Linear association between number of modifiable risk factors and multiple chronic conditions: Results from the Behavioral Risk Factor Surveillance System

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ABSTRACT

Multiple (≥ 2) chronic conditions (MCCs) are responsible for a large fraction of healthcare costs. Our aim was to examine possible associations between MCCs and composite measures of behavioral risk factors (RFs). Data were publicly available 2013 Behavioral Risk Factor Surveillance System and included 483,865 non-institutionalized US adults ages ≥ 18 years. Chronic conditions included asthma, arthritis, chronic obstructive pulmonary disease, cognitive impairment, heart disease, stroke, cancer, and kidney disease. RFs included obesity, current smoking, sedentary lifestyle, inadequate fruit and vegetable consumption, and sleeping other than 7–8 h, while depression, hypertension, high cholesterol, and diabetes were considered in each category. Stata was used to study associations between 2 different MCCs and 2 composite measures of RFs in both unadjusted and adjusted analysis. Over 96% of respondents reported ≥ 1 of the 9 RFs and 71.5% reported ≥ 1 of the chronic conditions. For each combination there was a linear increase (with similar slopes) in MCC rate with more RFs and a statistically significant increase in adjusted odds ratios (ORs) for the MCC with each additional RF. For the MCC based on 8 chronic conditions, ORs were 1.3 (95% CI 1.1, 1.6) for 1 RF, 2.3 (1.9, 2.7) for 2, 3.7 (3.1, 4.4) for 3, 5.7 (4.8, 6.8) for 4, 9.1 (7.6, 10.8) for 5, 14.6 (12.2, 17.4) for 6, 24.0 (19.7, 29.2) for 7, 38.1 (29.6, 48.9) for 8, and 100.0 (56.3, 177.8) for all 9, each vs. zero RFs. Findings highlight the need for effective integrated programs to address multiple RFs and chronic conditions.

1. Introduction

Adults with multiple (≥ 2) chronic conditions (MCCs) account for about two-thirds of all healthcare costs in the U.S. (Anderson, 2010). MCCs are a major factor in the rise in Medicare spending (Thorpe et al., 2010), estimated to be responsible for 93% of those costs (Centers for Medicare and Medicaid Services, 2012). There is no standard definition of chronic conditions included in MCCs (Willadsen et al., 2016; Goodman et al., 2013) but chronic diseases, risk factors, mental health problems, and cognitive impairment can be among them (CMS: Centers for Medicare and Medicaid Services, n.d.; U.S. Department of Health and Human Services, n.d.). More attention is starting to be focused on MCCs as their contribution to health care costs is recognized (Centers for Medicare and Medicaid Services, 2012; Goodman et al., 2013; U.S. Department of Health and Human Services, n.d.; Gupta, 2016). While a recent review (Willadsen et al., 2016) of 163 MCC studies found that 85% included risk factors (RFs) in their definitions of MCCs, apparently none studied possible associations between MCCs and RFs. Behavioral risk factors such as hypertension, obesity, and smoking have been shown to be associated with many separate chronic conditions (Brownson et al., 2010). Risk factors can also occur concurrently and are sometimes studied using composite measures. For example, Adams et al. (2016) and Liu et al. (2016) studied slightly different combinations of 5 RFs and both found that 92%–94% of all adults reported at least one RF. Addressing RFs collectively may help in understanding how they might predict MCCs, which in turn could inform clinical and

Table 1

Components of composite measures of risk factors and chronic conditions, 2013 Behavioral Risk Factor System, 50 states + DC, adults ages 18 +, N ~ 400,000.

