Metabolic syndrome and chronic disease

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Abstract

Introduction: Metabolic syndrome (MetS) is a combination of risk markers that appear to promote the development of chronic disease. We examined the burden of MetS in Canada through its current and projected association with chronic disease.

Methods: We used measures from the Canadian Health Measures Survey 2007–2009 to identify the prevalence of MetS in Canadian adults and examine associations between sociodemographic factors and major chronic diseases. We estimated the projected cumulative incidence of diabetes and percent risk of a fatal cardiovascular event using the Diabetes Population Risk Tool (DPoRT) and Framingham algorithms.

Results: After adjusting for age, we found that 14.9% of Canadian adults had MetS. Rates were similar in both sexes, but higher in those who are non-Caucasian or overweight or obese ($p < .001$ for all three). The importance of MetS for public health was demonstrated by its significant association with chronic disease relative to the general population, particularly for diagnosed (11.2% vs. 3.4%) and undiagnosed (6.0% vs. 1.1%) type 2 diabetes. The ten-year incidence estimate for diabetes and mean percent risk of a fatal cardiovascular disease (CVD) event were higher in those with MetS compared to those without (18.0% vs. 7.1% for diabetes, and 4.1% vs. 0.8% for CVD).

Conclusion: MetS is prevalent in Canadian adults and a high proportion of individuals with MetS have diagnosed or undiagnosed chronic conditions. Projection estimates for the incidence of chronic disease associated with MetS demonstrate higher rates in individuals with this condition. Thus, MetS may be a relevant risk factor in the development of chronic disease.

Introduction

The vast majority of patients in the Canadian healthcare system are living with one or more chronic diseases.[1] Cardiovascular disease, chronic obstructive pulmonary disease, cancer and diabetes are the most common causes of hospitalization and premature death in Canada, accounting for almost three-quarters of all deaths.[2] Together, these chronic diseases account for 80% of primary care visits and more than two-thirds of medical costs.[1,3] Knowing more about the risk factors and indicators for chronic disease may, therefore, help public health efforts aimed at addressing this growing concern.

Metabolic syndrome (MetS) is a condition that describes the clustering of risk markers that increase an individual's likelihood of developing chronic disease.[4] A number of leading chronic conditions have been shown to be associated with MetS. These include cardiovascular disease (CVD)[5], type 2 diabetes,[6] cancers,[7] and chronic kidney disease (CKD)[8].

The growing prevalence of obesity and sedentary lifestyles contributes to the prevalence of MetS.[9-11] While the pathogenesis of MetS may be attributed to obesity and metabolic susceptibility,[12] a variety of socioeconomic factors have also been shown to influence the prevalence of MetS. For example, Canadian adults with a postgraduate degree had half the odds of acquiring MetS compared with those who have completed high school (odds ratio [OR] = 0.45, 95% confidence interval [CI]: 0.25–0.81).[13] Ethnicity also affects observed prevalence rates (OR = 0.54, 95% CI: 0.4–0.73 in non-Hispanic Blacks relative to non-Hispanic Whites).[14] Considering differences based on ethnicity has resulted in a variety of official MetS definitions being sanctioned by international health authorities.[4,15,16] MetS has also been described as a progressive disorder; the several components of MetS tend to worsen over time and collectively contribute to an increased risk for chronic disease.[17]

Hivert et al.[18] demonstrated the utility of MetS as a relevant public health tool. Using electronic health records to identify and track patients with MetS for future development of CVD and diabetes, they showed that patients with MetS had a higher incidence of these chronic conditions and incurred higher healthcare costs than did those patients without MetS.[18] This signifies an important role for MetS as a chronic disease indicator that could benefit individual health as well as healthcare costs and resources.[18] The limited availability of prevalence estimates derived from Canadian data to date has meant that international estimates are often used instead. It is therefore important to develop Canadian findings on MetS and its association with chronic conditions.

