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Obesity-related multimorbidity and risk of cardiovascular disease in the middle-aged population in the United States

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Abstract

To investigate the prevalence of obesity-related multimorbidity (co-occurrence of 2 obesity-related chronic diseases, ORCDs) and the risk of cardiovascular disease in the presence of multimorbidity in middle-aged adults in the United States. National Health and Nutrition Examination Survey data from 2007-2016 were used. Target ORCDs included hypertension (H), diabetes (D), coronary heart disease (C), and stroke (S). Age-standardized prevalence for obesity-related multimorbidity in its combination and permutation was calculated. Risk for cardiovascular disease (C or S) was estimated conditional on demographics, degree of obesity, and presence and duration of pre-existing ORCDs. Analyses were conducted at Washington University in 2019. The analytic sample included 14,243 individuals age 40-79 years, representing a population size of 110,003,550. Age-standardized prevalence for obesity-related multimorbidity was 12.3%. Hypertension was most commonly the first diagnosed ORCD for populations with 2-4 ORCDs, followed by diabetes for populations with 2-3 ORCDs. Compared with no pre-existing hypertension/diabetes/stroke, pre-existing hypertension in combination with diabetes/stroke significantly increased risk of coronary heart disease [H+S (multivariable-adjusted hazard ratio,

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Author contributions

S-H Chang had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. S-H Chang conceived the study concept and designed the study. LM Pollack, M Wang, M Leung, GA Colditz, C Herrick, and S-H Chang analyzed and interpreted the data. LM Pollack, M Wang, and S-H Chang drafted the manuscript. LM Pollack, M Wang, M Leung, GA Colditz, C Herrick, and S-H Chang critically revised the manuscript for important intellectual content. M Wang and S-H Chang provided statistical expertise. GA Colditz and S-H Chang obtained funding. LM Pollack, M Wang, M Leung, GA Colditz, and S-H Chang provided administrative, technical, or material support. S-H Chang supervised the study.

DISCLOSURE

The authors report no conflicts of interest. The study sponsors had no role in the study design; collection, analysis, and interpretation of data; writing of the report; or in the decision to submit the paper for publication. The conclusions and opinions presented herein are solely the responsibility of the authors and do not necessarily represent the official views of the National Institutes of Health, the Agency for Healthcare Research and Quality, or the Foundation for Barnes Jewish Hospital. Part of this work was presented as a poster at the ObesityWeek annual meeting in Las Vegas, NV, 2019. No financial disclosures were reported by the authors of this paper.

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aHR 27.6, 95% CI 10.9-70.2), D+H+S (aHR 20.3, 95% CI 7.9-52.2)]. Compared with no hypertension/diabetes/coronary heart disease, pre-existing hypertension in combination with diabetes/coronary heart disease significantly increased risk of stroke [C+D+H (aHR 32.6, 95% CI 12.2-87.1), C+H (aHR 25.4, 95% CI 12.1-53.6), D+H(aHR5.3, 95% CI 2.6-10.8)]. Obesity-related multimorbidity is prevalent and highly associated with cardiovascular disease development. To reduce the detrimental health impact of multimorbidity, intervention strategies should target preventing increasing multimorbidity and detecting/managing diabetes and hypertension prior to the onset of cardiovascular disease.

Keywords

obesity; multimorbidity; chronic disease

INTRODUCTION

The prevalence of obesity (body mass index, BMI, ≥ 30) remains high today in the United States with an overall age-adjusted prevalence of approximately 38%.¹ Over the most recent decade, age-standardized prevalence of obesity increased among adults aged ≥ 40 years, from 36% in 2007-2008 to 43% in 2015-2016 in adults 40-59 years, and from 35% to 41% in adults 60 years or older.² Research has demonstrated a positive association between obesity and cardiovascular disease,³ type-2 diabetes,⁴ and some cancers.⁵

The high prevalence of obesity in the United States (along with the aging population) may largely account for the increasing prevalence of multimorbidity⁶ (i.e., the coexistence of ≥ 2 chronic diseases)⁷⁻¹⁰ Obesity and multimorbidity not only significantly increase the risk of premature mortality and reduce life expectancy¹¹⁻¹⁴ but also impose a tremendous financial burden on the healthcare system.¹⁵

Despite the growing literature on obesity, obesity-related chronic disease (ORCD), and multimorbidity,^{3,10,16} little is known about the prevalence of obesity-related multimorbidity (i.e., the co-occurrence of ≥ 2 ORCDs) in the U.S., the relationship between ORCDs, and an individual's risk of developing cardiovascular disease in the presence of pre-existing ORCDs and increasing degree of obesity. A better understanding of these relationships is essential to prevent increasing obesity-related multimorbidity and reduce its burden.