Measures	Percent	95% CI	Missing	(%)
Risk factors				
Obesity[*]	28.3	28.0, 28.6	26,378	(5.5)
Smoking[*]	18.2	18.0, 18.5	15,215	(3.1)
Sedentary lifestyle[*]	26.3	26.0, 26.6	33,772	(7.0)
Eat < 5-a-day[*]	82.8	82.5, 83.0	56,993	(11.8)
Sleep other than 7–8 h[*]	43.6	43.3, 43.9	7260	(1.5)
Hypertension[a]	32.4	32.1, 32.7	1387	(0.3)
High cholesterol[a]	38.6	38.3–38.9	70,116	(14.5)
Diabetes[a]	10.2	10.1, 10.4	805	(0.2)
Depression diagnosis[a]	17.7	17.5, 17.9	2267	(0.5)
Measure with all 9 risk factors above			139,683	(28.9)
Have none of above risk factors	3.6	3.5, 3.8		
Any 1	16.0	15.7, 16.2		
Any 2	22.5	22.2, 22.8		
Any 3	21.8	21.5, 22.1		
Any 4	16.3	16.1, 16.6		
Any 5	10.9	10.7, 11.1		
Any 6	5.8	5.6, 5.9		
Any 7	2.4	2.3, 2.5		
Any 8	0.7	0.7, 0.8		
All 9	0.1	0.1, 0.1		
Measure with only 5 RFs (those with [*])			83,454	(17.2)
Have none of [*] risk factors	6.4	6.2, 6.5		
Any 1	29.5	29.2, 29.8		
Any 2	33.7	33.4, 34.0		
Any 3	21.5	21.2, 21.7		
Any 4	7.8	7.6, 8.0		
All 5	1.1	1.1, 1.2		
Chronic conditions (see also[a])				
Asthma	9.0	8.8, 9.1	3405	(0.7)
Arthritis	25.0	24.8, 25.3	2909	(0.6)
Heart disease	6.6	6.5, 6.7	4562	(0.9)
Stroke	2.9	2.9, 3.0	1451	(0.3)
Cognitive impairment	10.7	10.5, 10.8	12,904	(2.7)
Chronic obstructive pulmonary disease	6.5	6.3, 6.6	2697	(0.6)
Cancer other than skin	6.5	6.4, 6.7	1140	(0.2)
Kidney disease	2.6	2.5, 2.7	1678	(0.3)
Number of chronic conditions (out of 12)			93,804	(19.4)
Have 0 chronic conditions	28.5	28.2, 28.8		
Any 1	23.6	23.3, 23.9		
Any 2	18.1	17.9, 18.4		
Any 3	12.7	12.5, 12.9		
Any 4	8.0	7.8, 8.2		
Any 5	4.6	4.5, 4.7		
Any 6	2.4	2.3, 2.5		
Any 7 or more of the 12	2.1	2.0, 2.1		

Abbreviations: CI: confidence interval; RF: risk factor.

[*] Indicates one of the 5 risk factors.

[a] Can be risk factor or chronic conditions.

public health practice.

Our objective for this current work was to study MCCs based on different definitions and their associations with composite measures of up to 9 risk factors. The chronic conditions chosen were asthma, arthritis, heart disease, stroke, chronic obstructive pulmonary disease (COPD), cognitive impairment, cancer other than skin, and chronic kidney disease. The RFs were current smoking, sedentary lifestyle, inadequate fruit and vegetable consumption, sleeping other than 7–8 h, and obesity. Because diabetes, hypertension, high cholesterol, and depression can be considered either chronic conditions (Willadsen et al., 2016; Goodman et al., 2013) or RFs (Brownson et al., 2010) they would be included in the study in each category. Prevalence rates of the composite measures plus their associations with each other would be studied. We would also test the hypothesis that there is a linear association between the number of RF's and MCC rates as was found for other outcomes (Adams and Grandpre, 2016). The hope was that results might aid in the development and targeting of integrated prevention programs addressing multiple RFs aimed at reducing rates of MCCs and lowering associated health care costs.

2. Methods

2.1. Data

We used publicly available (Behavioral Risk Factor Surveillance System (BRFSS) (Atlanta, Georgia), n.d.) Behavioral Risk Factor Surveillance System (BRFSS) data from 2013 in order to include sleep as a RF. The BRFSS is a large, representative, state-based telephone survey of non-institutionalized U.S. adults (Behavioral Risk Factor Surveillance System. Atlanta (GA), n.d.) and our data included 483,865 respondents ages ≥ 18 years in the 50 states and DC. In general, data have been shown to be comparable to results from national surveys based on self-reported behaviors (Nelson et al., 2013; Pierannunzi et al., 2013). For all measures described below, responses of "don't know" or refusal to answer were excluded from analysis. The median response rate for cell phone and land line surveys combined was 46.4%, ranging from 29.0% in Alabama to 58.0% in Colorado (Behavioral Risk Factor Surveillance System, 2013).

2.2. Risk factor measures

Survey questions are available on-line (Behavioral Risk Factor Surveillance System. Atlanta (GA), n.d.) and only potentially modifiable risk factors were included. Current smokers were respondents who smoked 100 cigarettes and now smoked every day or some days. Respondents who did not participate in any leisure time physical activity in the past month were considered to have a sedentary lifestyle. Obesity was a body mass index ≥ 30 based on self-reported height and weight. Inadequate fruit and vegetable consumption was defined as consuming the combination < 5 times per day based on responses to six separate questions. Hours of sleep in a 24-hour period were reported as round numbers and dichotomized into 7–8 h vs. any other number of hours, as both too little and too much sleep have been associated with adverse outcomes (Gallicchio and Kalesan, 2009). RFs that could also be chronic conditions included hypertension, high cholesterol, depression, and diabetes, each defined as "ever told", except diabetes excluded women who were told only when pregnant.

Once unknowns were removed, final N's for the 9 separate RFs ranged from 426,872 for fruit and vegetable consumption to 483,060 for diabetes. Composite measures were generated which included all 9 RFs and the 5 RFs that were just RFs, by counting the number of RFs, with totals that ranged from 0 to 9, or 0 to 5, respectively. Unknowns were removed from the composite measure if any of its components were unknown, resulting in final sample sizes of 344,182 for the measure including all 9 and 400,411 for the measure that included only the 5 RFs. Alternate measures were created that represented respondents who reported any vs. none of the RFs for that measure.

