	507.3392	327.0786	241.9559	225.1992	180.2607
2013	551.6646	495.3605	320.5448	235.7487	231.1198	174.8157







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Appendix 8. Mean Annual Total Costs by Deductible Type by Disease Category (unadjusted)

DM

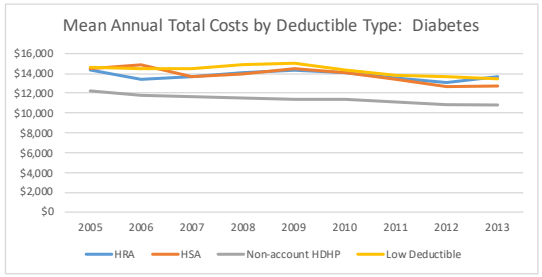
	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	14295.15901	14546.6128	12233.7601	14554.59815	2061.39891	2312.8527
2006	13405.63135	14868.81695	11846.05042	14426.92738	1559.58093	3022.76653
2007	13720.22153	13642.25951	11639.91124	14526.02864	2080.31029	2002.34827
2008	14131.75479	13994.31617	11534.83607	14877.3287	2596.91872	2459.4801
2009	14322.29938	14503.04544	11411.71708	15028.2057	2910.5823	3091.32836
2010	14027.56971	14109.11982	11402.7128	14406.14894	2624.85691	2706.40702
2011	13582.10935	13337.52968	11132.93139	13854.35939	2449.17796	2204.59829
2012	13080.23284	12669.93664	10893.35848	13685.20298	2186.87436	1776.57816
2013	13691.86599	12726.6443	10815.17043	13456.14811	2876.69556	1911.47387

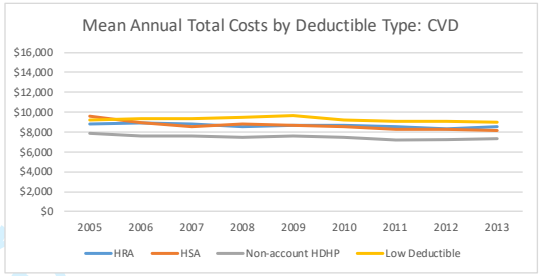
CVD, no DM

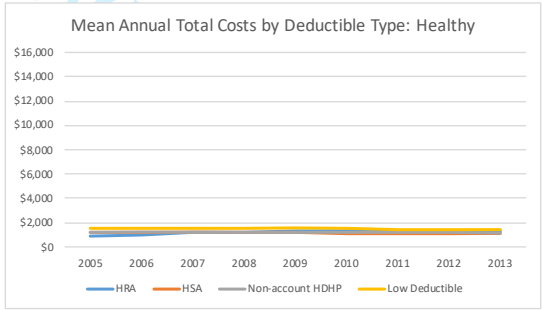
	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	8850.256505	9598.062586	7866.036401	9271.997354	984.220104	1732.026185
2006	8915.313118	8876.553784	7631.195185	9320.588567	1284.117933	1245.358599
2007	8848.853019	8493.630408	7573.834261	9384.138362	1275.018758	919.796147
2008	8580.592785	8784.496764	7512.799245	9526.765184	1067.79354	1271.697519
2009	8720.503012	8711.905936	7616.054761	9658.355955	1104.448251	1095.851175
2010	8648.269763	8540.065897	7448.820658	9277.827305	1199.449105	1091.245239
2011	8573.48888	8220.636208	7255.241166	9070.624837	1318.247714	965.395042
2012	8320.183574	8280.958581	7230.308001	9028.639503	1089.875573	1050.65058
2013	8477.33171	8152.846695	7339.746457	8988.416795	1137.585253	813.100238

Healhty, no CVD, no DM

	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	886.9861308	1213.842657	1224.830341	1495.335946	-337.84421	-10.987684
2006	1008.234675	1209.061845	1225.083036	1506.232586	-216.848361	-16.021191
2007	1147.217313	1223.599031	1221.549034	1515.32876	-74.331721	2.049997
2008	1199.469737	1217.558335	1201.53683	1530.071192	-2.067093	16.021505
2009	1285.869673	1162.702343	1206.441497	1561.344602	79.428176	-43.739154
2010	1324.598342	1141.728807	1171.974055	1489.797593	152.624287	-30.245248
2011	1275.707557	1111.261067	1156.502128	1466.704303	119.205429	-45.241061
2012	1290.420283	1111.124486	1154.080793	1434.908082	136.33949	-42.956307
2013	1292.016802	1109.158634	1140.75247	1421.652668	151.264332	-31.593836







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Appendix 9. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plans, by Disease Category (unadjusted)

OOP Costs

DM

	Low Deductibl	HDHP	HDHP-LDHP
2005	1368.324	1959.252	590.928
2006	1441.811	2029.778	587.967
2007	1388.378	2038.749	650.371
2008	1368.538	2006.348	637.81
2009	1362.979	1965.911	602.932
2010	1338.029	1945.981	607.952
2011	1303.13	1943.895	640.765
2012	1284.478	1960.074	675.596
2013	1258.84	1989.25	730.41
Mean	1346.05633	1982.13756	

CVD (no DM)

	0	1	
2005	987.0506	1479.058	492.0074
2006	1030.623	1530.359	499.736
2007	1000.954	1540.841	539.887
2008	975.2969	1537.254	561.9571
2009	976.0373	1515.611	539.5737
2010	954.6136	1486.501	531.8874
2011	933.4627	1468.28	534.8173
2012	911.3351	1473.901	562.5659
2013	893.9074	1485.194	591.2866
Mean	962.586733	1501.88878	

Healthy (no CVD/DM)

	0	1	
2005	166.4346	250.436	84.0014
2006	171.8132	272.3515	100.5383
2007	169.8192	279.7187	109.8995
2008	162.8924	285.4981	122.6057
2009	165.9155	287.9714	122.0559
2010	160.5264	281.4719	120.9455
2011	155.5968	274.167	118.5702
2012	147.853	266.1062	118.2532
2013	142.2151	261.422	119.2069
Mean	160.340689	273.238089	

Relative costs	LDHP	HDHP
vs. DM	8.39497661	7.25425055
vs. CVD	6.00338404	5.49663037

Total Costs

DM

	Low Deductibl	HDHP	HDHP-LDHP	HDHP - OOP/T	LDHP - OOP/Total costs
2005	10308.47	9699.435	-609.035	20.20%	13.27%
2006	10341.91	9845.497	-496.413	20.62%	13.94%
2007	9992.148	9743.071	-249.077	20.93%	13.89%
2008	10114.71	9606.592	-508.118	20.89%	13.53%
2009	10133.87	9549.384	-584.486	20.59%	13.45%
2010	9926.813	9458.704	-468.109	20.57%	13.48%
2011	9529.334	8935.642	-593.692	21.75%	13.67%
2012	9488.913	8769.875	-719.038	22.35%	13.54%
2013	9138.999	8606.055	-532.944	23.11%	13.77%
Mean		9357.13944		**Mean**	**21.22%** **13.62%**

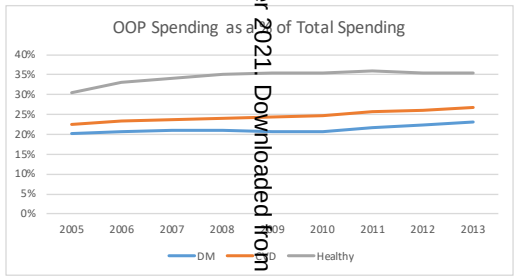
CVD, no DM

	0	1		
2005	6903.557	6572.213	-331.344	22.50%	14.30%
2006	6918.276	6582.855	-335.421	23.25%	14.90%
2007	6663.636	6458.677	-204.959	23.86%	15.02%
2008	6680.236	6350.276	-329.96	24.21%	14.60%
2009	6626.569	6201.896	-424.673	24.44%	14.73%
2010	6400.159	6034.349	-365.81	24.63%	14.92%
2011	6221.113	5721.829	-499.284	25.66%	15.00%
2012	6064.94	5662.128	-402.812	26.03%	15.03%
2013	5922.871	5545.22	-377.651	26.78%	15.09%
Mean		6125.49367		**Mean**	**24.60%** **14.84%**

Healthy, no CVD, no DM

	0	1		
2005	899.2028	820.705	-78.4978	30.51%	18.51%
2006	895.8246	821.0606	-74.764	33.17%	19.18%
2007	889.7641	818.8746	-70.8895	34.16%	19.09%
2008	892.4623	813.7006	-78.7617	35.09%	18.25%
2009	906.1254	811.5594	-94.566	35.48%	18.31%
2010	876.4865	796.0561	-80.4304	35.36%	18.31%
2011	851.6796	761.3796	-90.3	36.01%	18.27%
2012	824.5298	752.7057	-71.8241	35.35%	17.93%
2013	807.2234	737.2551	-69.9683	35.46%	17.62%
Mean		792.588522		**Mean**	**34.51%** **18.39%**

	DM	CVD	Healthy
2005	20.20%	22.50%	30.51%
2006	20.62%	23.25%	33.17%
2007	20.93%	23.86%	34.16%
2008	20.89%	24.21%	35.09%
2009	20.59%	24.44%	35.48%
2010	20.57%	24.63%	35.36%
2011	21.75%	25.66%	36.01%
2012	22.35%	26.03%	35.35%
2013	23.11%	26.78%	35.46%



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Appendix 10. Average ACG score over time by Deductible Type by Disease Category (unadjusted)

DM

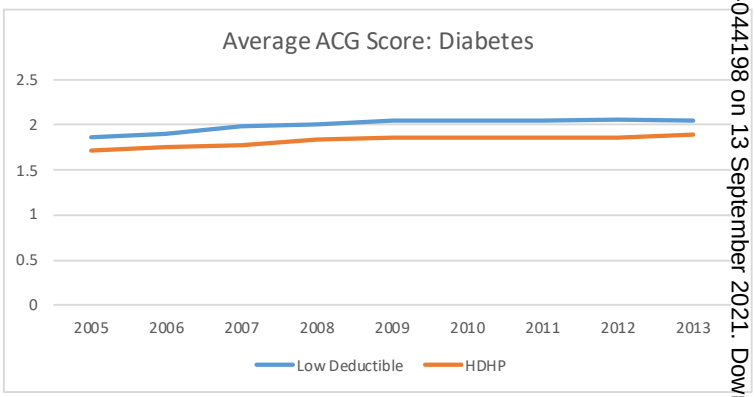
	Low Deductible	HDHP
2005	1.861649017	1.714135177
2006	1.900161553	1.755773667
2007	1.97781806	1.770965478
2008	2.012055696	1.828904806
2009	2.044269382	1.848417882
2010	2.037977855	1.864763712
2011	2.057163586	1.865177058
2012	2.057682309	1.866217048
2013	2.05615462	1.891463564

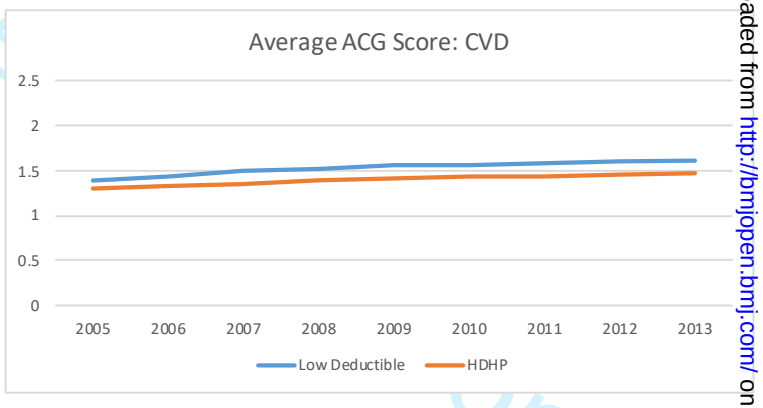
CVD

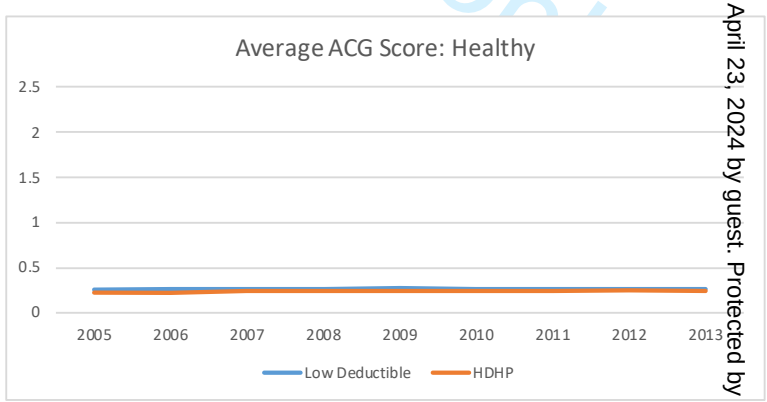
	0	1
2005	1.388339763	1.299303003
2006	1.436105621	1.329121657
2007	1.491629805	1.350587912
2008	1.514304403	1.383810136
2009	1.551069175	1.419532189
2010	1.560214495	1.429574365
2011	1.578042255	1.442374895
2012	1.599309203	1.455452532
2013	1.609740152	1.469366178

Healthy

	0	1
2005	0.255855261	0.22290789
2006	0.263268967	0.229830085
2007	0.267363128	0.235275946
2008	0.269366642	0.238672036
2009	0.273416246	0.242011671
2010	0.268782921	0.244339555
2011	0.27245572	0.246896724
2012	0.271553431	0.248249108
2013	0.271018578	0.248220379







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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	p2 1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	p3 2	Explain the scientific background and rationale for the investigation being reported
Objectives	p3 3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	p4 4	Present key elements of study design early in the paper
Setting	p4 5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	p4 6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	p4/5 7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	p4 8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	p5 9	Describe any efforts to address potential sources of bias
Study size	p4/6 10	Explain how the study size was arrived at
Quantitative variables	p4/5 11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	p5 12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	p6 13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	p6 14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	p6/7 15*	Report numbers of outcome events or summary measures over time
Main results	p6/7 16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

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Other analyses	p7	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	p5	18	Summarise key results with reference to study objectives
Limitations	p8/9	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	p8/9	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	p9	21	Discuss the generalisability (external validity) of the study results
Other information			
Funding	p11	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Trends in High Deductible Health Plan Enrollment and Spending among Commercially Insured Members with and without Chronic Conditions: A Natural Experiments for Translation in Diabetes (NEXT-D2) Study

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Abstract:

Objectives: To examine trends in high deductible health plan (HDHP) enrollment among members with diabetes and cardiovascular disease (CVD) compared to healthy members and compare out-of-pocket (OOP) and total spending for members with chronic conditions in HDHPs vs. low deductible plans.
Design: Descriptive study with time trends.
Setting: A large national commercial insurance database.
Participants: 1.2 million members with diabetes, 4.5 million members with CVD (without diabetes) and 18.0 million healthy members (defined by a low comorbidity score) under the age of 65 and insured between 2005 to 2013.
Outcome measures: Percentage of members in a HDHP (i.e., annual deductible ≥$1000) by year, annual mean OOP and total spending, adjusted for member sociodemographic and employer characteristics.
Results: Enrollment in HDHPs among members in all disease categories increased by 5 percentage points a year and was over 50% by 2013. On average over the study period, HDHP enrollment among members with diabetes and CVD was 2.84 (95% CI: 2.78, 2.90) and 2.02 (95% CI: 1.98, 2.05) percentage points lower, respectively, than among healthy members. HDHP members with diabetes, CVD, and low morbidity had higher annual OOP costs ($636 [95% CI: 630, 642], $539 [95% CI: 537, 542], and $113 [95% CI: 112, 113]) and lower total costs (-$529 [95% CI: -597, -461], -$364 [95% CI: -385, -342], and -$79 [95% CI: -81, -76]), respectively, than corresponding low-deductible members when averaged over the study period. Members with chronic diseases had yearly OOP expenditures that were 5 to 7 times higher than healthier members.
Conclusions: High HDHP enrollment coupled with the high OOP costs associated with HDHPs may be particularly detrimental to the financial well-being of people with diabetes and cardiovascular disease, who have more health care needs than healthier populations.