Using data representative of the U.S. general population, this study aimed to investigate the (1) prevalence of four ORCDs (coronary heart disease, hypertension, stroke, diabetes); (2) order in which those ORCDs were diagnosed; and (3) risk of an individual developing cardiovascular disease (coronary heart disease or stroke) in the presence of multimorbidity and degree of obesity.

METHODS

Data

This study used 2007-2016 data from the National Health and Nutrition Examination Survey (NHANES) released files, collected by the National Center for Health Statistics.¹⁷ The

NHANES is a complex, multistage, probability-sample-design dataset that combines interviews and physical examinations to assess the health and nutritional status for the U.S. civilian noninstitutionalized population.¹⁷ Trained personnel (including a physician, medical and health technicians, and dietary and health interviewers) travel to different site locations across the U.S. and conduct interviews in the respondents' home or at a mobile examination center.¹⁷ Physical examinations and laboratory tests are conducted at the mobile examination center – a controlled environment where anthropometry and other measurements are conducted under the same conditions, including standing height (cm) and weight (kg), which were used in our analysis to calculate BMI.¹⁸

Demographic, examination (body measures), and questionnaire (blood pressure, diabetes, medical conditions) data files were linked using a unique respondent sequence number to obtain data on age, gender, race/ethnicity, measured weight and height and thus BMI (weight in kilograms divided by the square of height in meters), pregnancy status, self-reported diagnosis of target ORCDs and age of diagnosis, and cancer diagnoses. Because NHANES is a public-use, de-identified dataset, and individuals cannot be identified in the data, including during the linking process, we did not request formal exemption by the Human Research Protections Office at Washington University.

Analytic Sample

Individuals age 40-79 years were included. This age range was targeted, because ORCDs and multimorbidity are more prevalent in middle-aged populations, and individuals age 80 are top-coded at 80 years of age in NHANES.¹⁹ The following exclusion criteria was applied: (i) underweight (BMI <18.5) individuals at the time of examination;¹³ (ii) women pregnant at the time of survey, because BMI fluctuates during pregnancy; (iii) people who reported having ever been diagnosed with any type of cancer, because BMI levels could be unstable due to cancer treatment(s); (iv) individuals who reported age of target disease diagnosis >age at survey because of data error; and (v) individuals who reported age of diabetes diagnosis <age 18 or used insulin to treat diabetes before age 30 in an attempt to exclude individuals with type-1 diabetes,²⁰ because the peak age for diagnosis is mid-teens.²¹

Target ORCDs

The ORCDs included in this study were hypertension (H), diabetes (D), coronary heart disease (C), and stroke (S). They were chosen because they are among the 20 conditions defined as chronic by the U.S. Department of Health and Human Services Interagency Workgroup on Multiple Chronic Conditions and because of their availability in the NHANES.²² They are also the most common chronic conditions for Medicare beneficiaries, who represent approximately one third of our study population.²³

In the questionnaire data files of the NHANES, respondents who answered “Yes” to the following question were classified as having the following ORCDs: “Have you ever been told by a doctor or health professional that you have diabetes/hypertension/coronary heart disease/stroke?” Individuals who reported yes were then asked their age at first diagnosis. Age at first diagnosis for each ORCD was used to inform the order in which ORCDs were

diagnosed. Self-reported diagnosis data were used because the longitudinal order of ORCD diagnosis was one major focus of this study, which cannot be ascertained using measured laboratory data at the time of survey.