2.3. Chronic conditions, MCCs

With the exception of cognitive impairment (CI) all chronic conditions were defined as "ever told" and included heart disease, stroke, current asthma (ever told and still have it), COPD, arthritis, cancer other than skin, and kidney disease. Cognitive impairment was defined as a "yes" response to "Because of a physical, mental, or emotional problem, do you have difficulty remembering, concentrating, or making decisions?" This question has been asked since 2008 by the census bureau and is now a standard disability question on federal surveys (US Census Bureau, n.d.). This measure is consistent with other measures of CI but should not be considered cognitive decline because the question lacks a time frame (Jessen et al., 2014; Rabin et al., 2015). Our measures of MCCs included respondents who reported ≥ 2 of the component chronic conditions. MCC8 included asthma, arthritis, heart

Table 2
Demographics of study measures of multiple chronic conditions (MCCs) and risk factors; 2013 Behavioral Risk Factor Surveillance System, adults age 18 +, sample size ~390,000.

Group (N)	MCC8[a]		MCC12[b]		Any of 5 risk factors[c]		Any of 9 risk factors[d]	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Total (483,865)	16.8	16.6, 17.0	47.9	47.6, 48.2	93.6	93.5, 93.8	96.4	96.2, 96.5
Gender								
Males (198,275)	14.1	13.9, 14.4	46.1	45.6, 46.6	95.3	95.1, 95.5	97.5	97.3, 97.6
Females (285,590)	19.2	19.0, 19.5	49.5	49.0, 49.9	92.0	91.8, 92.3	95.4	95.1, 95.6
Age (years)								
18–24 (26,462)	4.3	3.9, 4.7	15.6	14.6, 16.8	94.0	93.4, 94.5	94.4	93.5, 95.2
25–34 (49,040)	6.5	6.1, 6.9	21.4	20.6, 22.2	93.7	93.3, 94.1	94.7	94.2, 95.1
35–44 (58,397)	9.1	8.7, 9.6	30.0	29.2, 30.8	93.6	93.2, 94.0	95.4	95.0, 95.7
45–54 (81,983)	16.3	15.8, 16.8	45.6	44.9, 46.4	93.9	93.5, 94.3	96.3	96.0, 96.6
55–64 (104,813)	24.1	23.5, 24.6	62.6	61.9, 63.2	93.5	93.2, 93.8	97.1	96.9, 97.4
65–74 (88,714)	31.8	31.1, 32.4	74.7	74.1, 75.3	93.3	92.9, 93.6	98.0	97.8, 98.2
75 + (69,792)	41.8	41.0, 42.6	79.8	79.1, 80.4	93.2	92.8, 93.7	98.4	98.2, 98.6
Race/ethnicity								
White (376,229)	18.4	18.2, 18.7	50.3	50.0, 50.7	93.1	93.0, 93.3	96.2	96.1, 96.4
Black (39,132)	18.2	17.5, 18.9	50.6	49.5, 51.7	96.7	96.3, 97.0	98.1	97.7, 98.4
Hispanic (30,982)	10.5	9.9, 11.2	37.7	36.5, 39.0	93.7	93.1, 94.3	96.1	95.5, 96.6
AInd/AN (7682)	24.0	21.8, 26.4	56.8	53.6, 59.9	96.6	95.4, 97.4	97.7	96.7, 98.5
Other (21,349)	10.6	9.7, 11.7	36.1	34.3, 38.0	93.2	92.3, 94.0	95.4	94.5, 96.2
Income (thousands)								
Unknown (69,257)	18.1	17.5, 18.6	50.7	49.8, 51.6	93.7	93.2, 94.2	96.4	95.9, 96.8
$75 + (115,532)	8.3	8.0, 8.6	35.0	34.4, 35.6	90.7	90.3, 91.0	94.5	94.3, 94.8
$50– < 75 (64,834)	12.7	12.3, 13.2	44.7	43.8, 45.5	93.3	92.9, 93.7	96.4	96.1, 96.8
$25– < 50 (108,970)	17.1	16.6, 17.5	50.8	50.1, 51.5	94.4	94.1, 94.8	97.1	96.9, 97.4
$15– < 25 (74,903)	23.2	22.6, 23.8	58.6	57.6, 59.5	96.1	95.7, 96.4	98.1	97.8, 98.3
< $15 (49,483)	30.0	29.1, 30.9	66.0	64.8, 67.2	96.4	96.0, 96.8	98.0	97.5, 98.4
Education								
College grad (167,846)	10.0	9.8, 10.3	36.6	36.2, 37.1	89.2	88.9, 89.5	93.8	93.6, 94.1
Some college (132,418)	16.7	16.3, 17.0	48.3	47.7, 48.9	94.0	93.7, 94.3	96.7	96.4, 96.9
High school (140,798)	18.8	18.4, 19.2	53.1	52.5, 53.7	96.0	95.7, 96.3	98.1	97.8, 98.3
< High school (40,541)	25.1	24.3, 25.9	61.9	60.6, 63.1	96.9	96.5, 97.3	98.3	97.8, 98.7
Disability								
Yes (128,381)	47.6	47.0, 48.2	82.0	81.5, 82.5	96.7	96.5, 97.0	99.0	98.8, 99.1
No (344,609)	8.5	8.3, 8.6	37.5	37.2, 37.9	92.8	92.6, 93.0	95.6	95.4, 95.7
Cost barrier to health care								
Yes (58,884)	24.3	23.7, 25.0	58.0	57.0, 59.0	96.2	95.8, 96.6	98.0	97.6, 98.3
No (423,765)	15.4	15.1, 15.6	46.3	46.0, 46.7	93.2	93.0, 93.3	96.1	96.0, 96.3