Article Summary

Strengths and limitations of this study

- This is the first study to compare enrollment in high deductible health plans between members with chronic diseases (i.e., diabetes and cardiovascular disease) and healthy members.
- This study uses nine years of claims data from large, national health insurer in the United States.
- The study also examines out-of-pocket and total costs between members in high deductible and low deductible plans.
- The study is descriptive and we cannot infer causal relationships.
- The data do not include insurance premium information, so we cannot assess the full financial burden on members.

Key Words: health insurance, high deductible health plan, diabetes, cardiovascular disease, out-of-pocket costs

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Introduction

Recent research suggests that high deductible health plans (HDHPs), which provide incentives for patients to manage their own health care costs, are associated with concerning impacts on patients with chronic conditions. However, little is known about trends in HDHP enrollment among patients with chronic conditions versus healthier populations and the associated economic burden.

To reduce health care costs and monthly premiums, an increasing number of employers offer HDHPs. These arrangements provide incentives for patients to utilize select high-value services and reduce health care costs through inexpensive preventive care and higher annual deductibles.[1] In 2019, 82% of commercially insured Americans had an annual deductible; of these, over two-thirds (69%) had a deductible of over $1000 and over one in ten (14%) had a deductible over $3000.[2] HDHPs paired with a tax-preferred savings account for out-of-pocket (OOP) spending (i.e., Health Savings Accounts [HSA] or Health Reimbursement Arrangements [HRA]) are the most rapidly growing plan type, now covering 30% of commercially insured Americans.[2] HDHPs have been shown to reduce health care spending, but also reduce preventive care[3] and cause members to delay care because of costs.[4] If given a choice in plans by their employer, employees who choose HDHPs tend to be younger and healthier and more likely to live in neighborhoods with a higher proportion of individuals of higher income, higher education and white race.[5]

Diabetes and cardiovascular disease (CVD) are the two most prevalent chronic illnesses in the United States. High quality of care for such conditions requires multiple office visits, tests, exams and medications.[6-13] Typically, HDHPs fully cover some preventive services and one annual preventive visit, but require full cost-sharing up to the annual deductible for all other services and often additional cost sharing (i.e., coinsurance or co-payment) after the deductible is met. Our Natural Experiments in Diabetes Translation (NEXT-D1) study used a robust study design to examine the impact of HDHPs among members with diabetes. Studies demonstrated decreased utilization of both appropriate and discretionary services, with concerning impacts on vulnerable populations. For example, HDHPs were associated with delays in seeking care for major macrovascular disease symptoms, diagnostic tests, and procedure-based treatments,[14] reductions in specialist visits,[15] delayed outpatient visits for acute preventable complications[15] and higher emergency department visits for acute complications among the poor.[15] The negative impacts of HDHPs are consistently more pronounced in low income HDHP members or members with a HSA-HDHP. [15,16] Other studies have suggested similar impacts of HDHPs on members with cardiovascular disease.[17]

Despite these concerning effects, trends in HDHP enrollment and OOP burden among patients with chronic illness versus healthier patients are unknown. Our objective was to assess 2005-2013 trends in HDHP enrollment among members with diabetes and cardiovascular disease in a large national insurer, compared to a cohort of healthy members. We also compared the demographics, comorbidities, and trends in OOP

spending and total spending of members with chronic conditions and healthier members in HDHPs (with and without savings accounts) to counterparts in low deductible plans.

Methods

Study Design: This descriptive study assessed annual trends from 2005-2013 and differences in HDHP enrollment between subgroups of members with chronic conditions compared to healthy members and, within disease category, assessed member-level and employer-level characteristics associated with HDHP enrollment and compared differences in OOP spending and total costs between members with HDHPs and low-deductible health plans.

Data: We used a large claims database that included approximately 55.5 million unique commercially-insured members of all ages from 2005-2013. Members with Medicare Advantage were excluded from this study since they were not subject to comparable insurance arrangements. The data included enrollment status and all medical and pharmacy claims. We used the Johns Hopkins ACG® System (version 11.1),[18,19] to assign diagnostic categories and an overall comorbidity score using claims data (i.e., diagnoses, procedures and medications) from the prior 12 months. We also linked individuals to neighborhood-level socioeconomic characteristics from the 2008-2012 American Community Survey (ACS; i.e., 5-year estimates at the census-tract level).[20]

Study Population: We included members under the age of 65 years old with diabetes and cardiovascular disease and a comparison group of healthier members. We created the three mutually exclusive categories of members based on ACG diagnostic categories: diabetes (inclusive of Type 1 and Type 2 diabetes) with or without cardiovascular disease (CVD); CVD or risk factors (i.e., lipid disorders or hypertension) without diabetes; and "healthy" (defined as ACG morbidity score ≤1 and excluding members with a diabetes or CVD diagnosis). We included members with at least 12 months of continuous enrollment covered by employers insuring 10 or more members (for whom we could reliably assess HDHP status). We used the ACG diagnosis flag (or score) from the last month of each member's 12-month enrollment period (i.e., "anniversary month"). Measures calculated over each 12-month enrollment period were assigned to the calendar year of each anniversary month.

Outcomes and Covariates: For each annual employer enrollment period, we classified members as being enrolled in a HDHP or non-HDHP plan on the anniversary month. We used actual or imputed deductible levels; the imputations were based on adding actual deductible payments per person per benefit year at the employer then assigning a deductible level to that employer using a regression model that included all enrollees' summed deductible levels and other employer characteristics (see details in Appendix 1). Using a common convention, we defined HDHPs as plans with a deductible level ≥$1000 and low deductible plans as plans with a deductible level ≤$500. Within HDHPs, we examined two levels of HDHP (i.e., $1000-2499 and ≥$2500) and identified HDHP members with a savings account plan (i.e., HSA or HRA) using flags provided by the data vendor.

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For member demographics, we examined age; sex; region (i.e., Midwest, Northeast, South and West); and neighborhood-level income (i.e., low poverty, low-medium poverty, high-medium poverty, and high poverty), education (i.e., low, low-medium, high-medium, and high education level), and race/ethnicity (i.e., white, non-Hispanic vs. all other races/ethnicities) using ACS categories (see details in Appendix 2). As a measure of comorbidity, we included the ACG score, measured as a continuous variable. We also measured two employer-level variables: self-insured vs. fully-insured status and employer size (i.e., 10-99, 100-999 and ≥ 1000 employees). All covariates were measured on the anniversary month.

We calculated members' annual OOP expenditures, which include all cost-sharing (i.e., deductibles, copayments, and coinsurance) but not premium payments, adjusted for inflation to 2015 USD values using the Consumer Price Index for medical care, and total medical expenditure (i.e., insurer allowed amount inclusive of OOP costs, commonly referred to as "total cost") using a vendor-provided field that standardizes claims-level prices across geography and time which is inflation-adjusted to 2015.

Using employer-level data, we determined which members had a choice of a HDHP or a plan with a lower deductible from their employer. As a secondary analysis, we examined HDHP enrollment in the subset of members with employer-level plan choice.

Statistical Analysis: We first generated descriptive statistics of demographic and employer characteristics for HDHP and low deductible members in each of the three disease categories. We then used generalized estimating equations (GEE), applying the robust sandwich estimator and assuming an exchangeable working correlation structure to account for member-level clustering (since a member could contribute to the database for multiple years), with marginal models to assess all outcomes.[21] We used average adjusted predictions[22] to examine member-level predictors of being in a HDHP within each disease category, controlling for study year. Predictors in the model included the member and employer level characteristics mentioned above (i.e., age, sex, region, income, education, race/ethnicity, ACG score, self-insured status, employer size and study year). We also used average adjusted prediction models to estimate annual percentage of members enrolled in a HDHP and trends (i.e., slope) in HDHP enrollment for each disease category, controlling for the same variables as the enrollment prediction model. We calculated average marginal effects on the GEE models[22] to estimate the average difference in the percentage of members enrolled in a HDHP over the study period between each chronic disease group and healthier members, controlling for the same variables as the prediction model, except for ACG score (which is highly collinear with our disease categories).

Within each disease category, we used GEE models and adjusted prediction at the means,[22] controlling for the same variables as the HDHP enrollment prediction model, to examine the adjusted annual OOP and total costs for members with high and low deductible plans and the trends in costs over time for each disease category. Within each disease category, we used marginal effects at the means to estimate the absolute

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and relative differences in OOP and total costs between HDHP and low deductible health plan members. For each study year, we also calculated the average percent of total expenditure that HDHP members paid OOP (based on adjusted values), by disease category. And, within each disease category, we examined average comorbidity (i.e., ACG) score over the study period for members in high vs. low deductible plans.

In the models to assess percentage of members enrolled in a HDHP and predictors of HDHP enrollment, the denominator was all members in that disease category. The analyses that examined OOP and total costs compared members in HDHP (≥ $1000) to members in low deductible plans (≤$500) and therefore excluded members with deductibles of $501-$999.

All analyses were performed in SAS Studio 3.7 or STATA 15. This study was approved by the Harvard Pilgrim Health Care Institutional Review Board.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Our sample included three mutually exclusive disease categories: 1.2 million unique members (2.6 million member-years) with diabetes, 4.5 million unique members (9.4 million member-years) with cardiovascular disease and risk factors (without diabetes) and 18.0 million unique healthy members (40.4 million member-years). Appendix 3 includes demographic and employer characteristics for members in HDHP and low deductible health plans.

Predictors of HDHP Enrollment within Disease Category

In the predicted probability models (Table 1), HDHP enrollment among members with diabetes and cardiovascular disease and healthy members was statistically significantly higher for members with the following characteristics: higher income; white, non-Hispanic race/ethnicity; lower comorbidity score; living in the West, Midwest or South (compared to the Northeast); being insured through a fully-insured (vs. self-insured) employer; and working for a smaller employer. Age had mixed results across disease categories. Across all disease categories, the largest absolute predictors of HDHP status were region, fully-insured employer status and smaller employer size. For instance, on average over the study period, 49.30% (95% CI:49.13, 49.47) of members with diabetes insured through a smaller employer (i.e., 10-99 enrollees) were enrolled in a HDHP compared to 23.93% (95% CI: 23.72, 23.94) of members with diabetes insured through a large employer (i.e., ≥ 1000 enrollees).

Percentage of Members Enrolled in a HDHP Over Time

Enrollment in HDHPs increased markedly over the study period for all disease categories, increasing by approximately 5 percentage points per year across all groups

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when adjusting for the variables in Table 1. HDHP enrollment increased by 5.29 percentage points (95% CI: 5.27, 5.31), 5.27 percentage points (95% CI: 5.26, 5.28), and 5.11 percentage points (95% CI: 5.10, 5.12) per year for members with diabetes, CVD and healthy members, respectively, over the study period. Members with chronic diseases had lower levels of HDHP enrollment than healthier members throughout the entire study period (Figure 1). On average over the study period, HDHP enrollment among members with diabetes and CVD was 2.84 (95% CI: 2.78, 2.90) and 2.02 (95% CI: 1.98, 2.05) percentage points lower, respectively, than among healthy members. However, by the end of the study period, over half of members in each disease category were in a HDHP. In 2013, 53.43% (95% CI: 53.39, 53.47) of healthy members were in a HDHP compared to 52.48% (95% CI: 52.33, 52.63) of members with diabetes and 53.21% (95% CI: 53.12, 53.29) of members with CVD in the adjusted models. While non-account HDHPs were the most common HDHP type for HDHP members in all three disease categories (Appendix 4a), the higher percentage of enrollment in HDHPs among healthy members, compared to members with chronic diseases, was driven by higher enrollment in HSA-eligible HDHPs (Appendix 4b). The percentage of members enrolled in a very high deductible health plan (≥$2500) increased over the study period for all disease categories, from less than 1% in 2005 to 14-15% in 2015 (Appendix 5). In the last three years of the study period, the percentage of members in a HDHP with a deductible between $1000 and $2499 remained relatively flat, and the increase observed in HDHP plan enrollment overall was driven by enrollment in very high deductible health plans.

During the study period, the percent of members with an employer that offered both HDHPs and a lower deductible plans increased from 10-11% in 2005 to 33-34% in 2013 in all disease areas. (Appendix 6) The percentage of members with employer-level plan choice that enrolled in a HDHP increased over the study period, but was 12-13 percentage points lower than the percentage of all members (i.e., with and without plan choice). In 2013, among members with employer-level plan choice, 41.25% (95% CI: 41.18, 41.32) of healthy members, 39.10% (95% CI: 38.83, 39.37) of members with diabetes and 40.58% (95% CI: 40.43, 40.73) with cardiovascular disease were in a HDHP. On average, over the study period, members with plan choice that had a chronic disease were 4-5 percentage points less likely than healthier members with plan choice to enroll in a HDHP.

Out of Pocket Costs

For all disease categories, HDHP members had higher OOP costs than low deductible plan members (Figure 2). The differences in OOP costs between HDHP and low-deductible plans were, on average over the study period, $636 (95% CI: 630, 642), $539 (95% CI: 537, 542), and $113 (95% CI: 112, 113) for members with diabetes, CVD and healthy members, respectively. In relative terms, compared to LDHP members, average OOP costs for HDHP members were 47.26% (95%: 46.73, 47.78), 56.03% (55.71, 56.63) and 70.41% (95% CI: 70.13, 70.69) higher, respectively. Inflation-adjusted OOP costs decreased slightly over time for both low and high deductible health plan members in all three disease categories, with a steeper decline observed among low deductible health plan members. OOP costs for low deductible plan members

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decreased, on average, by $20 (95%: 19, 21), $17 (95% CI: 17, 18), and $6 (95%: 6, 6) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $6 (95%: 4, 8), $10 (95% CI: 9, 11), and $3 (95%: 3, 4) per year. Across all disease categories, members in HRA and HSA-eligible HDHPs had higher OOP costs than non-account HDHPs (Appendix 7).