Statistical Analyses

Ten years of data were pooled to yield sample sizes large enough to generate reliable estimates for rarer disease combinations and permutations. All data management and analyses followed NHANES analytic guidelines to adjust for complex sampling designs to obtain population-level estimates.^{24,25} All tests were two-sided. An alpha level of 0.05 was used to determine statistical significance. All statistical analyses were performed in 2019 using STATA/SE 11.2 (StataCorp, College Station, TX) and R 3.6.0 (R Core Team, 2019).

Age-standardized disease prevalence by the combination and order of the 4 ORCDs

Direct-standardization methods²⁶ were used to calculate age-standardized prevalence. U.S. Census data from 2000 were used as the standard population in line with recommendations for use of continuous NHANES data.²⁷ Age-specific prevalence from the study population was multiplied by the proportion of people in the standard population, and results were summed over age groups:

$$\text{Age-adjusted prevalence} = \sum_{k=1}^4 p_k \times w_k,$$

where p_k is the prevalence of the disease combination/permutation in the study population and w_k is the proportion of the population in age group k ($K = 1 - 4$ for population age 40-49, 50-59, 60-69, and 70-79, respectively) in the standard population.

Age-standardized prevalence was reported for obesity-related multimorbidity and for all combinations and permutations of ORCDs. For populations with 1 ORCD, age-standardized disease prevalence was reported in the order of disease diagnosis, which was further illustrated by a river plot. The river plot is a type of Sankey/flow diagram. The width of the curves connecting to each disease permutation is proportional to its age-standardized prevalence.

Risk of cardiovascular disease in the presence of multimorbidity and degree of obesity

An exponential time-to-event model was used to estimate the risk of developing cardiovascular disease,¹⁴ with the outcome variable defined as coronary heart disease or stroke. Covariates were selected a priori based on known risk factors for coronary heart disease and stroke and availability of data: age at survey (40-49, 50-59, 60-69, 70-79 years), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), gender, measured BMI at exam categorized as normal weight (BMI 18.5-24.9), overweight (BMI 25.0-29.9), class I obese (BMI 30.0-34.9), class II obese (BMI 35.0-39.9), class III obese (BMI 40.0-), pre-existing ORCD(s), duration of pre-existing ORCDs (if any), and duration squared. Pre-existing ORCD(s) was defined as one of the target ORCDs (except for the outcome disease) diagnosed prior to or in the same year as the year of diagnosis of the outcome variable. The pre-existing ORCDs included in the coronary heart disease model were hypertension,

diabetes, and stroke. The pre-existing ORCDs included in the stroke model were hypertension, diabetes, and coronary heart disease. Duration of pre-existing ORCDs was computed by subtracting age at first diagnosis of an ORCD from age at survey.

Notations and Abbreviations

We used “+” between ORCDs to indicate ORCD combinations. We used the following to indicate the order in which target ORCDs were diagnosed: (1) “>” indicates one of those ORCDs is diagnosed before another ORCD, (2) “=” indicates one of those ORCDs is diagnosed in the same year as another ORCD, and (3) “ ” indicates one of those ORCDs is diagnosed before or in the same year as another ORCD. We used “+” following an ORCD permutation to indicate “at least” the said order. For example, H>D+ indicates at least a diagnosis of diabetes in the following years after a hypertension diagnosis, which includes H>D (a diagnosis of H followed by a diagnosis of D) and H>D (diagnoses of other diseases following the diagnoses of H>D).

RESULTS

Analytic sample and study population

We identified 16,862 individuals age 40-79 years in the NHANES, 2007-2016 (Fig. S1). After applying our exclusion criteria, the analytic sample included 14,243 individuals, representing 110,003,550 individuals in the middle-aged population in the United States. Among the study population, 48.5% was male (Table 1). The majority was non-Hispanic white (68.4%), followed by Hispanic (12.5%), non-Hispanic black (11.6%), and other (7.5%). The largest percentage of individuals were overweight (35.1%), followed by normal weight (24.3%), class I obese (22.8%), class II obese (9.6%), and class III obese (8.1%).

Age-standardized disease prevalence by the combination of the 4 ORCDs

In the study population (N=110,003,550), age-standardized prevalence for obesity-related multimorbidity was 12.3% (Fig. S2): 10.3% for two ORCDs, 1.8% for three ORCDs, and 0.2% for four ORCDs (Fig. 1C-E). Moreover, age-standardized prevalence was 32.1% for one ORCD (Fig. 1B) and 55.6% for no ORCD (Fig. 1A).