Abbreviations: AI/AN: American Indian/Alaska Native; MCC: multiple chronic conditions; RF: risk factor; CI: confidence interval.
[a] MCC8: MCC5 with heart disease and stroke counted separately plus cancer and kidney disease.
[b] MCC12: MCC8 plus diabetes, depression, hypertension, high cholesterol.
[c] Obesity, sedentary lifestyle, sleeping ≠ 7–8 h, eating fruits and vegetables < 5 times/day, smoking.
[d] 5 RFs plus diabetes, hypertension, high cholesterol, and depression.

disease, stroke, COPD, CI, cancer, and kidney disease while MCC12 added hypertension, depression, diabetes, and high cholesterol. Final sample sizes were 456,087 for MCC8 and 390,061 for MCC12.

2.4. Other variables

Demographic measures included gender, age (18–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75 years and older), self-reported race/ethnicity (non-Hispanic white, Black or African American, Hispanic of any race, American Indian/Alaska Native, and other), education (college graduate, some college, high school graduate, < high school), and household income (≥ $75,000, $50,000–$74,999, $25,000–$49,999, $15,000–$24,999, < $15,000, and unknown). Other health measures included reporting a cost barrier to health care (there was a time in the past 12 months when they needed to see a doctor but could not because of cost) and disability (defined as either limited in any way in any activities because of physical, mental, or emotional problems or having a health problem that requires use of special equipment).

2.5. Statistical analysis

Stata version 14.1 (StataCorp LP, College Station, TX) was used in 2017 for all data analysis to account for the complex sample design of the BRFSS. Data were weighted to be representative of the adult population in each state by age, gender, race/ethnicity, marital status, education, home ownership and telephone source. Point estimates and 95% confidence intervals are reported for each composite measure of MCCs and RFs and their components. Unadjusted associations of each risk factor with each chronic condition were determined, along with associations between the composite RF measures and each MCC. Logistic regression was done to confirm associations of composite risk factor measures and their separate components with MCCs when controlling for all the demographic measures listed. Unadjusted results of associations between MCCs and RFs were plotted in Excel and selected trend lines and formulas were added.

3. Results

Prevalence of the separate chronic conditions and risk factors and selected combinations are shown in Table 1 indicating that 71.5% of all

Table 3
Percentages and 95% confidence intervals (CIs) for adults with multiple chronic conditions (MCCs), by number of risk factors (RFs), for different MCC and RF measures; 2013 Behavioral Risk Factor Surveillance System, adults age 18 +, 50 states and DC, Total sample size ~ 390,000.

# Risk factors	5 RFs[b]		9 RFs[c]	
	%	95% CI	%	95% CI
MCC8[a]				
0	8.5	7.9, 9.2	3.6	3.1, 4.2
1	10.0	9.7, 10.3	4.7	4.4, 5.1
2	15.4	15.0, 15.8	9.0	8.6, 9.4
3	23.2	22.6, 23.7	15.9	15.4, 16.4
4	34.3	33.2, 35.3	25.0	24.3, 25.7
5	42.4	39.5, 45.3	35.9	34.9, 36.9
6			48.4	47.0, 49.7
7			61.9	59.7,64.0
8			72.2	68.3,75.7
9			87.1	80.3,91.7
MCC12[d]				
0	31.4	30.2,32.6		
1	36.9	36.3,37.5		
2	47.5	46.9,48.1		
3	59.7	58.9,60.5		
4	71.3	70.2,72.5		
5	76.5	73.3,79.4		

Abbreviations: MCC: multiple chronic conditions; RF: risk factor; CI: confidence interval.
[a] MCC8: MCC5 with heart disease and stroke counted separately plus cancer and kidney disease.
[b] Obesity, sedentary lifestyle, sleeping ≠ 7–8 h, eating fruits and vegetables < 5 times/day, smoking.
[c] 5 RFs plus diabetes, hypertension, high cholesterol, and depression.
[d] MCC12: MCC8 plus diabetes, depression, hypertension, high cholesterol.