Total Costs

For all disease categories, HDHP members had lower total costs than low deductible plan members (Figure 3). The differences in total costs between HDHP and low-deductible plans were, on average over the study period, -$529 (95% CI: -597, -461), -$364 (95% CI: -385, -342), and -$79 (95% CI: -81, -76) for members with diabetes, cardiovascular disease and healthy members, respectively. In relative terms, compared to low deductible members, average total costs for HDHP members were 5.35% (95%: 4.66, 6.04), 5.60% (5.27, 5.93) and 9.05% (95% CI: 8.77, 9.33) lower for members with diabetes, cardiovascular disease and healthy members, respectively. Our measure of total costs decreased over the study period for both HDHP and low deductible health plan members in all three disease categories, with a steeper decrease observed among HDHP members. Total costs for low deductible plan members decreased, on average, by $248 (95%: 229, 267), $449 (95% CI: 434, 464), and $21 (95%: 20, 22) per year for members with diabetes, cardiovascular disease and healthy members, respectively, with corresponding decreases for HDHP members of $348 (95%: 318, 379), $567 (95% CI: 544, 589), and $28 (95%: 26, 29) per year, respectively. Members with chronic diseases in HRA- and HSA-eligible HDHPs had consistently higher total costs than non-account HDHPs (Appendix 8).

Members with chronic diseases in both high and low deductible plans had higher OOP costs and total expenditures than healthy members in similar plans (Figures 2 and 3). While HDHP members' OOP share of total expenditure was lower for members with chronic diseases (i.e., on average over the study period, OOP share was 21% of total expenditure for members with diabetes, 25% for members with cardiovascular disease and 35% for healthy members), members with chronic diseases had yearly OOP expenditures that were 5 (for CVD members) to 7 (for diabetes members) times higher than healthy members (Appendix 9).

Within each disease category, HDHP members had lower comorbidity scores than low deductible plan members and the comorbidity scores remained relatively stable over time (Appendix 10).

Discussion

HDHP enrollment increased rapidly among both chronically ill and healthy commercially-insured individuals from 2005-2013. Members with diabetes and CVD had slightly lower levels of HDHP enrollment than healthy members throughout the study period. However, by the end of the study period in 2013, over half (52-53%) of members with chronic conditions and healthy members were in HDHPs. Similar to previous

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research, we found that members who were healthier and lived in neighborhoods with higher income and education and a higher proportion of white, non-Hispanic individuals were more likely to be in a HDHP.[5] Across all disease categories, members insured through larger and self-insured employers were significantly less likely to be in a HDHP, suggesting that these employers may offer more generous benefit packages to their employees. Among the subset of members who were offered a choice of a HDHP or lower deductible plan from their employer, most members opted for a lower deductible health plan and members with chronic diseases were less likely to choose a HDHP than healthier members.

As expected, members with chronic diseases in both high and low deductible plans have higher OOP costs and total expenditures than healthy members in similar plans. However, the OOP cost burden was 5-7 times higher for HDHP members with chronic diseases compared to healthy members in HDHPs. These findings are concerning because our previous studies have shown that HDHPs are associated with avoided or delayed care and adverse health outcomes among diabetes patients[14-16] and other studies suggest similar impacts of HDHPs among members with cardiovascular disease.[17] Higher OOP costs combined with stagnant incomes[23] and increasing HDHP enrollment among patients with chronic conditions suggests increasing financial burden on this vulnerable population.

Within each disease category, members in HDHPs had higher OOP costs but lower total medical expenditures than those in low deductible plans. Lower total medical costs among HDHP members has been demonstrated in other studies.[3] The lower total costs among HDHP members in our study could indicate that HDHP members are different or healthier than low-deductible members in ways not captured by our adjusting covariates. However, it could also reflect less utilization among HDHP members in response to increased cost sharing. We observed decreasing trends in total costs over time for both HDHP and low deductible health plan members across all disease categories. Since our measure of total cost is based on standardized prices over time, and expenditure is price times quantity, this suggests that utilization is decreasing over time among all members. The larger downward trend in total cost among HDHP members compared to low deductible plan members suggests a greater decrease in utilization among HDHP members. HSA- and HRA-eligible HDHP members with chronic diseases consistently had higher OOP and higher total costs than members in non-account based HDHPs, (Appendix 7) possibly because the accounts provide funds that lower barriers to utilization and reduce the effective OOP cost of care through use of pre-tax dollars. However, another study found that more than half of members with HSA-eligible HDHPs do not contribute money to their HSA,[24] suggesting that HSA accounts may not actually reduce the OOP burden for the majority of HDHP members. Our finding that members with chronic diseases paid OOP for a lower share of total costs than healthier members is because members with chronic diseases have much higher total costs and many high costs members hit their deductible and OOP max limits.[25]

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Our study has multiple limitations. The ACG codes and scores rely on the appearance of diagnoses in medical claims. There may be increased provider coding of chronic conditions over time as risk-adjustment payment became more prominent, or reduced coding among HDHP members if they were less likely to seek routine care. However, we found that ACG scores among each disease category remained relatively stable over our study period (Appendix 10) and past analyses have shown minimal reductions in outpatient visits among members who were forced to switch into a HDHP.[15] Members may make health care decisions based on their total expected costs, which include OOP costs and premiums, minus contributions to savings accounts. While we have data on OOP costs, we do not have data on premium amounts or on employer and employee contributions to savings accounts, so total member expenditure is unknown. Increased OOP costs in HDHPs may be offset by the lower premiums or employer contributions to accounts or by increased wages. Our study includes data from large, mid-size and small employers with commercial health insurance plans offered by a large, national insurer; therefore, our study results may not be generalizable to regional plans, very small employers (<10 members), or members insured in the non-group market. Although we knew the exact deductible level of most smaller employers, we had to infer it from claims at large employers. However, the sensitivity and specificity of our algorithm was high and increased across employer size category, ranging 96% to 100% (Appendix 1). We expect adjustment for the uncertainty of the imputation process would have a negligible effect on confidence bounds. We were missing neighborhood-level socioeconomic variables for a small proportion of members (≤3% across the disease and deductible level categories, Appendix 3) and these members were excluded from the GEE models. Finally, since our study aimed to examine overall trends in HDHP enrollment and costs, our main analyses combined HDHP members whose employers offered only a HDHP with members who were offered a choice by their employer to enroll in a HDHP or a lower-deductible plan. Future research should examine HDHP enrollment among members who have plan choice to better understand factors associated with selecting HDHPs.

Conclusion

HDHP enrollment has increased rapidly among both healthy and chronically ill populations and by 2013 over half of members with chronic conditions in one large national insurer had HDHPs. HDHP members pay significantly more for their health care out of pocket than low deductible plan members, and HDHP members with chronic diseases have OOP spending that is 4-5 times higher than that of healthy members. Policymakers should consider options for protecting clinically vulnerable patients enrolled in HDHPs such as funding HSAs or facilitating enrollment in more generous plan designs.[26]

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Table 1. Predicted Probability of HDHP Enrollment by Disease Category

	Diabetes			Cardio-vascular Disease			Healthy		
	Predicted Probability (%)	95% CI lower bound	95% CI upper bound	Predicted Probability (%)	95% CI lower bound	95% CI upper bound	Predicted Probability (%)	95% CI lower bound	95% CI upper bound
Number of unique members	1,211,925			4,495,831			18,035,883		
Sex									
Female	32.72	32.61	32.82	33.00	32.95	33.06	34.40	34.37	34.43
Male	32.73	32.63	32.83	33.08	33.03	33.13	34.44	34.42	34.47
Neighborhood income level**									
High	35.10	34.92	35.28	35.45	35.35	35.56	36.67	36.61	36.73
Medium-high	33.41	33.29	33.54	33.82	33.75	33.89	35.22	35.18	35.25
Medium-low	31.72	31.57	31.87	32.39	32.32	32.47	34.02	33.98	34.06
Low	30.14	29.97	30.31	31.16	31.08	31.24	32.74	32.70	32.78
Neighborhood education level **									
High	33.74	33.29	34.18	33.70	33.40	34.00	35.90	35.75	36.04
Medium-high	33.38	33.14	33.62	34.01	33.86	34.16	35.26	35.18	35.34
Medium-low	33.12	32.96	33.28	33.53	33.43	33.62	34.86	34.81	34.91
Low	32.43	32.33	32.52	32.79	32.75	32.84	34.21	34.19	34.23
Race/ethnicity **									
White, not hispanic	34.09	33.99	34.19	34.18	34.14	34.23	35.94	35.91	35.96
Non-white race/ethnicity	31.06	31.06	31.06	31.09	31.03	31.16	32.06	32.03	32.10
Region	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northeast	22.54	22.30	22.77	22.09	21.98	22.20	23.17	23.12	23.23
West	31.03	30.83	31.23	31.91	31.80	32.02	34.30	34.25	34.34
Midwest	31.93	31.80	32.07	32.89	32.82	32.96	34.77	34.25	34.81
South	34.96	34.86	35.06	35.28	35.22	35.33	36.63	36.60	36.66
Employer insurance model									
Fully insured	40.09	39.98	40.21	40.39	40.33	40.45	40.83	40.80	40.86
Self insured	25.46	25.35	25.56	25.37	25.31	25.42	27.62	27.59	27.64
Employer size (ref: >1000 employees)									
≥ 1000 employees	23.83	23.72	23.94	24.16	24.10	24.22	25.61	25.58	25.64
100-999 employees	33.11	32.99	33.23	33.03	32.97	33.10	34.92	34.89	34.95
10-99 employees	49.30	49.13	49.47	49.10	49.01	49.19	49.99	49.95	50.04

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*Models control for study year as a categorical variable and age and ACG (i.e., comorbidity) score as continuous variables. Higher ACG score was associated with lower probability of HDHP enrollment in all disease categories. The results for age were mixed: higher age was associated with higher probability of HDHP enrollment for members with CVD and healthy members and lower probability of enrollment for members with diabetes. The denominator of the models includes all members (as unique member-years), not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999).
** Income level, education level and race were determined at the neighborhood level using the American Community Survey. See Appendix 2 for a detailed description of each category.

Figures (in excel file):
Figure 1. Percentage of Members Enrolled in a HDHP, by Disease Category (adjusted)
Figure 2. Mean Annual OOP Costs by Disease Category, HDHP vs. LDHP (adjusted)
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)

Appendices (in separate word and excel files):
Appendix 1. Deductible Level Imputation
Appendix 2. Definition of Covariates
Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health Plans and Low Deductible Health Plans, by Disease Category
Appendix 4a. Percentage of Members Enrolled in a HDHP by HDHP Type (i.e. HSA, HRA or non-account HDHP) for Each Disease Category (unadjusted)
Appendix 4b. Percentage of Members Enrolled in a HSA, HRA or non-account HDHP by Disease Category (unadjusted)
Appendix 5. Percentage of Members Enrolled in a HDHP by HDHP level (i.e., $1000-$2499 or ≥$2500) (adjusted)
Appendix 6. Percentage of Members with Employer-level Choice of HDHP and non-HDHP, by Disease Category (adjusted) and Percentage of Members with Employer-level Plan Choice that Enrolled in a HDHP, by Disease Category (adjusted)
Appendix 7. Mean Annual OOP Costs by Deductible Type by Disease Category (unadjusted)
Appendix 8. Mean Annual Total Costs by Deductible Type by Disease Category (unadjusted)
Appendix 9. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plans, by Disease Category (unadjusted)
Appendix 10. ACG Score by Disease Category

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Author Contributions: LFG, DRD and JFW contributed to the conception and design of the project. LFG, FZ, RL, JW, DRD, and JFW contributed to the acquisition, analysis and interpretation of the data. LFG, FZ, RL, JW, DRD, and JFW contributed to drafts of the manuscript. LFG provided final approval of the version to be published and is accountable for the accuracy and integrity of the work.

Data Statement: Data are not shareable because of our data use agreement with the data vendor, but we are happy to share programming code upon request.

Reporting Checklist: This study meets all criteria for STROBE cohort studies.

Ethics Statement: This study was approved by the Harvard Pilgrim Health Care Institutional Review Board,

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References:

1. The Kaiser Family Foundation and Health Research & Educational Trust. Employer Health BenefitsL 2017 Annual Survey. Menlo Park, California: The Kaiser Family Foundation and Health Research & Educational Trust, 2017.

2. The Kaiser Family Foundation. Employer Health Benefits 2019 Annual Survey San Francisco, California: The Kaiser Family Foundation, 2019.

3. Buntin MB, Haviland AM, McDevitt R. Health care spending and preventive care in high-deductible and consumer-directed health plans. Am J Manag Care. 2011;17(3):222-230.

4. Frostin P, Dretzka E. Consumer Engagement in Health Care: Findings From the 2018 EBRI/Greenwald & Associates Consumer Engagement in Health Care Survey. EBRI Issue Brief, no. 468. Employee Benefit Research Institute, December 13, 2018. [Available from: https://www.ebri.org/crawler/view/high-deductible-health-plan-enrollees-are-more-engaged-in-their-health-care]

5. Lave JR, Men A, Day, BT, Wang W, Zhang Y. Employee choice of a high-deductible health plan across multiple employers. Health Services Research. 2011;46:138-54.

6. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. Lancet 1998;352(9131):837-53.

7. Holman RR, Paul SK, Bethel MA, et al. 10-year follow-up of intensive glucose control in type 2 diabetes. N Engl J Med 2008;359(15):1577-89. doi: 10.1056/NEJMoa0806470

8. Capewell S, Morrison CE, McMurray JJ. Contribution of modern cardiovascular treatment and risk factor changes to the decline in coronary heart disease mortality in Scotland between 1975 and 1994. Heart 1999;81(4):380-6. doi: 10.1136/hrt.81.4.380

9. Standards of medical care in diabetes--2015: summary of revisions. Diabetes Care 2015;38 Suppl:S4. doi: 10.2337/dc15-S003

10. American Diabetes A. Standards of Medical Care in Diabetes-2019 Abridged for Primary Care Providers. Clin Diabetes 2019;37(1):11-34. doi: 10.2337/cd18-0105

11. Centers for Disease Control and Prevention. Get Active! Atlanta, GA: Centers for Disease Control and Prevention, 2018. [Available from: https://www.cdc.gov/diabetes/managing/active.html]

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12. American Diabetes A. 10. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes-2020. Diabetes Care 2020;43(Suppl 1):S111-S34. doi: 10.2337/dc20-S010

13. American College of Cardiology. Guidelines and Clinical Documents: American College of Cardiology; 2020 [Available from: https://www.acc.org/guidelines accessed June 30 2020.