Of the population with one ORCD (N=35,392,812, Fig. 1B), hypertension was the most prevalent (85.9%), followed by diabetes (10.4%), coronary heart disease (2.1%), and stroke (1.7%). Of the population with two ORCDs (N=11,165,789, Fig. 1C), 70.4% had D+H, 12.8% had C+H, and 12.7% had H+S. By disease permutation, for the most prevalent two-ORCD combination (D+H), 54.4% were diagnosed with H D (H>D 35.5% + D=H 19.0%). Nearly 35.0% were diagnosed with D H (D>H 16.0% + D=H 19.0%). To summarize, 74.6% had H , followed by D (38.0%), C (9.6%), and S (7.0%).

Of the population with three ORCDs (N=1,875,965, Fig. 1D), 48.4% had H+D+C, 37.5% had D+H+S, 12.5% had C+H+S, and 1.6% had C+D+S. By disease permutation, for the most prevalent three-ORCD combination (C+D+H), 22.1% were diagnosed with H D C (H>D>C 11.6% + D=H>C 4.7% + C=D=H 4.6% + H>C=D 1.3%). In summary, 56.2% had H , followed by D (39.4%), C (19.2%), and S (13.7%). Of the population with four

ORCDs (N=221,778, Fig. 1E), 61.0% had H, followed by C (44.2%), D (29.0%), and S (6.2%).

Age-standardized disease prevalence by the order of the 4 ORCDs

The order of the diagnosed ORCDs among the population with 1 ORCD (N=48,656,344) is demonstrated in Table 2 and the river plot (Fig. S3). While most of the H population never progressed beyond a diagnosis of H, the remaining H population was diagnosed with D (H D+, most prevalent among the H population, widest among all paths going out from H in Fig. S3), C (H C+, second most prevalent among the H population), or S (H S+, least prevalent among the H population) in the same/following year(s) after a diagnosis of H. Furthermore, among the population with obesity-related multimorbidity, H D+ was the most prevalent (12.6% of the population with 1 ORCD, Table 2 corresponding to the width of the curves in Fig. S3), followed by D H+ (8.5% of the population with 1 ORCD) and H C+ (3.4% of the population with 1 ORCD). The remaining permutations of the diagnosed ORCDs can be found in Fig. S3.

Disease risk

Fig. 2 summarizes multivariable-adjusted hazard ratios (aHR) and 95% confidence intervals (CI) for developing cardiovascular disease by degree of obesity (Fig. 2A) and by pre-existing ORCDs (Fig. 2B, complete results in Table S1). Independent of pre-existing ORCDs, compared with normal weight, class III obesity was associated with increased risk of coronary heart disease (aHR 1.6, 95% CI 1.0-2.4) and stroke (aHR 1.8, 95% CI 1.3-2.5). Independent of degree of obesity, compared with no pre-existing condition (diabetes, hypertension, or stroke), individuals with one pre-existing condition (diabetes, hypertension, or stroke) had 4-7 fold increased risk of coronary heart disease; and individuals with pre-existing hypertension or coronary heart disease had 4 fold increased risk of stroke. Individuals with pre-existing multimorbidity had substantial increased risk of coronary heart disease: H+S (aHR 27.6, 95% CI 10.9-70.2), D+H+S (aHR 20.3, 95% CI, 7.9-52.2), D+S (aHR 13.1, 95% CI 4.2-40.8), D+H (aHR 8.0, 95% CI 4.9-13.3). Similarly, individuals with pre-existing multimorbidity had substantial increased risk of stroke: C+D+H (aHR 32.6, 95% CI 12.2-87.1), C+H (aHR 25.4, 95% CI 12.1-53.6), C+D (aHR 7.0, 95% CI, 2.4-20.2), D+H (aHR 5.3, 95% CI 2.6-10.8).