adults reported one or more chronic condition and 96.4% reported at least one RF. Demographics of the MCC and risk factor measures are shown in Table 2, indicating the widespread prevalence of any RFs and demographic differences in MCC rates. Disabled adults and those reporting a cost barrier to health care were significantly more likely than those not reporting those measures to report MCCs and any of the RFs. Not shown are results of 95 unadjusted cross tabulations of each of the nine RFs with each of the possible chronic conditions (with heart disease and stroke combined into cardiovascular disease [CVD]). Those results showed that for 88 of the 95 possible pairs, respondents with the risk factor were significantly more likely than those without the RF to report the chronic condition. The exceptions were fruit and vegetable consumption which was not associated with asthma or cancer, and current smoking was not positively associated with diabetes, cancer, kidney disease, hypertension and high cholesterol. If the measure of ever having smoked was substituted for current smoking, the latter five chronic conditions were all significantly higher among those who ever smoked.

For all combinations of MCCs and composite RF measures lowest rates for the MCC were among adults reporting none of the RFs and each additional RF significantly increased the percentage of adults reporting the MCC (Table 3 & Fig. 1). The Figure includes bars for all 3 combinations and trend lines representing the least-squares fit for the 2 combinations that are based on the same 17 measures, representing different assignments to MCCs and RFs. Formulas for those 2 trend lines show slopes that are almost identical, each rounding to 9.7, but with quite different Y intercepts. Not shown are results indicating that for the measure composed of 5 RFs, 82.9% of respondents with just one RF reported inadequate fruit and vegetable consumption and for the measure with 9 RFs, 69.2% with just one RF did. Table 3 results were confirmed by logistic regression (Table 4) with adjusted odds ratios (OR) > 100 for MCC8 among adults with all 9 RFs. When the logistic regression was repeated with separate RFs rather than the composite measures, the only separate RF that did not have ORs > 1.0 in all

adjusted results was inadequate fruit and vegetable consumption. Other ORs for the separate risk factors were between 1.3 (CI 1.3–1.4) for sedentary lifestyle and 3.6 (CI 3.5–3.8) for depression. ORs for "any vs. none" of the RFs were 2.0 and 2.1 for the measure with 5 RFs and 4.3 for the measure with 9 RFs (Table 4).

4. Discussion

Results of this study of MCCs show that for different combinations of chronic conditions and as many as 9 RFs, each additional risk factor, beginning with 1, increased the likelihood of MCCs up to > 80% for adults with all 9. Linear least squares regression lines for the unadjusted results (Fig. 1) for the MCC with 12 chronic conditions and 5 RFs and the MCC with 8 chronic conditions and all 9 RFs have virtually identical, relatively steep slopes. Both RFs and chronic conditions are very common with > 96% of all adults reporting any of the former and 71.5% reporting at least one of the latter. Results were similar for all combinations whether diabetes, hypertension, high cholesterol, and depression were considered as RFs or as chronic conditions. Adjusted ORs also increased step-wise with each added RF, with ORs > 100 for an MCC based on 8 chronic conditions among the few reporting all 9. This appears to be a unique finding as among other studies that included RFs (Willadsen et al., 2016; Barile et al., 2015) we found none that studied this many risk factors or reported such dose-response gradients for RFs and rates of MCCs.

All 9 of the RFs appeared to be important. First, our results showed unadjusted associations between all except 2 of the 95 possible combinations of separate risk factors and chronic conditions. Secondly, logistic regression results indicated that 8 of the 9 separate risk factors were consistently associated with higher odds of MCCs. The one exception was inadequate fruit and vegetable consumption which was associated with arthritis, CVD, COPD, CI, diabetes, high blood pressure, depression, kidney disease and high cholesterol but not asthma or cancer. Eating fruits and vegetables < 5 times/day also had OR > 1.0 for logistic regression with MCC12 as the outcome and each of the 5 RFs entered separately in the model. In addition, inadequate fruit and vegetable consumption was also the most prevalent risk factor and most likely to be reported by adults with only 1 RF. Results clearly showed that the increase in RFs from 0 to 1 significantly increased the likelihood of each MCC, providing more evidence of the importance of this RF. Results showing that adults with none of the 9 RFs had the lowest rates of MCCs were also consistent with these findings. Highest ORs varied by combination of MCC and RFs but included depression, obesity, and smoking. No attempt was made to determine the model with the best fit; our desire was simply to confirm that potential demographic confounders were not the cause of these results. Future studies can add more variables and interaction terms.