14. Wharam JF, Lu CY, Zhang F, et al. High-Deductible Insurance and Delay in Care for the Macrovascular Complications of Diabetes. Ann Intern Med 2018;169(12):845-54. doi: 10.7326/M17-3365

15. Wharam JF, Zhang F, Eggleston EM, et al. Diabetes Outpatient Care and Acute Complications Before and After High-Deductible Insurance Enrollment: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. JAMA Intern Med 2017;177(3):358-68. doi: 10.1001/jamainternmed.2016.8411

16. Wharam JF, Zhang F, Eggleston EM, et al. Effect of High-Deductible Insurance on High-Acuity Outcomes in Diabetes: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. Diabetes Care 2018;41(5):940-48. doi: 10.2337/dc17-1183

17. Lewey J, Gagne JJ, Franklin J, et al. Impact of High Deductible Health Plans on Cardiovascular Medication Adherence and Health Disparities. Circ Cardiovasc Qual Outcomes 2018;11(11):e004632. doi: 10.1161/CIRCOUTCOMES.118.004632

18. Reid RJ, Roos NP, MacWilliam L, et al. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. Health Serv Res 2002;37(5):1345-64. doi: 10.1111/1475-6773.01029

19. The Johns Hopkins University. The Johns Hopkins ACG System. Baltimore, MD: The Johns Hopkins University; 2020 [Available from: https://www.hopkinsacg.org/advantage/ accessed June 30 2020.

20. United States Census Bureau. American Community Survey (ACS) Washington, D.C.: United States Census Bureau, 2020 [Available from: https://www.census.gov/programs-surveys/acs/ accessed June 30 2020.

21. STATA. Marginal means, adjusted predictions, and marginal effects. Accessed January 27, 2021. [Available at: https://www.stata.com/features/overview/marginal-analysis/]

22. Williams R. Using the margins command to estimate and interpret adjusted predictions and marginal effects. Stata Journal. 2012;2:308-331.

23. Desilver D. For most U.S. workers, real wages have barely budged in decades Washington, D.C.: Pew Research Center. 2018 [Available from:

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https://www.pewresearch.org/fact-tank/2018/08/07/for-most-us-workers-real-wages-have-barely-budged-for-decades/ accessed August 20 2020.

24. Kullgren JT, Cliff EQ, Krenz C, et al. Use of health savings accounts among US adults enrolled in high-deductible health plans. JAMA Network Open. 2020;3(7):e2011014.

25. Fronstin P, Roebuck MC. Persistency in high-cost health care claims: "It's where the spending is, stupid." EBRI Issue Brief, no. 493. Employee Benefit Research Institute, October 24, 2019. [Available from: https://www.ebri.org/crawler/view/persistency-in-high-cost-health-care-claims-it-s-where-the-spending-is-stupid]

26. Wharam JF, Ross-Degnan D, Rosenthal MB. The ACA and high-deductible insurance--strategies for sharpening a blunt instrument. N Engl J Med 2013;369(16):1481-4. doi: 10.1056/NEJMp1309490

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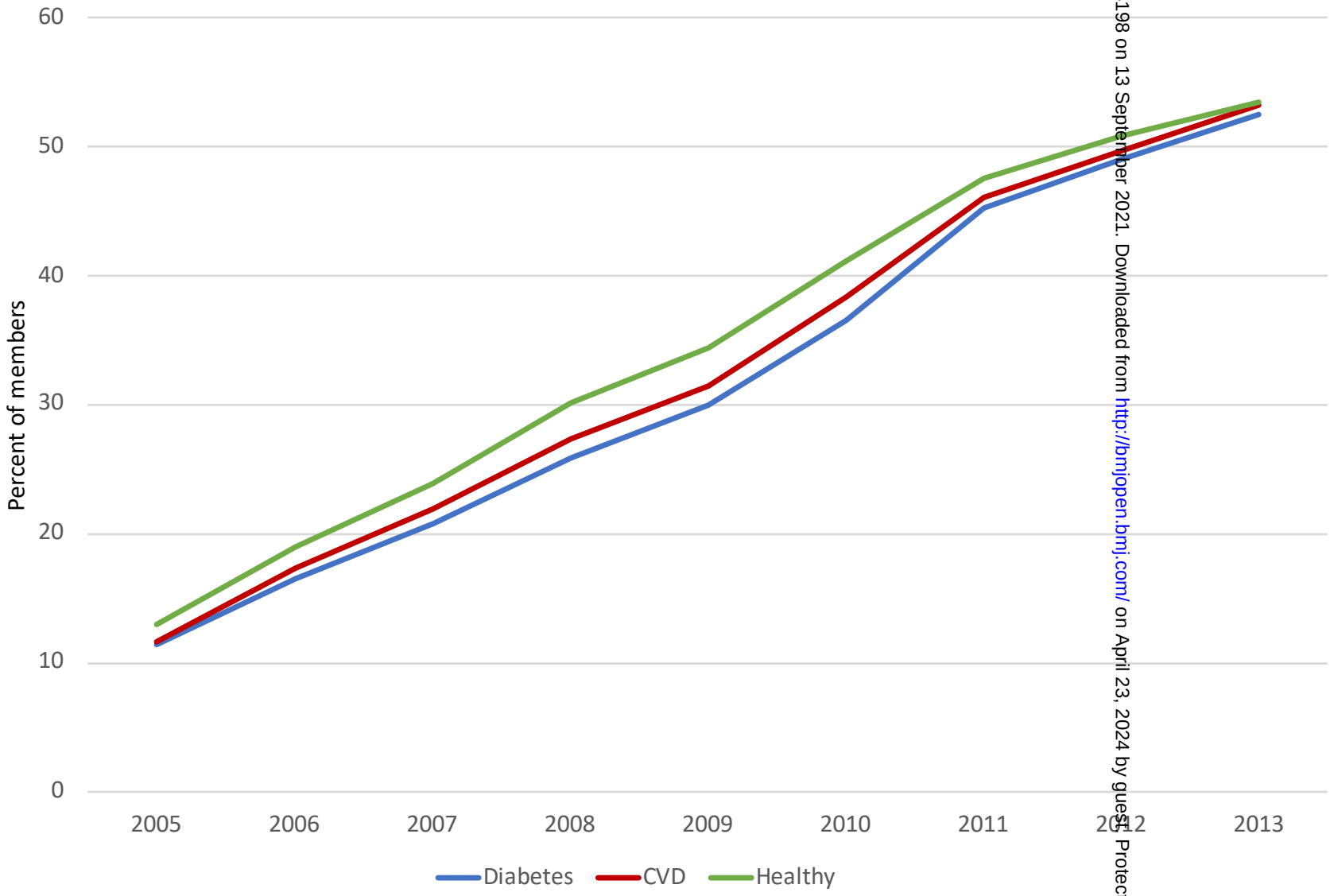
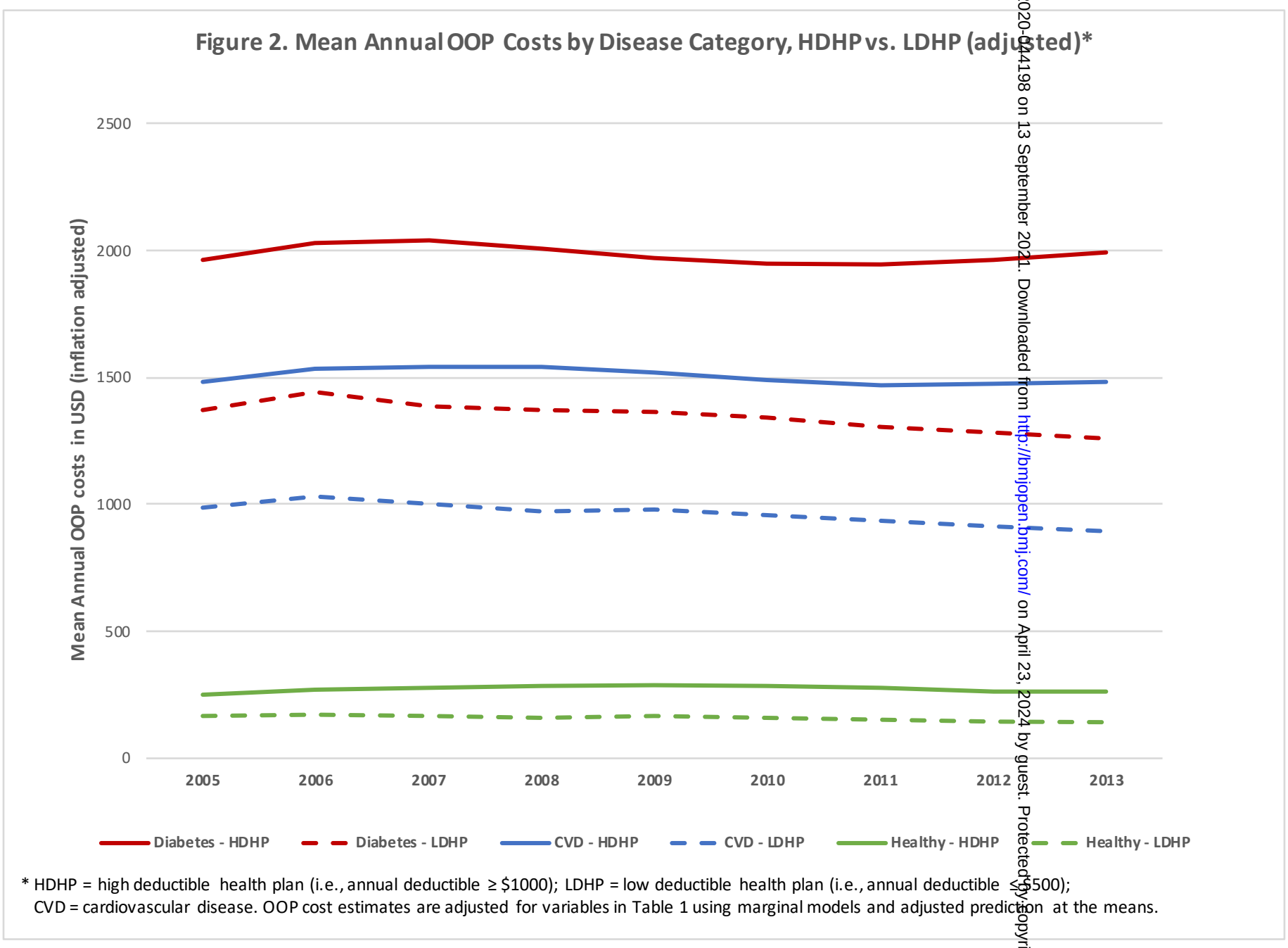
Figure 1. Percentage of Members Enrolled in a HDHP, by Disease Category (adjusted)*



*The denominator includes all members, not just those in high deductible or low deductible plans (i.e., includes members with deductibles of $501-$999). Estimates are adjusted for variables in Table 1 using marginal models and average adjusted predictions.



* HDHP = high deductible health plan (i.e., annual deductible ≥ $1000); LDHP = low deductible health plan (i.e., annual deductible < $1500); CVD = cardiovascular disease. OOP cost estimates are adjusted for variables in Table 1 using marginal models and adjusted prediction at the means.

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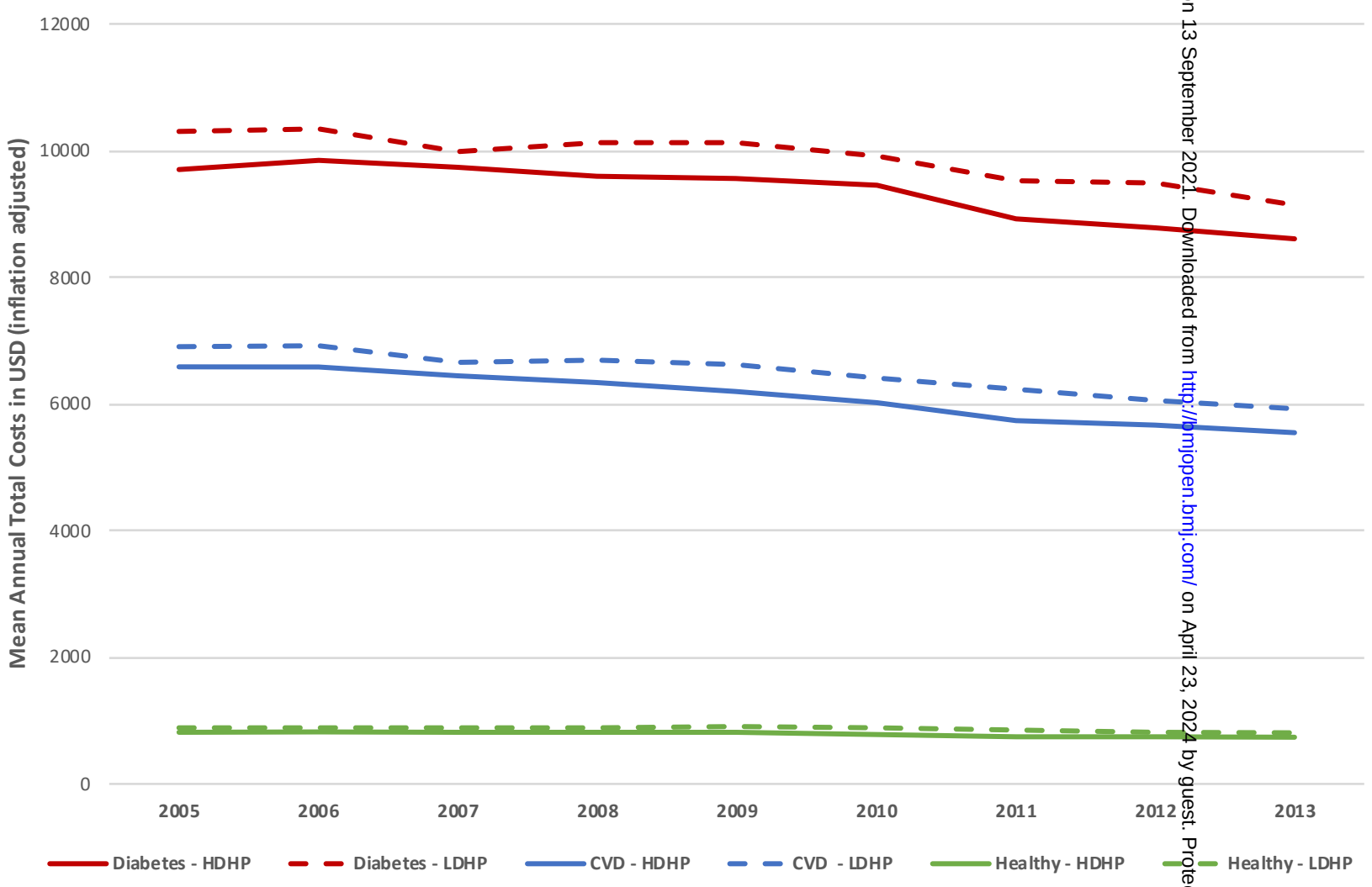
Figure 3. Mean Annual Total Costs by Disease Category: HDHP vs. LDHP (adjusted)*



* HDHP = high deductible health plan (i.e., annual deductible ≥ $1000); LDHP = low deductible health plan (i.e., annual deductible ≤ $500); CVD = cardiovascular disease. Total cost estimates are adjusted for variables in Table 1 using marginal models and adjusted prediction at the means.