DISCUSSION

This study is the first to examine the prevalence of obesity-related multimorbidity (targeting 4 ORCDs: diabetes, hypertension, coronary heart disease, and stroke) in its combination and permutation in the United States, and the risk of developing cardiovascular disease, conditional on demographics, degree of obesity, and presence and duration of pre-existing ORCDs. The prevalence of obesity-related multimorbidity was 12% in the U.S. population age 40-79 years from 2007-2016. Among the population with obesity-related multimorbidity, hypertension was most commonly the first diagnosed ORCD for populations with 2-4 ORCDs, followed by diabetes for populations with 2-3 ORCDs, and followed by coronary heart disease for the population with 4 ORCDs.

Independent of degree of obesity, the risk of coronary heart disease or stroke increased with one pre-existing condition and to a much greater extent with pre-existing multimorbidity. These findings validate the goals of the U.S. Preventive Services Task Force (USPSTF) guidelines intended to detect and treat hypertension and diabetes while asymptomatic, prior to the onset of coronary heart disease and stroke. Hypertension screening is recommended in all adults age 18²⁸ and diabetes screening is recommended in overweight and obese adults age 40-70.²⁹ Both USPSTF recommendations are recommended for coverage under the Affordable Care Act preventive care benefit.³⁰

We found >10% of the population had obesity-related multimorbidity. This is partially consistent with U.S. population-based estimates of chronic disease multimorbidity,^{7,8,10,31} in which higher prevalence of multimorbidity (9-60%) was found in previous studies due to the inclusion of a wider range of chronic conditions. Among these, Ward et al. 2014 found that the most common dyad was arthritis and hypertension, and the most common triad was arthritis, hypertension, and diabetes in U.S. adults age 18. In our study, arthritis was not included, but we observed hypertension and its combination with diabetes was the most prevalent dyad.

Consistent with previous studies, we found the risk of cardiovascular disease increases with BMI, particularly for those with a high degree of obesity,³ but our estimated risks associated with BMI accounted for the presence and duration of pre-existing ORCD(s). Staimez et al. who also accounted for pre-existing disease found that obesity was one of the risk factors with the greatest population attributable fractions for multimorbidity in the U.S. population.¹⁰ The fact that high BMI contributes to an increased risk of developing cardiovascular disease even while controlling for the presence and duration of pre-existing ORCDs emphasizes the importance of obesity prevention.

Our study shows that hypertension in combination with diabetes and/or stroke increased the risk of coronary heart disease markedly greater than that for hypertension alone; and, hypertension in combination with diabetes and/or coronary heart disease increased the risk of stroke markedly greater than that for hypertension alone. Prior studies have not examined cardiovascular disease risk when hypertension is combined with pre-existing ORCDs, while controlling for duration of pre-existing disease. Coronary heart disease and stroke share a common etiology.³² Both hypertension and diabetes are involved in the pathophysiology of atherosclerotic vascular disease, of which coronary heart disease and stroke are manifestations. Substantiating our findings, Xu et al.¹⁶ found that pre-existing stroke was associated with developing heart disease and to a lesser degree pre-existing heart disease was associated with developing stroke. These findings taken together with the fact that hypertension is a precursor to both coronary heart disease and stroke explains why individuals with hypertension and stroke or diabetes, hypertension, and stroke had the highest coronary heart disease risk and individuals with coronary heart disease, diabetes, and hypertension or coronary heart disease and hypertension had the highest stroke risk. Our findings underscore the importance of primary and/or secondary prevention strategies to prevent increasing multimorbidity.

From a clinical perspective, given the pathophysiologic association of hypertension and diabetes with coronary heart disease and stroke, it is concerning that some individuals were diagnosed with coronary heart disease or stroke in the same year or before diabetes and hypertension. Among individuals with 2 ORCDs, 16.2% of individuals were diagnosed with coronary heart disease or stroke in the same year or before diabetes or hypertension. This was even more common among those with 3 or 4 ORCDs. Some of this may be related to recall bias; however, since diabetes and hypertension can be detected when asymptomatic through screening at routine clinical encounters, these should ideally be diagnosed and treated in advance of coronary heart disease and stroke, which are typically detected after acute events. Individuals with coronary heart disease and stroke diagnosed concurrently or before diabetes or hypertension represent an opportunity for improvement in primary prevention measures. It is possible that these individuals were not accessing primary preventive care before their acute event or that appropriate screening and treatment were not occurring. Supporting this hypothesis, it is estimated that 90% of individuals with pre-diabetes are unaware they have this condition.³³ Additionally, while 94% of individuals who are diagnosed with diabetes are connected to care, a recent study, also utilizing NHANES data, highlights the persistence of gaps in meeting glycemic control, blood pressure and lipid targets among these individuals.³⁴