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In this study, our aim was to (1) estimate the prevalence of MetS in the Canadian adult population; (2) examine the relationship between MetS, risk factors and chronic disease; and (3) characterize the future risk of chronic diseases associated with MetS through measures of undiagnosed disease, as well as through 10-year projections for diabetes and CVD, using established prediction tools.

Methods

Data source

We used data from the 2007–2009 Canadian Health Measures Survey (CHMS).[19] This cross-sectional survey, conducted by Statistics Canada, recruited a representative sample of 5600 Canadians aged 6 to 79 years, which covers about 96.3% of the Canadian population. The survey used a mobile examination clinic to measure, for example, participants' blood pressure (BP) and serum factors. Information about current health status, socioeconomic variables, etc., was gathered through a general household interview.[19] Statistics Canada provides weights for each participant that capture the number of people represented by that participant in the population and account for non-response and the demographic distribution of the population. Additional information on sampling and estimations is described elsewhere.[20,21]

Study population

Some of the CHMS study participants (n = 2634) were asked to fast before the tests at the mobile examination clinic; we used data from this subsample in this study. The response rate for this subsample was 85.2%, which when combined with the overall response rate for the CHMS, makes the overall fasting subsample response rate 46.3%.[19,20,22] Pregnant women (n = 8) and individuals aged under 20 years (n = 933) were excluded from the analysis, leaving a study population of 1693 participants. For analyses using this subsample, Statistics Canada provided separate weights, based on the 2006 Census, for fasting participants, to ensure that analyses in this restricted subpopulation would remain representa-

tive of the entire Canadian population. These weighting factors account for non-response and for the demographic distribution of the country. Missing values were removed prior to analyses.

To test for potential selection bias as a result of various exclusion criteria, we performed a sensitivity analysis to compare the baseline demographic status of our study population with national-level estimates. Comparing our study population with recent Canadian estimates, we found that our study population (Table 1) showed similar estimates for age,[23] education,[24] gender,[25] ethnicity[26] and income,[27] indicating that it is representative of the general Canadian population.

Key definitions

Metabolic syndrome
We used the revised National Cholesterol Education Program (rNCEP) Adult

TABLE 1
Characteristics of the study population (N = 1693)

Characteristics	N	%	95% CI
Sex			
Women	886	50.4	49.8–50.9
Men	807	49.6	49.1–50.2
Age, years			
20–39	536	37.8	37.1–38.4
40–59	603	41.3	40.8–41.8
60–80	554	20.9	20.6–21.2
Mean age (SE), years	45.3 (0.2)		
Cultural / ethnic background			
Caucasian	1441	84.3	74.2–94.4
Non-Caucasian	205	15.7[E]	5.6–25.8
Total household income, $			
≤ 29 999	290	14.6	11.6–17.7
30 000–49 999	324	18.4	16.3–20.5
50 000–79 999	400	26.4	22.5–30.3
≥ 80 000	583	40.6	33.6–42.9
Highest level of education			
Less than secondary	206	11.4	7.6–15.2
Secondary graduate	289	18.8	13.1–24.5
Some post-secondary / post-secondary graduate	1178	69.8	61.5–78.2
Smoking status			
Never smoked	810	45.7	41.8–49.5
Former smoker	553	31.2	27.9–34.5
Current smoker – daily or occasional	325	23.1	20.6–25.6
Leisure time physical activity			
Active / moderately active	800	44.3	37.2–51.5
Inactive	893	55.7	48.5–62.8
BMI, kg/m^2			
< 25	676	43.5	37.8–49.2
25–29	638	37.8	33.8–41.8
≥ 30	351	18.7	15.6–21.2

Source: Canadian Health Measures Survey, 2007–2009, clinic dataset.

Abbreviations: BMI, body mass index; CI, confidence interval; SE, standard error.

Notes: Missing data (not applicable, not stated, don't know) not included in calculation of proportions.

Percentages have been weighted using CHMS survey weights.

[E] Interpret with caution (coefficient of variation: 16.6%–33.3%).