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Appendix 1: Deductible Level Imputation

To determine employer deductible levels, we used a benefits type variable that we had for most smaller employers (with approximately 100 or fewer employees). For larger employers, we took advantage of the fact that health insurance claims data are the most accurate source for assessing out-of-pocket obligations among patients who utilize health services. Our claims data contained an in-network/out-of-network individual deductible payment field. For patients who use expensive or frequent services, the sum of their yearly deductible payments adds up to clearly identifiable exact amounts such as $500.00, $1000.00, $2000.00, etc. When even several members have these same amounts, it provides strong evidence that the employer offered such an annual deductible level. It is also possible to detect employers that offer choices of deductible levels when multiple employees have deductibles at two or more levels, such as 20 employees with an exact annual amount of $1000.00 and 12 employees with $500.00. For employer accounts with at least 10 enrollees, we therefore summed each member's in-network (individual-level) deductible payments and number of claims over the enrollment year and assessed other key characteristics such as percentage with Health Savings Accounts. We randomly selected half of the employer account data set that contained both our calculated employer characteristics (independent variables, below) and actual annual deductible levels from the benefits table (dependent variable, after categorization; below). We then used a multinomial logistic model that predicted the 4-level outcome of individual-level deductible ≤$500/$501-$999/$1000-$2499/≥$2500 (again, dependent variable) based on multiple aggregate employer characteristics (independent variables) such as the percentage with Health Savings Accounts and Health Reimbursement Arrangements, the deductible payment per employer in the 75 percentile of payments, the percentage of employees reaching exact deductible levels or with deductible payments but not reaching an exact deductible level, the employer account size, the percentage of enrollees per account with summed whole dollar annual deductible amounts (from claims data) between $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, ≥$2500, etc.

The statistical model was as follows:

$$\text{Logit}(\Pr=Y_i) = \beta_0 + \sum \beta_k X_{ki}$$

Where:

Y_i = dependent variable (4-level deductible category)
X_{ki}= k^{th} characteristics for i^{th} employer
$\beta_{0=}$ intercept
$\beta_{k=}$ coefficient for k^{th} characteristic

The SAS code we used to implement this model was:

```
proc logistic data=csn_impute_PLUS_to_be_imputed descending;
class
        d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat d_wusd1perc_500_1000_cat
        d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat
        d_wusd2perc_0_100_cat d_wusd2perc_100_500_cat d_wusd2perc_500_1000_cat
        d_wusd2perc_1000_2500_cat d_wusd2perc_ge2500_cat
        d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat d_wusd3perc_500_1000_cat
        d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat
        d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat d_wusd4perc_500_1000_cat
        d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat;

model real_dduct_cat =
        pyr sampletot hsa_cnt_over_total cdhp_cnt_over_total perc_grp2 perc_grp3 perc_grp4
        perc_grp5 d_wusd1perc_0_100_cat d_wusd1perc_100_500_cat d_wusd1perc_500_1000_cat
        d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat d_wusd2perc_0_100_cat
        d_wusd2perc_100_500_cat d_wusd2perc_500_1000_cat d_wusd2perc_1000_2500_cat
        d_wusd2perc_ge2500_cat d_wusd3perc_0_100_cat d_wusd3perc_100_500_cat
        d_wusd3perc_500_1000_cat d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat
```