Diabetes-heart disease-stroke multimorbidity is associated with substantial reduction in life expectancy beyond that of a single diagnosis of one of those diseases.^{11,13,14} The risk for all-cause mortality for one condition increases by about 2-fold compared to that for no conditions, whereas the risk for mortality for any two conditions increases by ~4-fold, and the risk for mortality for all three conditions increases by ~7-fold.¹¹ Furthermore, the economic costs of obesity-related morbidity are substantial.³⁵

Study limitations

We could not distinguish between type-1 and 2 diabetes. However, we excluded individuals who reported a diabetes diagnosis before the age of 18 and who were treated with insulin for diabetes before age 30 in an attempt to exclude individuals with type-1 diabetes.²⁰ Moreover, 90-95% of diabetes in the United States is type-2; therefore, type-1 diabetes makes up a small percentage of the U.S. population relative to type-2 diabetes.³⁶ Second, self-reported data on ORCD diagnoses were used in our study, which is subject to recall bias,³⁷ potentially underestimating the prevalence of obesity-related multimorbidity and/or introducing imprecision to the order of the ORCDs. Nonetheless, compared to claims data, using self-reported data on disease diagnoses in the NHANES circumvents claims data issues, including the reference period in which diagnoses are identified and sample selection based on health insurance status. Third, our finding about a higher risk of developing an ORCD with pre-existing disease(s) could be subject to detection bias due to more intensive care, followed by a higher likelihood of detection of other ORCDs. Last, our data are cross-sectional and thus we could not capture the dynamics of BMI change throughout the study period, which could lead to an underestimation or overestimation of ORCD development.

Conclusion

More than 1/10 U.S. adults 40 years of age have obesity-related multimorbidity, and it is highly associated with the development of cardiovascular disease. Intervention strategies to reduce cardiovascular disease should include preventing increasing multimorbidity and detecting and managing hypertension and diabetes prior to the onset of cardiovascular disease. Close monitoring and timely diagnosis of ORCDs highly correlated with pre-existing ORCD(s) may also help limit the detrimental health and economic burden of multimorbidity in this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS:

ORCDs	obesity-related chronic diseases
H	hypertension
D	diabetes
C	coronary heart disease
S	stroke.

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Highlights

- The prevalence of obesity-related multimorbidity was 12% in the U.S. population age 40-79 years from 2007-2016.
- Among the population with obesity-related multimorbidity, hypertension was most commonly the first diagnosed disease.
- Risk of cardiovascular disease increased substantially with pre-existing multimorbidity, independent of degree of obesity.
- Intervention strategies to reduce cardiovascular disease should include preventing increasing multimorbidity.

A. No ORCD (N=61,347,206, 55.62% of the total population)**B. One ORCD (N=35,392,812, 32.12% of the total population)** **C. Two ORCDs (N=11,165,789, 10.29% of the total population)** **D. Three ORCDs (N=1,875,965, 1.76% of the total population)**

E. Four ORCDs (N=221,778, 0.21% of the total population) **Fig. 1.**

Age-standardized prevalence for the combinations and permutations of ORCDs, NHANES, 2007-2016 (total population N=110,003,550)

A. Degree of obesity **B. Pre-existing ORCDs** **Fig. 2.**

Multivariable-adjusted hazard ratios for obesity-related chronic disease arrival

Table 1.

Sample and population characteristics stratified by obesity-related chronic disease (ORCD) status, NHANES, 2007-2016