With the exception of gender and sometimes age, other demographic results were quite consistent between risk factors and MCCs. For example high rates of both RFs and MCCs were found for American Indians/Alaska Natives, those with less education, lower income, the disabled, and those reporting a cost barrier to health care. The only result that was not confirmed by logistic regression was the similarity in MCC rates for blacks and non-Hispanic whites, where logistic regression consistently showed lower ORs for blacks. While age was a strong predictor of MCCs, 8 of 9 separate risk factors still had ORs > 1.0 with age included in the model. Because these results are from a cross sectional survey, causation cannot be proven but there have been ample other studies showing associations between these risk factors and many of the separate chronic conditions. (Brownson et al., 2010; Barnes and Yaffe, 2011; Baumgart et al., 2015)

The highest rates of MCCs among the subgroups examined were for disabled adults, among whom 82.0% reported MCC12, which was similar to the rate for that MCC among adults with all 5 RFs (76.5%). Also of note were findings that adults with barriers to healthcare were much more likely than those without such barriers to report MCCs. That result
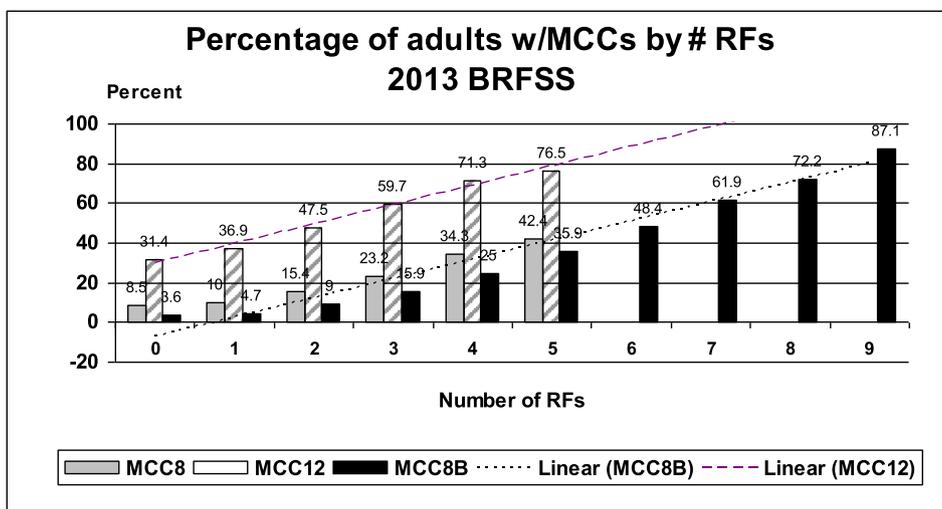
Percentage of adults w/MCCs by # RFs 2013 BRFSS

Fig. 1. Percentage of adults with multiple chronic conditions by number of risk factors, 2013 Behavioral Risk Factor Surveillance System, N ~390,000; data from Table 3 in text.

Abbreviations: MCC: multiple chronic conditions; RF: Risk factors;

BRFSS: Behavioral Risk Factor Surveillance System

5 risk factors: Obesity, sedentary lifestyle, sleeping ≠ 7-8 hours, fruits and vegetables < 5 X/day, smoking.

9 risk factors: 5 RFs plus diabetes, hypertension, high cholesterol, and depression.

Graph key explained

MCC8: Asthma, arthritis, heart disease, stroke, COPD, cognitive impairment , cancer, kidney disease vs. 5 RFs

MCC12: MCC8 plus diabetes, depression, hypertension, high cholesterol vs. 5 RFs.

MCC8B: MCC8 vs. 9 RFs

Summary: Formula is the formula for the linear trend line; trend lines are shown only for selected measures

MCC	Formula	R^2	# RF
MCC8	Y=7.1486x-2.72	0.9532	5
MCC12	Y=9.74x+19.793	0.9862	5
MCC8B	Y=9.6782x-16.86	0.9625	9

Note that the trend lines shown for MCC8B and the 9 risk factor measure and MCC12 and the 5 RF measure are based on the same measures which are just assigned differently.

has important implications for effective long term management of MCCs and the availability of health care coverage for adults ages 18–64 with MCCs.

While multiple risk factors have been well documented for cardiovascular disease, this study adds new information about additional risk factors and outcomes. These results suggest that primary prevention that added the risk factors of depression and too much or too little sleep, and the outcomes of arthritis, asthma, cancer, COPD, CI, and kidney disease might be worth pursuing. A key finding was the similarity of results whether high blood pressure, high cholesterol, depression, and diabetes were considered chronic conditions or risk factors. These results are consistent with results (Adams and Grandpre, 2016) for the outcomes of cognitive decline, and dementia with a similar measure of RFs and have important implications for primary prevention. Together, these results indicate that many of the risk factors which increased risk of CVD also increase the likelihood of a wide range of chronic conditions whether separately or co-occurring. Thus any primary prevention that has been effective for CVD might reduce the risk of dementia and other chronic conditions.