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```
        d_wusd4perc_0_100_cat d_wusd4perc_100_500_cat d_wusd4perc_500_1000_cat
        d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat
        p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct p75_1000_2500_dduct
        p75_gt2500_dduct
output out=prob_of_dduct_cat&IOS. p=p_dduct_cat predprobs=i;
run;
```

Further explanation of this code is below. Note that all values described are calculated over the benefit year per employer account, and a given employer account could be present for multiple years.

- csn_impute_PLUS_to_be_imputed = name of dataset that contains, at the employer account and benefit year level, accounts with missing deductible levels as well as a random half of the accounts that have actual deductible levels. The other random half is also present in the dataset but with actual deductible levels "hidden" so that they can later be used to validate the predictive algorithm.
- real_dduct_cat = dependent variable; category of actual deductible level from the gold standard source (<=$500, $500-$999, $1000-$2499, ≥$2500)
- pyr = benefit year of account's information and tied to the calendar year. An employer could have multiple benefit years represented in separate records per account-benefit year.
- sampletot = total enrollees per account during the benefit year
- hsa_cnt_over_total = percent of members per account listed as having a health savings account
- cdhp_cnt_over_total = percent of members per account listed as having a health savings account or health reimbursement arrangement
- perc_grp1. Percentage of enrollees per employer-year who have claims but $0 deductible amounts for all annual claims.
- perc_grp2. Percentage of enrollees per employer-year who have reached their annual deductible, evidenced by the sum of their deductible payments ending in $*0.00. Members must have at least one month after the month of the $*0.00 summation where the deductible field is blank, and all subsequent months must have blank deductible fields, indicating that the member reached his or her annual deductible amount.
- perc_grp3. Percentage of enrollees per employer-year who have an annual deductible amount that does not end in $*0.00.
- perc_grp4. Percentage of enrollees per employer-year who have enrollment during the benefit year where all months show no evidence of utilization (no health insurance claims).
- perc_grp5. Percentage of enrollees per employer-year who might have reached their deductible, as evidenced by having the last month of enrollment of the benefit year with a summed annual deductible amount that ends in $*0.00.
- d_wusd1perc_0_100_cat, d_wusd1perc_100_500_cat, d_wusd1perc_500_1000_cat, d_wusd1perc_1000_2500_cat d_wusd1perc_ge2500_cat. Category of percentage of enrollees with an employer's most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd2perc_0_100_cat, d_wusd2perc_100_500_cat, d_wusd2perc_500_1000_cat, d_wusd2perc_1000_2500_cat d_wusd2perc_ge2500_cat. Category of percentage of enrollees with an employer's second most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- d_wusd3perc_0_100_cat, d_wusd3perc_100_500_cat, d_wusd3perc_500_1000_cat, d_wusd3perc_1000_2500_cat d_wusd3perc_ge2500_cat. Category of percentage of enrollees with an employer's third most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.

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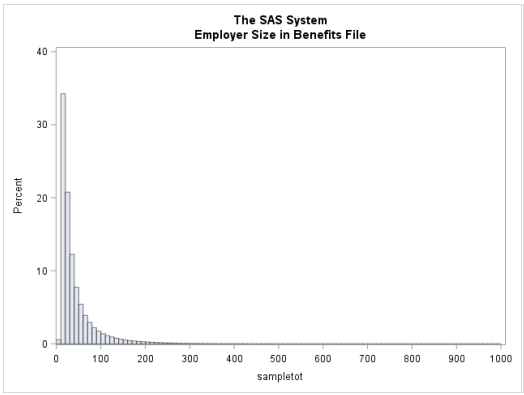
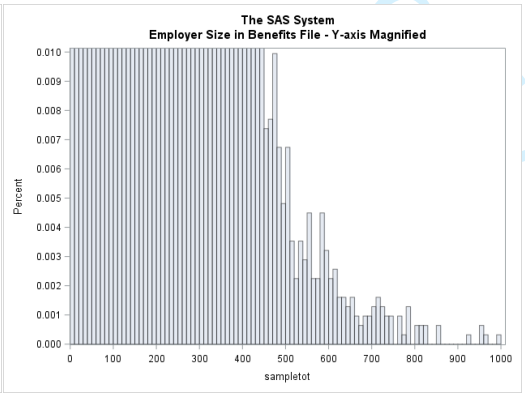
- d_wusd4perc_0_100_cat, d_wusd4perc_100_500_cat, d_wusd4perc_500_1000_cat, d_wusd4perc_1000_2500_cat d_wusd4perc_ge2500_cat. Category of percentage of enrollees with an employer's fourth most common whole number annual individual deductible payment total (e.g. dollar amount ending in 0.00) per employee that is $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.
- p75_0_100_dduct p75_100_500_dduct p75_500_1000_dduct p75_1000_2500_dduct p75_gt2500_dduct. Category of 75th percentile of deductible payments per employer benefit year, categorized as $0 to <$100, ≥$100 to ≤$500, >$500 to <$1000, ≥$1000 to <$2500, and ≥$2500, respectively.

This predictive model outputs the probability that employers had deductibles in the four categories (summing to 1.0) and we assigned the employer to the level that had the highest probability. We overwrote this assignment with the most common whole number deductible amount per year if it was not zero, and with the second most common whole number deductible amount if the most common amount was zero and at least 10 members had the value of the second most common whole number deductible amount. If an employer had members with both enrollment and evidence of utilization, but never had any amounts in the deductible field, we assigned that employer to <$500 deductible level. If an employer had only members that reached a whole number annual deductible amount such as $1000.00 or $2000.00, we assigned the most common deductible amount as the employer's deductible if that amount was greater than or equal to $1000 and to the 95% percentile value if that number was less than $1000. If at least 99% of employees had Health Savings Accounts or Health Reimbursement Arrangements, we also overwrote any previous assignment to classify the employer as a high-deductible employer. We assigned employers to have a choice between deductible levels of $1000 to $2499 and ≥$2500 when both were common and one accounted for at least 85% of $1000-$2499 or ≥$2500 deductible levels reached per employer. If we detected employers that had sufficient enrollees with whole number deductible levels both above and below $1000 (e.g. $250.00 and $1500.00), we assigned the employers' category as "choice," applying a similar 85% rule. Finally, for any employer that had gold standard deductible level information in our benefits file, we overwrote any previous imputed deductible level.

Our file that contains actual deductible amounts per employer covers the "small employer" segment of the insurer's business, a segment that generally includes employers with fewer than 100 or so enrollees. However, it does include a modest number of employers with more than 100 enrollees, even up to approximately 1000 enrollees. The histograms below, where the x-axis represents employer size and the y-axis shows the percentage of employers that are that size, demonstrate the distribution of employer sizes. The second plot "magnifies" the y-axis to demonstrate the smaller number of large employers.





To demonstrate the robustness of our imputation algorithm, and its predictive value as employer size increases (given that we do not have benefits information on most large employers), we took advantage of the fact that although this file mostly covers employers with 100 enrollees or fewer, there is some overlap with larger employers (i.e., those with ~100 to 1000 enrollees). A random half of our imputation sample had the actual deductible levels of employers of all sizes "hidden" from the imputation. Thus, this random half included a modest number of employers with 75 to 1000 enrollees. We tested the sensitivity and specificity of the imputation in this overlap zone, categorizing employer sizes as 75-100, 101-400, 401-700, and 701-1000 enrollees (Exhibit 1). At employers with 75-100 enrollees, we found sensitivity of 95.4% and specificity of

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98.3% (Exhibit 1a). Sensitivity and specificity increased across employer size to 100%, and Exhibits 1b-1d display these for employers of sizes 101-400, 401-700, and 701-1000.

We used an employer ID and an algorithm that determined linked employer subaccounts to identify an employer's subaccounts per benefit year, and removed benefit years when employers offered both low and high deductible levels.

Rationale for High-Deductible Cutoffs: When Health Savings Account-eligible high-deductible health plans came to market in 2005-2006, the Internal Revenue Service set the minimum deductible level for qualifying high-deductible health plans at $1050 (which could be adjusted upward for inflation annually). The range of this minimum deductible during our study period was $1050-$1250. For these reasons, we defined high-deductible health plans as annual individual deductibles of at least $1000 (otherwise some health savings account plans would be excluded). In addition, choosing this cutoff (as opposed to, e.g., $2000) improves the sensitivity and specificity of the imputation because this is common deductible level and more enrollees per employer meet this threshold. This cutoff is also a "real-world" deductible minimum that allows the most generalizable results. It should also be noted that $1000 was the *minimum* annual deductible level we included and not the mean deductible level. We cannot precisely calculate the mean deductible level of the high-deductible health plan group, but we estimate, using the most common non-zero deductible levels per employer account, an approximate mean deductible of $1900. We defined traditional plans as having deductible levels of ≤$500 after determining that a threshold of ≤$250 would lead to an inadequate sample size for the control group. Again, the mean deductible level of the control group members would be lower than $500.

Appendix Exhibit 1. Validation of Deductible Imputation Algorithm, Stratified by Employer Size

Exhibit 1a. Validation of deductible imputation algorithm, using employer accounts of size 75-100 enrollees.

	Gold Standard[a]=high-deductible (n)	**Gold Standard=low-deductible (n)**
We imputed high-deductible	882,588	24,786
We imputed low-deductible	15,612	511,770

	High-deductible	**Low-deductible**
Sensitivity	98.3%	95.4%
Specificity	95.4%	98.3%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

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Exhibit 1b. Validation of deductible imputation algorithm, using employer accounts of size 101-400 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	1,998,885	42,655
We imputed low-deductible	20,302	1,748,826

	High-deductible	Low-deductible
Sensitivity	99.0%	97.6%
Specificity	97.6%	99.0%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

Exhibit 1c. Validation of deductible imputation algorithm, using employer accounts of size 401-700 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	83,393	485
We imputed low-deductible	2,017	122,983

	High-deductible	Low-deductible
Sensitivity	97.6%	99.6%
Specificity	99.6%	97.6%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

Exhibit 1d. Validation of deductible imputation algorithm, using employer accounts of size 701-1000 enrollees.

	Gold Standard[a]=high-deductible (n)	Gold Standard=low-deductible (n)
We imputed high-deductible	9950	0
We imputed low-deductible	0	19,664

	High-deductible	Low-deductible
Sensitivity	100.0%	100.0%
Specificity	100.0%	100.0%

[a]Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer via the data vendor.

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Appendix 2: Definition of Covariates

Comorbidity score: We used version 11.1 of the Johns Hopkins ACG® System[1,2] to calculate members' baseline period morbidity score. The algorithm uses age, gender, and ICD-9-CM codes to calculate a morbidity score and the average of the reference population is 1.0.[2] Researchers have validated the index against premature mortality.[1]

Demographic characteristics: To derive proxy demographic measures, the data vendor linked members' most recent residential street addresses to their 2010 US Census tract.[3] Census-based measures of socioeconomic status have been validated [4,5] and used in multiple studies to examine the impact of policy changes on disadvantaged populations.[6-8] Using 2008-2012 American Community Survey[9] census tract-level data and validated cut-points,[4,5] we created categories that defined residence in neighborhoods with below-poverty levels of <5%, 5%-9.9%, 10%-19.9%, and ≥20%. Similarly, we defined categories of residence in neighborhoods with below-high-school education levels of <15%, 15%-24.9%, 25%-39.9%, ≥40%.[4,5] We classified members as from predominantly white, black, or Hispanic neighborhoods if they lived in a census tract with at least 75% of members of the respective race/ethnicity. We then applied a superseding ethnicity assignment using flags created by the E-Tech system (Ethnic Technologies), which analyzes full names and geographic locations of individuals.[10] We classified remaining members as from mixed race/ethnicity neighborhoods. This validated approach of combining surname analysis and census data has positive and negative predictive values of approximately 80 and 90 percent, respectively.[11]