	Overall	No ORCDs	D	H	C	S	D+H	D+C	D+S	H+C	H+S	C+S	D+H+S	D+H+C	D+C+S	H+C+S	D+H+C+S
Sample size	14 243	7 138	607	4 042	90	86	1 365	48	24	7 138	607	4 042	90	86	1 365	48	24
Population size	110 003	61 347	3 661	30 315	825	589	7 637	346	141	61 347	3 661	30 315	825	589	7 637	346	141
	550	206	926	735	368	783	500	163	544	206	926	735	368	783	500	163	544
Population %	100.00	55.77	3.33	27.56	0.75	0.54	6.94	0.31	0.13	55.77	3.33	27.56	0.75	0.54	6.94	0.31	0.13
Sex																	
Men	48.47	48.16	54.30	45.26	81.91	47.58	49.36	63.68	66.15	73.25	46.80	75.38	55.68	54.44	84.10	44.93	66.28
Women	51.53	51.84	45.70	54.74	18.09	52.42	50.64	36.32	33.85	26.75	53.20	24.62	44.32	45.56	15.90	55.07	33.72
Race																	
Non-Hispanic white	68.40	70.37	52.27	69.45	86.77	68.68	54.71	84.66	45.85	73.06	64.01	53.87	53.11	68.57	66.93	72.98	73.68
Non-Hispanic black	11.61	8.75	11.97	14.53	3.25	21.25	21.39	2.70	12.06	10.11	21.27	0.00	24.48	7.55	7.61	11.85	9.36
Hispanic	12.46	13.25	22.27	9.83	4.30	9.32	15.46	5.99	14.03	7.74	8.07	12.30	11.50	12.94	25.46	4.13	8.23
Other	7.53	7.62	13.48	6.20	5.69	0.75	8.44	6.65	28.06	9.08	6.66	33.83	10.91	10.94	0.00	11.05	8.73
Age (y)																	
40-49	35.43	45.55	27.86	26.41	8.73	29.89	15.56	11.84	2.35	9.33	16.68	0.00	7.52	7.96	0.00	1.67	5.02
50-59	32.54	33.08	31.91	33.17	24.41	19.17	34.65	18.16	51.00	22.11	27.30	12.58	21.26	16.90	44.13	28.10	22.25
60-69	21.63	15.74	28.34	26.50	43.53	31.30	32.05	37.10	17.84	33.65	31.56	52.08	43.76	47.90	16.69	33.70	43.21
70-	10.41	5.62	11.89	13.92	23.34	19.64	17.74	32.90	28.81	34.91	24.46	35.35	27.47	27.24	39.18	36.53	29.52
BMI category																	
Normal weight	24.33	32.06	16.05	14.86	25.20	33.38	8.56	9.92	1.85	19.29	20.04	5.92	9.54	10.91	0.00	42.41	17.14
Overweight	35.14	38.07	32.23	34.37	35.92	30.79	20.92	21.31	22.48	36.62	35.00	94.08	17.48	16.72	6.77	34.26	17.53
Class I obese	22.84	19.06	27.51	27.08	31.73	22.26	30.87	26.84	48.17	25.30	18.71	0.00	28.81	35.70	19.44	21.47	26.52
Class II obese	9.60	6.33	12.36	13.14	5.40	7.50	18.79	22.54	20.56	10.34	8.43	0.00	16.17	19.38	23.51	1.21	15.21
Class III obese	8.08	4.47	11.85	10.54	1.75	6.07	20.86	19.40	6.94	8.45	17.82	0.00	28.00	17.30	50.28	0.65	23.60
Duration of ORCDs (y)																	
D, mean (se)	1.31	0.00	9.15	0.00	0.00	0.00	10.53	11.59	14.51	0.00	0.00	0.00	13.54	13.41	16.39	0.00	12.38
	0.05	0.00	0.42	0.00	0.00	0.00	0.28	1.34	3.60	0.05	0.00	0.00	0.87	0.85	3.18	0.00	1.62
H, mean (se)	4.67	0.00	0.00	10.94	0.00	0.00	13.46	0.00	0.00	15.44	13.01	0.00	15.80	18.42	0.00	19.03	16.98
	0.11	0.00	0.00	0.20	0.00	0.00	0.36	0.00	0.00	0.96	0.91	0.00	0.87	1.22	0.00	1.83	2.42
C, mean (se)	0.40	0.00	0.00	0.00	8.62	0.00	0.00	9.50	0.00	10.55	0.00	11.83	0.00	10.67	12.78	11.81	11.62
	0.03	0.00	0.00	0.00	0.73	0.00	0.00	1.35	0.00	0.62	0.00	2.30	0.00	0.86	1.62	1.44	1.31

	Overall	No ORCDs	D	H	C	S	D+H	D+C	D+S	H+C	H+S	C+S	D+H +S	D+H + C	D+C +S	H+C +S	D+H +C +S
S, mean	0.28	0.00	0.00	0.00	0.00	9.40	0.00	0.00	8.36	0.00	9.02	10.59	9.31	0.00	8.67	11.34	7.73
(se)	0.02	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.85	0.00	0.71	1.24	1.29	0.00	3.26	1.00	1.82

D: diabetes; H: hypertension, C: coronary heart disease; S: stroke

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Table 2.