Treatment Panel III definition for MetS, which uses revised waist circumference criteria.[4] We also examined prevalence rates of MetS using the International Diabetes Federation (IDF) and Harmonized definitions.[15,16]

Undiagnosed and diagnosed chronic conditions

In the absence of any longitudinal data to determine whether individuals with MetS may develop chronic diseases with time, we determined whether participants may have had an undiagnosed condition. This is treated as a proxy measure for future chronic disease risk. Participants were deemed to have a particular condition undiagnosed if they said that they did not have the condition but had measurable physical attributes of the condition.

Diagnosed hypertension was based on a positive response to the question ''Do you have high blood pressure?'' or from self-reported use of specific medications (list available from the authors on request). Average systolic BP and diastolic BP were derived from an average of six blood pressure measurements.[22,28,29] We determined that individuals had undiagnosed hypertension if they reported no diagnosed hypertension but had BP readings above 140/90 mmHg (for either reading).

Diagnosed diabetes (type 2) was based on positive responses to the questions, ''Do you have diabetes?'' and ''Were you diagnosed with non-insulin dependent diabetes (type 2)?'' or from self-reported use of specific medications (list available from the authors on request).[22] As with BP, we determined that individuals had undiagnosed diabetes if they gave a negative response to questions about having physician-diagnosed diabetes but their fasting plasma glucose levels measured at 7.0 mmol/L or more. Individuals with type 1 diabetes were not included in the analysis.

Diagnosed CKD was based on a positive response to the question ''Do you suffer from kidney dysfunction or disease?''[22] Undiagnosed CKD was based on a negative response to this question plus either a low measured glomerular filtration rate ($\leq$ 60 mL/min using the Modification of Diet and Renal Disease Study equation[30]) or a high measured microalbumin to creatinine ratio (> 2.65 mg/mmol).

Diagnosed dyslipidemia was based on a positive response to the question ''Have you ever been told by a health professional that your blood cholesterol was high?''[22] Undiagnosed dyslipidemia was based on a negative response to this question plus the participant either meeting both the total cholesterol to high density lipoprotein (HDL) ratio ($\geq$ 5.5 in men, $\geq$ 4.5 in women) and low density lipoprotein (LDL) criteria ($\geq$ 3.5 mmol/L) or using appropriate medications (list available from the authors on request).

Descriptive variables

Analyses are described by sex, age (at clinic visit), education, ethnicity (self-reported cultural or racial group, not including Aboriginal populations) and total household income. Lifestyle factors include measured body mass index (BMI) and self-reported leisure time physical activity and smoking status.[19]

Analysis

We undertook multivariate analyses using statistical software SAS Enterprise Guide 4.1 (Cary, NC, US).[31] National estimates were calculated with the CHMS weights for the subsample of the population who had fasted and were age-adjusted using Canadian Census data. We calculated variance estimates using Statistics Canada Bootvar software (Statistics Canada, Ottawa, ON) and followed their reporting guidelines. Horvitz-Thompson estimation was used to analyze statistical significance following a t distribution with 11 degrees of freedom.

We examined prevalence estimates using the frequency procedure on SAS Enterprise Guide 4.1, and adjusted for these as described for individual reported estimates in the Results section. OR estimates were calculated from logistic regression models and adjusted for age and sex, where mentioned. Ten-year cumulative incidence projections for type 2 diabetes were estimated using the Diabetes Population Risk Tool (DPoRT).[32]

Originally developed using the National Population Health Survey, this prediction tool uses commonly collected survey data, such as self-reported estimates for health behaviours and sociodemographic factors, to predict the risk of developing incident physician-diagnosed diabetes. Sex-specific Weibull survival models were used to create DPoRT for individuals without diabetes mellitus, who are not pregnant and who are aged over 20 years. Predictive variables used in the model include age, sex, self-reported ethnicity, self-reported BMI, immigrant status (for women), education, smoking status and history of hypertension and heart disease, all of which were available for our analysis.[32]