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References:

1. Reid RJ, Roos NP, MacWilliam L, Frohlich N, Black C. Assessing population health care need using a claims-based ACG morbidity measure: a validation analysis in the Province of Manitoba. *Health services research.* 2002;37(5):1345-1364.
2. ACG. The Johns Hopkins ACG System. https://www.hopkinsacg.org/advantage/. Accessed 2 June, 2018.
3. USCensus. Census 2000 Gateway. 2000; https://www.census.gov/main/www/cen2000.html. Accessed 2 June, 2018.
4. Krieger N. Overcoming the absence of socioeconomic data in medical records: validation and application of a census-based methodology. *American Journal of Public Health.* 1992;82(5):703-710.
5. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures--the public health disparities geocoding project. *American Journal of Public Health.* 2003;93(10):1655-1671.
6. Trivedi AN, Zaslavsky AM, Schneider EC, Ayanian JZ. Relationship between quality of care and racial disparities in Medicare health plans. *Jama.* 2006;296(16):1998-2004.
7. Trivedi AN, Rakowski W, Ayanian JZ. Effect of cost sharing on screening mammography in medicare health plans. *The New England journal of medicine.* 2008;358(4):375-383.
8. Selby JV, Fireman BH, Swain BE. Effect of a copayment on use of the emergency department in a health maintenance organization. *New England Journal of Medicine.* 1996;334(10):635-641.
9. American Community Survey. https://www.census.gov/programs-surveys/acs/. Accessed 28 September, 2017.
10. Ethnic Technologies. Frequently Asked Questions. www.ethnictechnologies.com/faq. Accessed 24 October, 2018.
11. Fiscella K, Fremont AM. Use of geocoding and surname analysis to estimate race and ethnicity. *Health services research.* 2006;41(4 Pt 1):1482-1500.

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Appendix 3. Demographic and Employer Characteristics for Members in High Deductible Health Plans and Low Deductible Health Plans, by Disease Category

	Healthy (no cardiovascular disease or diabetes; ACG score ≤1) n=40,901,861 HDHP or LDHP member years, 18,197,003 members, 17,621,767 w/ LDHP or HDHP *				Diabetes n=2,594,613 HDHP or LDHP member years, 1,213,654 members, 1,167,709 w/HDHP or LDHP *				Cardiovascular Disease (no diabetes) n=9,409.979 HDHP or LDHP member years, 4,501,418 members, 4,341,894 w/HDHP or LDHP *			
	HDHP	HDHP %	Low Deductible	Low Deductible %	HDHP	HDHP %	Low Deductible	Low Deductible %	HDHP	HDHP %	Low Deductible	Low Deductible %
Sample Size	15,194,328		25,707,533		891,434		1,703,179		3,262,388		6,147,591	
Female	7,233,322	47.61	12,470,162	48.52	428,005	48.01	830,577	48.78	1,539,370	47.19	2,961,387	48.18
Gender unknown	802	0.01	4,272	0.02	13	0.00	432	0.03	83	0.00	1,164	0.02
No. (%) by age category												
Age 0 le 10	2,624,478	17.27	5,150,580	20.04	3,351	0.38	7,528	0.44	20,685	0.63	37,995	0.62
Age 11 to 20	3,019,754	19.87	5,524,374	21.49	18,420	2.07	35,128	2.06	45,983	1.41	84,679	1.38
Age 21 to 30	2,406,352	15.84	3,806,372	14.81	39,198	4.40	72,079	4.23	103,046	3.16	191,543	3.12
Age 31 to 40	2,648,264	17.43	4,464,680	17.37	103,287	11.59	200,104	11.75	375,710	11.52	745,081	12.12
Age 41 to 50	2,575,536	16.95	4,084,100	15.89	224,167	25.15	415,419	24.39	924,684	28.34	1,775,706	28.88
Age 51 to 60	1,617,095	10.64	2,278,281	8.86	362,355	40.65	697,277	40.94	1,336,975	40.98	2,478,107	40.31
Age 61 to 64	302,849	1.99	399,146	1.55	140,656	15.78	275,644	16.18	455,305	13.96	834,480	13.57
Mean Age (std)	29	16.89	27	16.78	50	11.18	50	11.25	50	10.59	50	10.56
No. (%) living in neighborhoods with below- poverty levels of												
Missing**	492,227	3.24	50,154	0.20	998	0.11	1,765	0.10	2,672	0.08	5,251	0.09
<5%[1]	3,881,960	25.55	7,685,399	29.90	163,434	18.33	370,023	21.73	777,528	23.83	1,666,823	27.11
5%-9.9%[1]	4,084,101	26.88	7,178,347	27.92	217,209	24.37	434,544	25.51	877,539	26.90	1,706,679	27.76
10%-19.9%[2]	4,309,548	28.36	6,957,116	27.06	296,413	33.25	530,286	31.14	1,014,449	31.10	1,774,930	28.87
>=20%3[2]	2,426,492	15.97	3,836,517	14.92	213,380	23.94	366,561	21.52	590,200	18.09	993,908	16.17
No. (%) living in neighborhoods with below-high-school education levels of												
Missing**	491,958	3.24	49,592	0.19	981	0.11	1,745	0.10	2,644	0.08	5,162	0.08
<15%[3]	10,938,154	71.99	19,475,329	75.76	559,322	62.74	1,120,672	65.80	2,311,519	70.85	4,501,490	73.22
15%-24.9%[3]	2,450,320	16.13	4,031,833	15.68	207,641	23.29	365,446	21.46	635,454	19.48	1,101,518	17.92
25%-39.9%[4]	1,033,470	6.80	1,710,228	6.65	97,651	10.95	172,925	10.15	262,115	8.03	452,423	7.36
>=40%[4]	280,426	1.85	440,551	1.71	25,839	2.90	42,391	2.49	50,656	1.55	86,998	1.42
Race/ethnicity, No. (%)[5]												
Missing**	486,320	3.20	40,819	0.16	691	0.08	1,214	0.07	2,178	0.07	3,968	0.06
Hispanic	1,522,483	10.02	2,829,806	11.01	104,893	11.77	200,538	11.77	230,962	7.08	496,619	8.08
Asian	576,755	3.80	1,364,478	5.31	25,916	2.91	66,025	3.88	72,703	2.23	185,792	3.02
Black neighborhood	258,600	1.70	616,188	2.40	29,938	3.36	75,519	4.43	77,462	2.37	190,978	3.11
Mixed neighborhood	2,934,347	19.31	5,584,177	21.72	217,099	24.35	435,009	25.54	730,505	22.39	1,434,429	23.33
White neighborhood	9,415,823	61.97	15,272,065	59.41	512,897	57.54	924,874	54.30	2,148,578	65.86	3,835,805	62.40
Region												
Missing**	490,854	3.23	46,495	0.18	927	0.10	1,532	0.09	2,403	0.07	4,501	0.07
Midwest	4,644,238	30.57	6,937,470	26.99	253,345	28.42	440,965	25.89	953,302	29.22	1,596,631	25.97
Northeast	916,550	6.03	3,192,642	12.42	45,274	5.08	166,038	9.75	184,088	5.64	705,135	11.47
South	6,762,146	44.50	11,174,002	43.47	489,678	54.93	865,579	50.82	1,734,814	53.18	2,994,215	48.71
West	2,380,540	15.67	4,356,924	16.95	102,210	11.47	229,065	13.45	387,781	11.89	847,109	13.78
Median Household Income	66,322	29,600.99	70,859	32,504.73	57,895	25,590.10	61,579	27,965.45	63,516	28,840.57	67,274	30,794.96
Mean Patient ACG	0	0.24	0	0.24	2	2.77	2	2.88	1	2.09	2	2.14
Mean Count Patids	15,897	49,851.85	12,979	32,881.27	18,602	62,964.34	15,192	40,784.14	16,862	58,759.71	14,427	38,373.68
Employer insurance type												
Self-insured	5,511,420	36.27	14,828,244	57.68	299,461	33.59	1,008,395	59.21	1,050,211	32.19	3,575,544	58.16
Fully-insured	9,682,908	63.73	10,879,289	42.32	591,973	66.41	694,784	40.79	2,212,177	67.81	2,572,047	41.84
Employersizecategory												
1000+members	4,584,599	30.17	14,054,462	54.67	236,972	26.58	940,438	55.22	866,806	26.57	3,356,707	54.60
100-999 members	4,913,017	32.33	7,739,251	30.10	298,015	33.43	519,265	30.49	1,054,269	32.32	1,860,104	30.26
10-99 members	5,696,712	37.49	3,913,820	15.22	356,447	39.99	243,476	14.30	1,341,313	41.11	930,780	15.14
Year												
2005	662,755	4.36	4,012,258	15.61	29,130	3.27	212,386	12.47	119,494	3.66	852,827	13.87
2006	969,258	6.38	3,649,884	14.20	46,555	5.22	217,735	12.78	188,338	5.77	834,234	13.57
2007	1,258,017	8.28	3,449,312	13.42	64,057	7.19	225,193	13.22	253,210	7.76	819,673	13.33
2008	1,549,752	10.20	3,204,539	12.47	81,846	9.18	224,104	13.16	319,536	9.79	800,941	13.03
2009	1,730,518	11.39	3,025,704	11.77	95,501	10.71	222,092	13.04	366,645	11.24	778,295	12.66
2010	1,943,724	12.79	2,407,596	9.37	114,999	12.90	173,510	10.19	425,688	13.05	605,860	9.86
2011	2,246,518	14.79	2,208,391	8.59	144,185	16.17	161,072	9.46	507,368	15.55	555,400	9.03
2012	2,369,611	15.60	1,933,232	7.52	152,915	17.15	137,548	8.08	531,926	16.30	468,358	7.62
2013	2,464,175	16.22	1,816,617	7.07	162,246	18.20	129,539	7.61	550,183	16.86	432,003	7.03

* Denominator for each disease category is member-years. The denominator includes just HDHP (i.e., deductible ≥$1000) or low-deductible (i.e., deductible ≤ $500) members in the respective columns; this analysis excludes members with deductibles of $501-$999.

** The neighborhood-level demographic and socioeconomic variables are based on a member's residential address; missingness means that a member did not have a stable address during the study period. Missingness was slightly higher in the healthy HDHP cohort

Appendix 4a. Percentage of Members Enrolled in a HDHP by HDHP Type (i.e. HSA, HRA or non-account HDHP) by Disease Category (unadjusted)
(Note: denominator of each line is all members in the disease cohort, i.e., diabetes, cardiovascular disease, or healthy)

DM

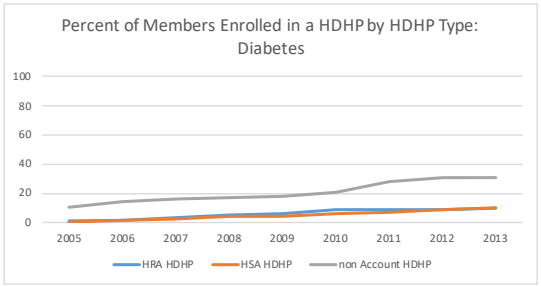
	HRA HDHP	HSA HDHP	non Account HI	LDHP	(choice, other, 500-999)
2005	1.113559535	0.267838664	10.43191014	86.07076622	2.115925443
2006	1.632677119	1.69346045	13.81107804	80.11022044	2.752563951
2007	3.054379004	2.648915637	15.74839825	75.3823419	3.165965204
2008	4.791947238	3.94425495	16.99663944	70.43901272	3.82814565
2009	6.000570083	4.617969606	18.00921134	66.57425327	4.797995709
2010	8.521426928	5.685492172	20.57566327	52.46509572	12.75232191
2011	8.931959555	6.783930158	27.52960108	48.28968225	8.464826957
2012	8.74638017	8.345438314	30.40781603	42.70699518	9.793370307
2013	9.778268229	10.03419651	30.66432248	40.29950778	9.223705006

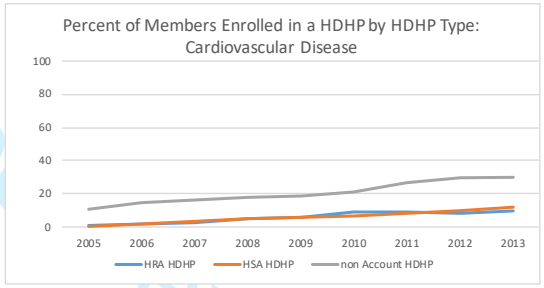
CVD

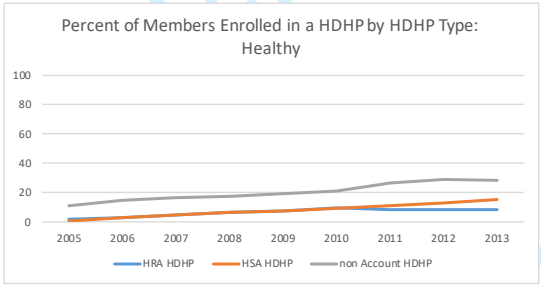
	1	2	3	4	5
2005	0.951260975	0.367706705	10.7136775	85.85120223	2.116152593
2006	1.4956943	2.16200494	14.29072773	79.47807097	2.573502065
2007	2.96171277	3.49198404	16.41103297	73.99330678	3.14196344
2008	4.959011071	4.923660215	17.58477109	68.82854491	3.704012709
2009	6.167859521	5.712716378	18.60927097	64.71920772	4.790945406
2010	8.806415359	7.015638556	20.75481595	52.04749265	11.37563749
2011	8.697616509	8.280659867	27.07542145	48.20302026	7.743281907
2012	8.539476476	10.19013956	29.6701315	42.59264488	9.007607586
2013	9.707545471	11.94801389	29.61642232	40.24621168	8.481806635

Healthy

	1	2	3	4	5
2005	1.773352076	0.542475333	10.99279527	84.52727843	2.164098894
2006	2.469559683	2.800287949	14.54157748	77.53379291	2.654781977
2007	4.220184248	4.308501093	16.5708293	71.4730366	3.427448759
2008	6.681771489	6.138596724	17.87138493	65.63856668	3.66968018
2009	7.148442203	7.601080094	19.16351836	61.31063775	4.776321595
2010	9.577953146	9.276929577	21.06226145	51.06043263	9.022423197
2011	8.714846333	10.85871908	26.94795415	46.84422153	6.634258909
2012	7.905851237	13.23606857	28.96155781	41.85266474	8.043857639
2013	8.443297075	15.2556489	28.56331353	39.46079551	8.276944986







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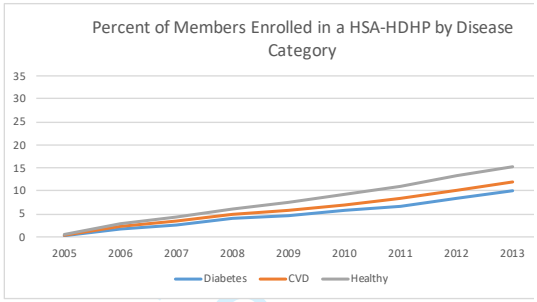
Appendix 4b. Percentage of Members Enrolled in a HSA, HRA or non-account HDHP by Disease Category (unadjusted)
(Note: demonimator of each line is all members in the disease cohort, i.e., diabetes, cardiovascular disease, or healthy)

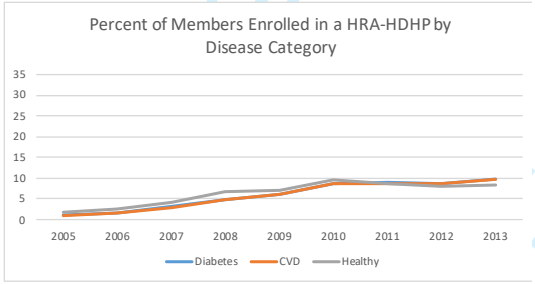
HSA-HDHP

	Diabetes	CVD	Healthy
2005	0.267839	0.367707	0.542475
2006	1.69346	2.162005	2.800288
2007	2.648916	3.491984	4.308501
2008	3.944255	4.92366	6.138597
2009	4.61797	5.712716	7.60108
2010	5.685492	7.015639	9.27693
2011	6.78393	8.28066	10.85872
2012	8.345438	10.19014	13.23607
2013	10.0342	11.94801	15.25565



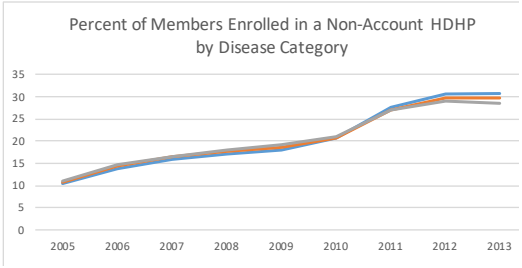
HRA-HDHP

	Diabetes	CVD	Healthy
2005	1.11356	0.951261	1.773352
2006	1.632677	1.495694	2.46956
2007	3.054379	2.961713	4.220184
2008	4.791947	4.959011	6.681771
2009	6.00057	6.16786	7.148442
2010	8.521427	8.806415	9.577953
2011	8.93196	8.697617	8.714846
2012	8.74638	8.539476	7.905851
2013	9.778268	9.707545	8.443297



Non Account-HDHP

	Diabetes	CVD	Healthy
2005	10.43191	10.71368	10.9928
2006	13.81108	14.29073	14.54158
2007	15.7484	16.41103	16.57083
2008	16.99664	17.58477	17.87138
2009	18.00921	18.60927	19.16352
2010	20.57566	20.75482	21.06226
2011	27.5296	27.07542	26.94795
2012	30.40782	29.67013	28.96156
2013	30.66432	29.61642	28.56331



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Appendix 5. Percentage of Members Enrolled in HDHP by Deductible Amount ($1000-$2499 and ≥$2500)

Deductible $1000-2499

	Diabetes	CVD	Healthy
2005	10.91604	11.10743	12.43166
2006	15.45958	16.11428	17.64392
2007	18.2095	19.15216	20.87959
2008	21.16371	22.2593	24.73561
2009	22.60751	23.76169	26.25005
2010	26.45562	27.53338	30.02893
2011	32.77277	32.83255	33.89115
2012	34.3502	34.16569	34.32813
2013	35.05437	34.55724	33.7226

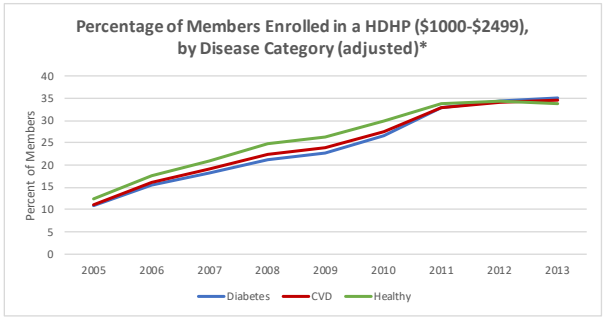
Diabetes	CVD	Healthy
0.1091604	0.1110743	0.1243166
0.1545958	0.1611428	0.1764392
0.182095	0.1915216	0.2087959
0.2116371	0.222593	0.2473561
0.2260751	0.2376169	0.2625005
0.2645562	0.2753338	0.3002893
0.3277277	0.3283255	0.3389115
0.343502	0.3416569	0.3432813
0.3505437	0.3455724	0.337226

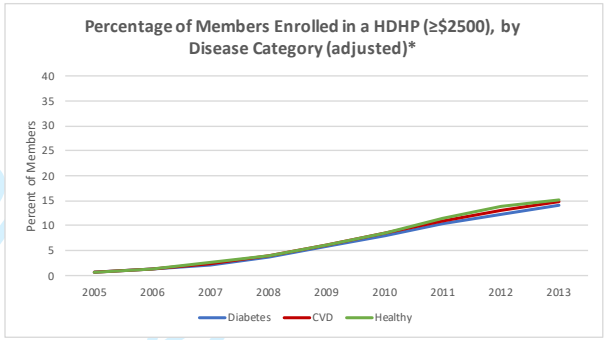
Deductible ≥ $2500

	Diabetes	CVD	Healthy
2005	0.69452	0.68785	0.6662
2006	1.2067	1.26371	1.31815
2007	2.24622	2.40487	2.53268
2008	3.69438	3.97341	4.02361
2009	5.81674	6.12616	6.24586