Age-standardized disease prevalence for populations with at least one ORCD corresponding to the river plot, NHANES, 2007-2016 (N=48 656 344)

	%	se		%	se		%	se		%	se
H	82.77	0.72	H only	64.61	0.95						
			H D+	12.59	0.63	H D	11.20	0.58			
						H D S+	0.73	0.12	H D S C	0.06	0.01
									H D S	0.67	0.12
						H D C+	0.69	0.11	H D C S	0.07	0.03
									H D C	0.62	0.11
			H C+	3.42	0.30	H C	2.43	0.26			
						H C D+	0.59	0.10	H C D S	0.05	0.03
									H C D	0.54	0.10
						H C S+	0.42	0.10	H C S D	0.09	0.04
									H C S	0.33	0.09
			H S+	2.77	0.25	H S	2.09	0.20			
						H S D+	0.36	0.10	H S D C	0.03	0.02
									H S D	0.34	0.10
						H S C+	0.34	0.09	H S C D	0.04	0.03
									H S C	0.30	0.09
D	17.21	0.75	D H+	8.46	0.44	D H	7.29	0.39			
						D H C+	0.65	0.12	D H C S	0.14	0.06
									D H C	0.52	0.10
						D H S+	0.55	0.11	D H S C	0.04	0.03
									D H S	0.50	0.10
			D only	7.86	0.52						
			D C+	0.87	0.19	D C	0.50	0.16			
						D C H+	0.33	0.09	D C H S	0.03	0.02
									D C H	0.30	0.09
						D C S+	0.06	0.03	D C S H	0.01	0.01
									D C S	0.04	0.03
			D S+	0.48	0.10	D S H+	0.28	0.08	D S H C	0.01	0.01
						D S	0.18	0.06	D S H	0.26	0.08
						D S C+	0.04	0.01	D S C H	0.01	0.01
									D S C	0.02	0.01
C	4.22	0.40	C H+	2.24	0.28	C H	1.64	0.23			
						C H D+	0.38	0.07	C H D S	0.08	0.05
									C H D	0.30	0.07

	%	se		%	se		%	se		%	se
Author Manuscript						C H S+	0.23	0.08	C H S D	0.07	0.04
									C H S	0.16	0.07
			C only	1.44	0.22						
			C D+	0.60	0.17	C D	0.38	0.16			
						C D H+	0.17	0.05	C D H S	0.03	0.02
									C D H	0.14	0.05
						C D S+	0.05	0.03	C D S H	0.02	0.01
									C D S	0.03	0.03
			C S+	0.21	0.08	C S H+	0.15	0.07	C S H D	0.04	0.03
						C S	0.05	0.02	C S H	0.11	0.07
						C S D+	0.02	0.01	C S D H	0.01	0.01
									C S D	0.01	0.00
Author Manuscript	S	3.21	0.29			S H	1.26	0.22			
						S H D+	0.27	0.08	S H D C	0.02	0.01
									S H D	0.25	0.07
						S H C+	0.20	0.08	S H C D	0.03	0.03
									S H C	0.17	0.07
						S only	1.28	0.18			
						S D	0.09	0.06			
						S D+	0.32	0.09	S D H C	0.01	0.01
									S D H	0.20	0.07
									S D C H	0.01	0.01
									S D C	0.01	0.00
						S C+	0.25	0.08	S C H D	0.03	0.03
									S C H	0.16	0.07
									S C D H	0.01	0.01
									S C D	0.01	0.01

All %s are based on the populations with at least one ORCD (N=48 656 344). The sum of the %s is >100% because individuals who reported the first diagnoses of the ORCDs in the same year were double counted in each category with .