We used the lipid-based Framingham 10-year risk calculator to estimate the risk of a fatal general CVD event, defined as either coronary death, myocardial infarction, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, transient ischemic attack, peripheral artery disease or heart failure. This risk prediction tool was originally created using data from the Framingham Heart Study and Framingham Offspring Study. Sex-specific Cox proportional hazards regressions were used to relate various risk factors to the incidence of fatal general CVD events. Mathematical CVD risk functions derived from this were then used in the development of the Framingham Risk Tool. Results are presented as high risk ($\geq$ 20%) or intermediate and high risk ($\geq$ 10%). The population subset for CVD projections was restricted to individuals aged 30 to 74 years who had no previous history of a CVD event.[33]

Ethics approval

Approval to conduct our study was obtained from the Ottawa Hospital Research Ethics Board (Protocol # 20120767-01H) prior to commencement.

Results

The majority of the survey participants were Caucasian, physically inactive and former or current smokers. Most had at least some post-secondary education and an annual household income of more than $50 000. The mean age of the study

population was 45 years, and the population was equally represented by each sex (Table 1).

Participants were deemed to have MetS when they met three or more rNCEP MetS criteria, resulting in a crude prevalence of 15.5% and an age-adjusted prevalence of 14.9%. In the overall population, 34.9% had no MetS risk markers, whereas 29.5% had one and 20.2% had two. The most prevalent MetS risk markers among those identified as having MetS were waist circumference (89.2%), hypertriglyceridemia (82.3%), low HDL cholesterol (75.4%), high fasting plasma glucose (53.3%) and high systolic or diastolic BP (40.3%) (Figure 1).

The rNCEP estimates were compared to prevalence estimates based on the IDF and Harmonized definitions, both of which resulted in significantly larger prevalence estimates (crude prevalence: IDF = 23.1%, Harmonized = 19.6%; age-adjusted prevalence estimates: IDF = 22.3%, Harmonized = 19.1%) (Table 2).

The prevalence of MetS varied by age group, but the difference by sex for each age group was not statistically significant (Figure 2). Variation occurred according to smoking status as well, although these patterns varied by sex (Table 2). On the other hand, ethnic background significantly influenced prevalence rates, with people of non-Caucasian origin having a higher prevalence than those of Caucasian origin. For both sexes, a high BMI and being physically inactive were significantly associated with a higher prevalence of MetS.

The odds of MetS varied according to participant characteristics, and was significantly associated with being non-Caucasian and older (Table 2). Other characteristics were also significant, although this varied based on sex. For example, the odds of MetS was significantly associated with being a current smoker in women but not in men.

We examined the prevalence of chronic conditions across three population groups: the overall population, individuals with obesity (BMI $\geq$ 30 kg/m^2) and individuals with MetS. Undiagnosed disease was more prevalent in those with MetS compared with those with obesity or the overall study population for all conditions examined, and was most prominent for dyslipidemia (28.3% vs. 18.5% and 10.0%, respectively) (Table 3). Note that the rate of undiagnosed diabetes was more than five times higher in those with MetS than in the overall population (6.0% vs. 1.1%, $p = .009$; interpret with caution).

We estimated the future burden of type 2 diabetes and CVD that can be attributed to MetS using existing algorithms. The mean 10-year predicted risk of diabetes in individuals with MetS, as opposed to those without, is 18.0% (95% CI: 15.3–20.7) versus 7.1% (95% CI: 6.2–8.1). The proportion of Canadian adults anticipated to develop diabetes between 2007 and 2017 is thus 8.7% (95% CI: 7.5–9.9) (Figure 3). Similarly, the mean predicted risks for fatal CVD are 4.1% (95% CI: 2.3–6.0; interpret with caution) vs. 0.8% (95% CI: 0.6–1.0). The risk of CVD can be further analyzed as being high, that is, a 20% or higher risk of a CVD event in 10 years, or as intermediate to high, a 10% to 20% CVD risk in 10 years. The proportion of Canadian adults with MetS with a high risk of a CVD event is 6.81% (95% CI: 3.2–10.4, $p = .004$ relative to those without MetS; interpret with caution). Furthermore, the proportion of Canadian adults at intermediate to high risk of a CVD event is 8.9% (95% CI: 4.3–13.6; interpret with caution) in those with MetS, compared with 2.0% (95% CI: 1.3–2.7, $p = .008$) in those without MetS.