2010	8.03579	8.44121	8.51678
2011	10.39904	10.94723	11.44764
2012	12.37166	13.09128	13.74244
2013	14.08734	14.80603	15.15463

Diabetes	CVD	Healthy
0.0069452	0.0068785	0.006662
0.012067	0.0126371	0.0131815
0.0224622	0.0240487	0.0253268
0.0369438	0.0397341	0.0402361
0.0581674	0.0612616	0.0624586
0.0803579	0.0844121	0.0851678
0.1039904	0.1094723	0.1144764
0.1237166	0.1309128	0.1374244
0.1408734	0.1480603	0.1515463

*Estimates are adjusted for variables in Table 1.





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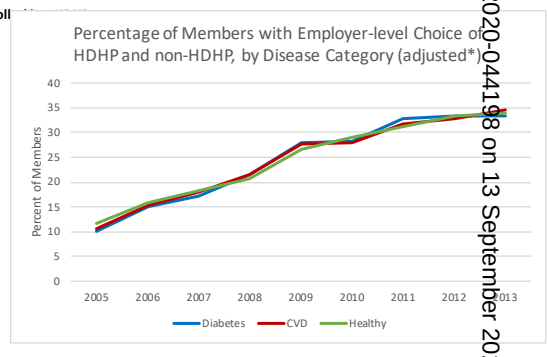
Appendix 6. Percentage of Members with Employer-level Choice of HDHP and non-HDHP and Percentage of Members wit Employer-level Plan Choice that Enroll

Members with Employer-level Plan Choice

	Diabetes	CVD	Healthy
2005	10.08195	10.59967	11.66249
2006	14.98163	15.30981	15.80417
2007	17.22922	17.9922	18.19298
2008	21.58658	21.45532	20.64135
2009	27.99466	27.77114	26.54475
2010	28.21836	27.92916	28.90129
2011	32.83495	31.67371	31.11506
2012	33.25026	32.72252	33.42743
2013	33.34627	34.55724	33.91297

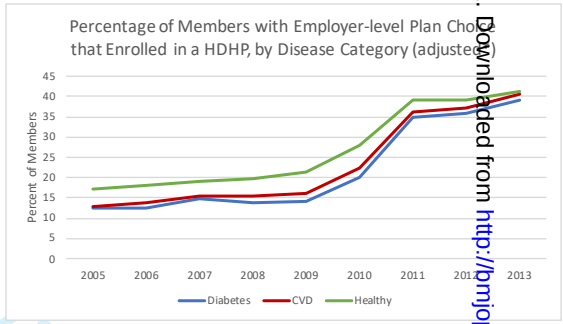
Diabetes	CVD	Healthy
0.1008195	0.1059967	0.1166249
0.1498163	0.1530981	0.1580417
0.1722922	0.179922	0.1819298
0.2158658	0.2145532	0.2064135
0.2799466	0.2777114	0.2654475
0.2821836	0.2792916	0.2890129
0.3283495	0.3167371	0.3111506
0.3325026	0.3272252	0.3342743
0.3334627	0.3455724	0.3391297



HDHP Enrollment

	Diabetes	CVD	Healthy
2005	12.47771	12.84836	17.16191
2006	12.52168	13.68354	18.11788
2007	14.6445	15.28622	19.10159
2008	13.79897	15.45891	19.78912
2009	14.11181	16.1932	21.3451
2010	20.06749	22.40512	27.93875
2011	34.80682	36.11686	39.01214
2012	35.78895	37.22782	39.2702
2013	39.0987	40.57872	41.24586

Diabetes	CVD	Healthy	Healthy vs. Dia	Healthy vs. CVD
0.1247771	0.1284836	0.1716191	0.046842	0.0431355
0.1252168	0.1368354	0.1811788	0.055962	0.0443434
0.146445	0.1528622	0.1910159	0.0445709	0.0381537
0.1379897	0.1545891	0.1978912	0.0599015	0.0433021
0.1411181	0.161932	0.213451	0.0723329	0.051519
0.2006749	0.2240512	0.2793875	0.0787126	0.0553363
0.3480682	0.3611686	0.3901214	0.0420532	0.0289528
0.3578895	0.3722782	0.392702	0.0348125	0.0204238
0.390987	0.4057872	0.4124586	0.0214716	0.0066714
		AVERAGE	0.05073991	0.03687089



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Appendix 7. Mean Annual OOP Costs by Deductible Type by Disease Category

DM

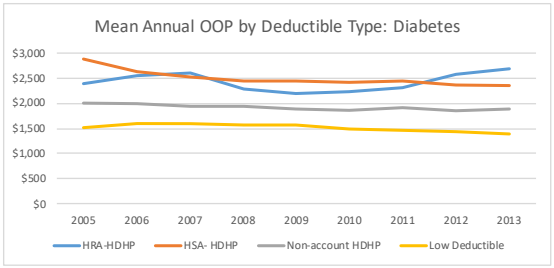
	HRA-HDHP	HSA- HDHP	Non-accou	Low Deduc	HRA minus	HSA minus non-account
2005	2393.916	2881.905	2003.091	1516.98	390.8251	878.814
2006	2559.193	2631.365	1988.599	1595.349	570.594	642.7656
2007	2590.896	2526.562	1938.282	1582.098	652.6135	588.28
2008	2296.826	2436.601	1926.693	1556.628	370.1324	509.9076
2009	2194.634	2431.91	1885.599	1565.047	309.0354	546.3113
2010	2238.621	2420.992	1865.441	1497.35	373.1802	555.5506
2011	2321.375	2440.716	1903.518	1447.1	417.8574	537.1983
2012	2574.192	2373.463	1850.834	1422.535	723.3575	522.6287
2013	2687.706	2353.21	1874.342	1388.097	813.3646	478.8685

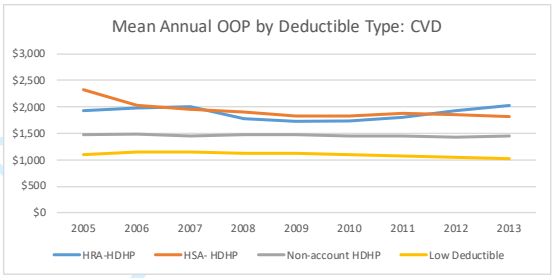
CVD (no DM)

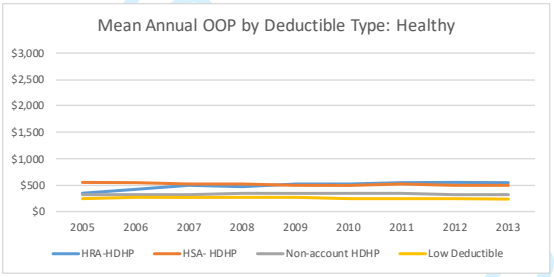
	1	2	3	4	HRA minus	HSA minus non-account
2005	1920.443	2326.151	1479.539	1090.894	440.9041	846.6121
2006	1986.084	2028.731	1485.003	1146.635	501.0815	543.7286
2007	2007.072	1961.689	1450.305	1140.393	556.7679	511.3849
2008	1790.413	1900.173	1474.796	1117.401	315.6174	425.3775
2009	1735.514	1840.534	1483.046	1130.698	252.4678	357.4885
2010	1734.52	1836.894	1459.298	1085.333	275.2217	377.5953
2011	1800.884	1867.053	1460.313	1059.419	340.5712	406.7393
2012	1934.948	1843.689	1427.32	1033.656	507.6274	416.3687
2013	2027.645	1817.272	1444.648	1020.506	582.9969	372.6236

Healthy (no CVD/DM)

	1	2	3	4	HRA minus	HSA minus non-account
2005	347.3469	551.8989	322.074	247.2184	25.2729	229.8249
2006	427.0065	544.3314	330.4697	261.703	96.53675	213.8617
2007	486.1821	533.8033	330.1245	266.8136	156.0576	203.6789
2008	474.593	527.5781	336.9341	257.3514	137.6588	190.644
2009	516.8504	502.2568	343.9218	263.8786	172.9286	158.335
2010	517.5078	494.6837	340.2603	254.0303	177.2475	154.4234
2011	539.9028	511.0485	335.8207	251.1227	204.082	175.2278
2012	552.2777	507.3392	327.0786	241.9559	225.1992	180.2607
2013	551.6646	495.3605	320.5448	235.7487	231.1198	174.8157







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Appendix 8. Mean Annual Total Costs by Deductible Type by Disease Category (unadjusted)

DM

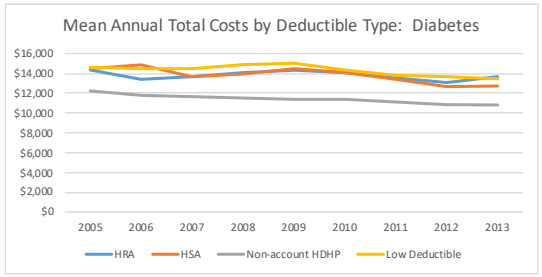
	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	14295.15901	14546.6128	12233.7601	14554.59815	2061.39891	2312.8527
2006	13405.63135	14868.81695	11846.05042	14426.92738	1559.58093	3022.76653
2007	13720.22153	13642.25951	11639.91124	14526.02864	2080.31029	2002.34827
2008	14131.75479	13994.31617	11534.83607	14877.3287	2596.91872	2459.4801
2009	14322.29938	14503.04544	11411.71708	15028.2057	2910.5823	3091.32836
2010	14027.56971	14109.11982	11402.7128	14406.14894	2624.85691	2706.40702
2011	13582.10935	13337.52968	11132.93139	13854.35939	2449.17796	2204.59829
2012	13080.23284	12669.93664	10893.35848	13685.20298	2186.87436	1776.57816
2013	13691.86599	12726.6443	10815.17043	13456.14811	2876.69556	1911.47387

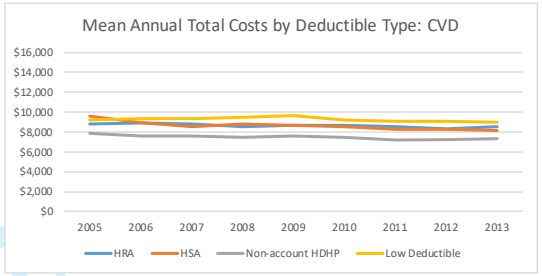
CVD, no DM

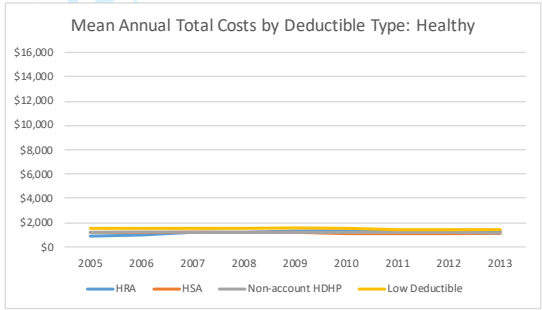
	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	8850.256505	9598.062586	7866.036401	9271.997354	984.220104	1732.026185
2006	8915.313118	8876.553784	7631.195185	9320.588567	1284.117933	1245.358599
2007	8848.853019	8493.630408	7573.834261	9384.138362	1275.018758	919.796147
2008	8580.592785	8784.496764	7512.799245	9526.765184	1067.79354	1271.697519
2009	8720.503012	8711.905936	7616.054761	9658.355955	1104.448251	1095.851175
2010	8648.269763	8540.065897	7448.820658	9277.827305	1199.449105	1091.245239
2011	8573.48888	8220.636208	7255.241166	9070.624837	1318.247714	965.395042
2012	8320.183574	8280.958581	7230.308001	9028.639503	1089.875573	1050.65058
2013	8477.33171	8152.846695	7339.746457	8988.416795	1137.585253	813.100238

Healhty, no CVD, no DM

	HRA	HSA	Non-account HI	Low Deductible	HRA - non-acco	HSA-non-account
2005	886.9861308	1213.842657	1224.830341	1495.335946	-337.84421	-10.987684
2006	1008.234675	1209.061845	1225.083036	1506.232586	-216.848361	-16.021191
2007	1147.217313	1223.599031	1221.549034	1515.32876	-74.331721	2.049997
2008	1199.469737	1217.558335	1201.53683	1530.071192	-2.067093	16.021505
2009	1285.869673	1162.702343	1206.441497	1561.344602	79.428176	-43.739154
2010	1324.598342	1141.728807	1171.974055	1489.797593	152.624287	-30.245248
2011	1275.707557	1111.261067	1156.502128	1466.704303	119.205429	-45.241061
2012	1290.420283	1111.124486	1154.080793	1434.908082	136.33949	-42.956307
2013	1292.016802	1109.158634	1140.75247	1421.652668	151.264332	-31.593836







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Appendix 9. OOP Costs as Share of Total Costs for Members in HDHP vs. Low Deductible Health Plans, by Disease Category (unadjusted)

OOP Costs

DM

	Low Deductibl	HDHP	HDHP-LDHP
2005	1368.324	1959.252	590.928
2006	1441.811	2029.778	587.967
2007	1388.378	2038.749	650.371
2008	1368.538	2006.348	637.81
2009	1362.979	1965.911	602.932
2010	1338.029	1945.981	607.952
2011	1303.13	1943.895	640.765
2012	1284.478	1960.074	675.596
2013	1258.84	1989.25	730.41
Mean	1346.05633	1982.13756	

CVD (no DM)

	0	1	
2005	987.0506	1479.058	492.0074
2006	1030.623	1530.359	499.736
2007	1000.954	1540.841	539.887
2008	975.2969	1537.254	561.9571
2009	976.0373	1515.611	539.5737
2010	954.6136	1486.501	531.8874
2011	933.4627	1468.28	534.8173
2012	911.3351	1473.901	562.5659
2013	893.9074	1485.194	591.2866
Mean	962.586733	1501.88878	

Healthy (no CVD/DM)

	0	1	
2005	166.4346	250.436	84.0014
2006	171.8132	272.3515	100.5383
2007	169.8192	279.7187	109.8995
2008	162.8924	285.4981	122.6057
2009	165.9155	287.9714	122.0559
2010	160.5264	281.4719	120.9455
2011	155.5968	274.167	118.5702
2012	147.853	266.1062	118.2532
2013	142.2151	261.422	119.2069
Mean	160.340689	273.238089	

Relative costs	LDHP	HDHP
vs. DM	8.39497661	7.25425055
vs. CVD	6.00338404	5.49663037

Total Costs

DM

	Low Deductibl	HDHP	HDHP-LDHP
2005	10308.47	9699.435	-609.035
2006	10341.91	9845.497	-496.413
2007	9992.148	9743.071	-249.077
2008	10114.71	9606.592	-508.118
2009	10133.87	9549.384	-584.486
2010	9926.813	9458.704	-468.109
2011	9529.334	8935.642	-593.692
2012	9488.913	8769.875	-719.038
2013	9138.999	8606.055	-532.944
Mean		9357.13944	

CVD, no DM

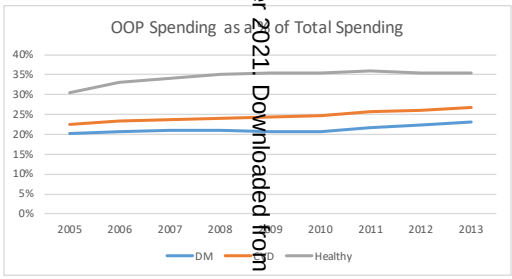
	0	1	
2005	6903.557	6572.213	-331.344
2006	6918.276	6582.855	-335.421
2007	6663.636	6458.677	-204.959
2008	6680.236	6350.276	-329.96
2009	6626.569	6201.896	-424.673
2010	6400.159	6034.349	-365.81
2011	6221.113	5721.829	-499.284
2012	6064.94	5662.128	-402.812
2013	5922.871	5545.22	-377.651
Mean		6125.49367	

Healthy, no CVD, no DM

	0	1	
2005	899.2028	820.705	-78.4978
2006	895.8246	821.0606	-74.764
2007	889.7641	818.8746	-70.8895
2008	892.4623	813.7006	-78.7617
2009	906.1254	811.5594	-94.566
2010	876.4865	796.0561	-80.4304
2011	851.6796	761.3796	-90.3
2012	824.5298	752.7057	-71.8241
2013	807.2234	737.2551	-69.9683
Mean		792.588522	

	HDHP - OOP/T	LDHP - OOP/Total costs
	20.20%	13.27%
	20.62%	13.94%
	20.93%	13.89%
	20.89%	13.53%
	20.59%	13.45%
	20.57%	13.48%
	21.75%	13.67%
	22.35%	13.54%
	23.11%	13.77%
Mean	**21.22%**	**13.62%**
	22.50%	14.30%
	23.25%	14.90%
	23.86%	15.02%
	24.21%	14.60%
	24.44%	14.73%
	24.63%	14.92%
	25.66%	15.00%
	26.03%	15.03%
	26.78%	15.09%
Mean	**24.60%**	**14.84%**
	30.51%	18.51%
	33.17%	19.18%
	34.16%	19.09%
	35.09%	18.25%
	35.48%	18.31%
	35.36%	18.31%
	36.01%	18.27%
	35.35%	17.93%
	35.46%	17.62%
Mean	**34.51%**	**18.39%**

	DM	CVD	Healthy
2005	20.20%	22.56%	30.51%
2006	20.62%	23.25%	33.17%
2007	20.93%	23.86%	34.16%
2008	20.89%	24.21%	35.09%
2009	20.59%	24.44%	35.48%
2010	20.57%	24.63%	35.36%
2011	21.75%	25.66%	36.01%
2012	22.35%	26.03%	35.35%
2013	23.11%	26.78%	35.46%



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Appendix 10. Average ACG score over time by Deductible Type by Disease Category (unadjusted)

DM

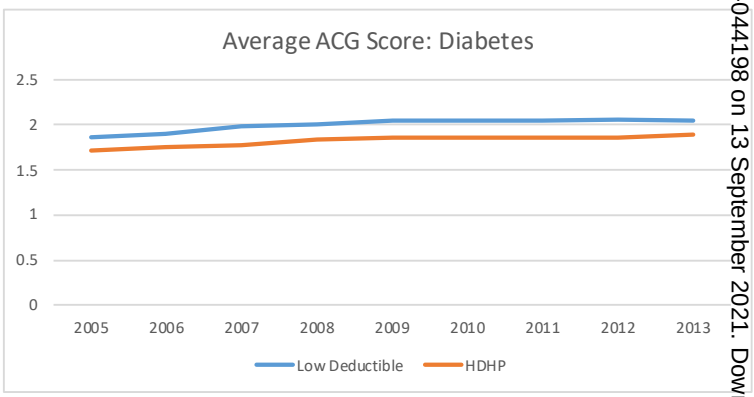
	Low Deductible	HDHP
2005	1.861649017	1.714135177
2006	1.900161553	1.755773667
2007	1.97781806	1.770965478
2008	2.012055696	1.828904806
2009	2.044269382	1.848417882
2010	2.037977855	1.864763712
2011	2.057163586	1.865177058
2012	2.057682309	1.866217048
2013	2.05615462	1.891463564

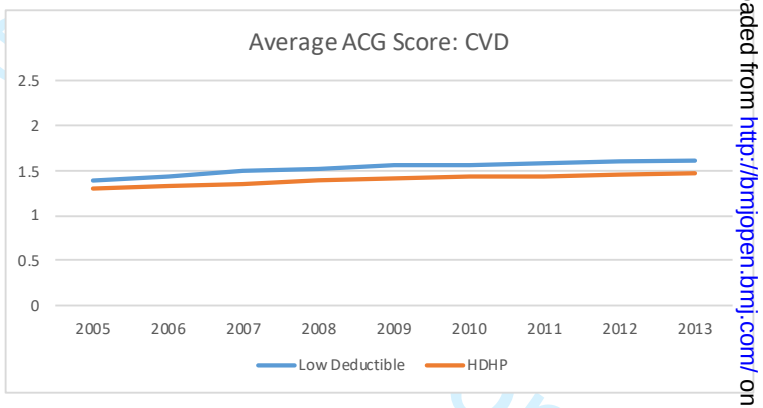
CVD

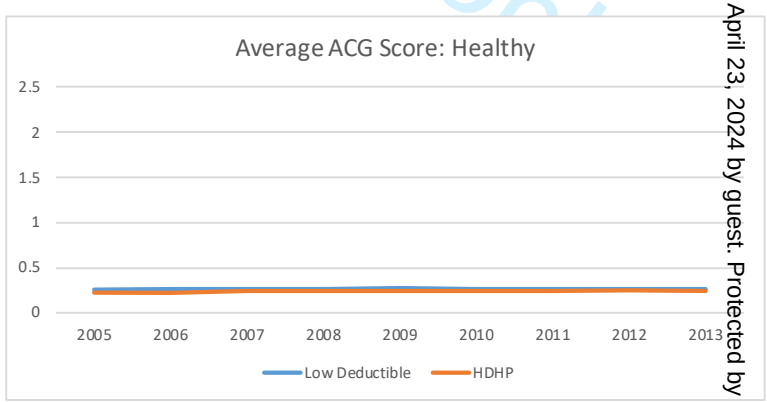
	0	1
2005	1.388339763	1.299303003
2006	1.436105621	1.329121657
2007	1.491629805	1.350587912
2008	1.514304403	1.383810136
2009	1.551069175	1.419532189
2010	1.560214495	1.429574365
2011	1.578042255	1.442374895
2012	1.599309203	1.455452532
2013	1.609740152	1.469366178

Healthy

	0	1
2005	0.255855261	0.22290789
2006	0.263268967	0.229830085
2007	0.267363128	0.235275946
2008	0.269366642	0.238672036
2009	0.273416246	0.242011671
2010	0.268782921	0.244339555
2011	0.27245572	0.246896724
2012	0.271553431	0.248249108
2013	0.271018578	0.248220379







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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	p2 1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	p3 2	Explain the scientific background and rationale for the investigation being reported
Objectives	p3 3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	p4 4	Present key elements of study design early in the paper
Setting	p4 5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	p4 6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	p4/5 7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	p4 8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	p5 9	Describe any efforts to address potential sources of bias
Study size	p4/6 10	Explain how the study size was arrived at
Quantitative variables	p4/5 11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	p5 12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	p6 13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	p6 14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	p6/7 15*	Report numbers of outcome events or summary measures over time
Main results	p6/7 16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

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Other analyses	p7	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	p5	18	Summarise key results with reference to study objectives
Limitations	p8/9	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	p8/9	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	p9	21	Discuss the generalisability (external validity) of the study results
Other information			
Funding	p11	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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