These results have significant implications for the potential reduction of health care costs. It has been estimated that adults with 4 or more chronic conditions (17.1% of all adults in our study) are responsible for 77.6% of all health care costs (Thorpe et al., 2015) with the rise in obesity being a significant contributing factor to increasing costs. Others (Ormond et al., 2011) estimated the potential savings by reducing just 2 RFs (diabetes and hypertension) and their related comorbidity at $9 billion annually in the short term and closer to $25 billion a year in the medium term. In addition to affecting overall healthcare costs, individual access to healthcare may be affected by the presence of one or more of the chronic conditions included in these MCCs. Although insurers decide what qualifies as a pre-existing condition, all the chronic conditions used in this study except CI are commonly included. Individuals with a pre-existing condition could be denied coverage or face higher premiums (Claxton et al., 2016). While having a pre-existing condition might not affect coverage for adults eligible for Medicare, over half of all adults with MCCs are ages 18–64 years (Willadsen et al., 2016; Adams, 2017a).

Strategies to achieve reductions in the wide range of chronic conditions that define MCCs will likely involve addressing multiple risk factors simultaneously and through various channels. Revising messages of existing public health programs to emphasize that outcomes such as CI and dementia (Adams and Grandpre, 2016) are also being targeted may help in motivating behavior change. General internists and family practitioners should be involved, as they are trained to treat the whole patient. One study of mortality among older adults in Australia (Hirani et al., 2014) concluded that addressing multiple risk factors in primary care was better at extending survival than addressing the individual RFs. A long-term primary prevention program in Finland that addresses the multiple risk factors of smoking, hypertension, and high cholesterol among middle aged adults has lowered heart disease mortality by > 80% since 1972 (Jousilahti et al., 2016). It is hoped that similar success could be achieved by targeting groups of these 9 RFs, resulting in fewer MCCs and lower associated health care costs.

Study limitations and strengths.

There are several limitations to this study. Only non-institutionalized adults are surveyed so adults in long term care who may

Table 4

Adjusted odds ratios (OR) and 95% confidence intervals (CI) for selected multiple chronic condition (MCC) measures[a,b], with either 5[c] or 9[d] risk factors (RFs) and adjusted for all measures listed, 2013 Behavioral Risk Factor Surveillance System; N ~380,000.

Measure	MCC8[a] & 9[d] RFs		MCC8[a] & 5[c] RFs		MCC12[b] & 5[c] RFs	
	OR	95% CI	OR	95% CI	OR	95% CI
Males (referent)						
Females	1.3	1.3, 1.4	1.3	1.3, 1.4	1.1	1.1, 1.1
Age 18–24 years (referent)						
Age 25–34 years	1.3	1.1, 1.6	1.6	1.4, 1.8	1.6	1.4, 1.8
Age 35–44 years	1.7	1.5, 2.1	2.5	2.2, 2.8	2.6	2.3, 2.9
Age 45–54 years	2.7	2.3, 3.2	4.5	4.0, 5.1	4.9	4.4, 5.4
Age 55–64 years	4.0	3.4, 4.8	7.7	6.8, 8.7	10.4	9.4, 11.5
Age 65–74 years	5.8	4.9, 6.8	11.6	10.2, 13.1	19.0	17.1, 21.2
Age 75 + years	9.3	7.8, 11.0	17.2	15.2, 19.6	24.7	22.2, 27.6
White non-Hispanic (referent)						
Black non-Hispanic	0.8	0.7, 0.8	0.8	0.8, 0.9	0.9	0.9, 1.0
Hispanic	0.5	0.5, 0.6	0.5	0.5, 0.6	0.7	0.6, 0.7
Am Ind/AK native	1.2	1.0, 1.4	1.2	1.0, 1.4	1.2	1.0, 1.4
Other	0.8	0.7, 1.0	0.8	0.8, 1.0	0.9	0.8, 1.0
College graduate (referent)						
Some college	1.3	1.2, 1.4	1.4	1.3, 1.4	1.3	1.2, 1.3
High School graduate	1.1	1.1, 1.2	1.2	1.1, 1.3	1.2	1.1, 1.3
< High School	1.4	1.3, 1.6	1.6	1.5, 1.7	1.5	1.4, 1.7
> $75,000 income (referent)						
$50 K-$74,999	1.3	1.2, 1.4	1.3	1.2, 1.4	1.2	1.2, 1.3
$25 K-$49,999	1.6	1.5, 1.7	1.6	1.6, 1.8	1.4	1.3, 1.4
$15 K-$24,999	2.2	2.1, 2.4	2.5	2.3, 2.7	1.9	1.8, 2.0
< $15,000 income	3.3	3.1, 3.6	3.9	3.6, 4.2	2.8	2.6, 3.1
Unknown income	1.7	1.6, 1.8	1.8	1.7, 1.9	1.3	1.2, 1.4
0 risk factors (RFs: referent)						
1 risk factor	1.3	1.1, 1.6	1.2	1.1, 1.3	1.3	1.2, 1.4
2 risk factors	2.3	1.9, 2.7	1.9	1.7, 2.1	2.1	1.9, 2.3
3 risk factors	3.7	3.1, 4.4	3.0	2.7, 3.3	3.4	3.1, 3.6
4 risk factors	5.7	4.8, 6.8	5.0	4.5, 5.5	5.7	5.2, 6.2
5 risk factors	9.1	7.6, 10.8	7.6	6.5, 8.9	7.7	6.4, 9.3
6 risk factors	14.6	12.2, 17.4				
7 risk factors	24.0	19.7, 29.2				
8 risk factors	38.1	29.6, 48.9				
9 risk factors	100.0	56.3, 177.8				
If any vs 0 entered in model						
Any vs. 0 of 5 RF[c]			2.0	1.8, 2.2	2.1	1.9,2.2
Any vs. 0 of 9 RF[d]	4.3	3.6, 5.1				
If separate RFs are entered instead of composite RF measures						
Smoking	1.6	1.6, 1.7	1.9	1.8, 2.0	1.6	1.5, 1.7
Sedentary lifestyle	1.3	1.3, 1.4	1.4	1.3, 1.4	1.3	1.3, 1.4
Sleep ≠ 7–8 h	1.6	1.5, 1.7	1.8	1.8, 1.9	1.6	1.5, 1.6
Fruit/veggies < 5 × / day	0.9	0.9, 1.0	1.0	0.9, 1.0	1.1	1.1, 1.2
Obese	1.4	1.3, 1.4	1.8	1.7, 1.8	2.5	2.4, 2.6
Diabetes	1.5	1.4, 1.6				
Depression	3.6	3.5, 3.8				
Hypertension	1.6	1.6, 1.7				
High cholesterol	1.5	1.4, 1.6				

Abbreviations: CI: confidence interval; MCC: multiple chronic condition; OR: adjusted odds ratio; RF: risk factor.

[a] MCC8: asthma, arthritis, chronic obstructive pulmonary disease, cognitive impairment, heart disease, stroke, cancer, and kidney disease.

[b] MCC12: MCC8 plus diabetes, depression, hypertension, high cholesterol.

[c] 5 risk factors: obesity, sedentary lifestyle, sleeping ≠ 7–8 h, eating fruits and vegetables < 5 times/day, current smoking.

[d] 9 risk factors: 5 risk factors plus diabetes, hypertension, high cholesterol, and depression.

be even more likely to have MCCs than those studied were excluded. Adults who are physically or mentally unable to respond to a survey are also excluded, which may omit some potential respondents with MCCs

(Adams, 2017b). Persons in households with no telephones are also excluded although it is unclear what affect that might have on results. Data are self-reported and reliability and validity can vary for different measures tested (Nelson et al., 2013; Pierannunzi et al., 2013). Risk factor measures such as smoking, height and weight used in obesity determination, sedentary lifestyle, and fruit and vegetable consumption were found to have moderate to high validity (Nelson et al., 2013). As long as a respondent was told they had a chronic condition, validity was good but some people may not be aware of a diagnosis (Pierannunzi et al., 2013). Validity of the sleep measure has not been assessed. Not addressed on the survey so not included in MCCs in this study are autism, hepatitis, HIV/AIDS, osteoporosis, psychotic disorders (CMS: Centers for Medicare and Medicaid Services, n.d.) and addiction or developmental disabilities (U.S. Department of Health and Human Services, n.d.) which are sometimes included.

There are some notable strengths of this study. Data are from a large population-based survey that includes non-institutionalized adults of all ages showing that the issue of MCCs is not confined to the elderly. Well validated data are available on 12 chronic conditions and 9 risk factors to allow multiple MCCs and composite measures of RFs to be studied. We were also able to study hypertension, high cholesterol, depression, and diabetes as both RFs and chronic conditions.

5. Conclusions

This study adds valuable information about MCCs with as many as 12 chronic conditions and 9 risk factors that was not available from earlier studies. Results found associations between composite measures of MCCs that could include arthritis, asthma, cancer, CVD, COPD, diabetes, kidney disease, cognitive impairment, diabetes, depression, high blood pressure and high cholesterol and the risk factors of smoking, sedentary lifestyle, inadequate fruit and vegetable consumption, sleeping other than 7–8 h/24 h, and obesity plus the latter 4 chronic conditions which could also be considered RFs. The similarity of the results whether diabetes, hypertension, depression and high cholesterol are defined as risk factors or chronic conditions is striking. The dose-response gradients are impressive, as is the result that having any one of the risk factors significantly increases the likelihood of each MCC. All 9 risk factors appear to be important and are very prevalent in the US population with 96% of all adults reporting at least one. These findings suggest that progress in reducing MCCs and their associated healthcare costs might be possible through effective interventions targeting multiple risk factors.

Transparency document

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Conflict of interest

The authors declare there are no conflicts of interest.

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