FIGURE 1
Prevalence of different metabolic syndrome risk markers in individuals with metbolic syndrome, CHMS 2007–2009
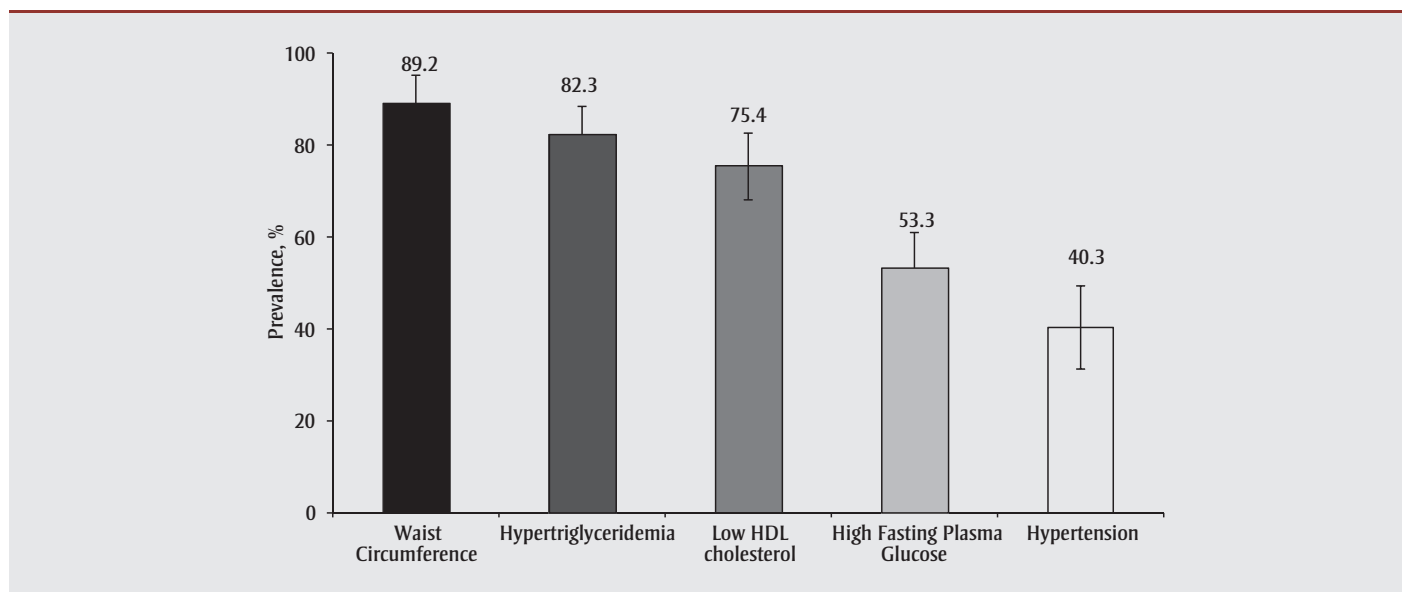
Abbreviation: HDL, high density lipoprotein.

TABLE 2
Metabolic syndrome prevalence and odds ratios according to population characteristics, CHMS 2007–2009

Definitions	Prevalence			Odds Ratios	
	%	95% CI	p value	OR	95% CI
rNCEP ATP III					
Crude	15.5	12.0–19.0	—		
Adjusted	14.9	13.3–16.6			
IDF					
Crude	23.1	20.4–25.8	< .001		
Adjusted	22.3	20.4–24.3			
Harmonized					
Crude	19.6	15.9–23.2	< .001		
Adjusted	19.1	17.3–20.9			
Characteristics					
Overall population					
Sex[a,b]					
Men (ref)	14.5	10.4–18.6	—	1	—
Women	16.5	12.6–20.3	.25	1.12	0.87–1.42
Ethnicity[a,b,c]					
Caucasian (ref)	15.5	12.1–18.8	—	1	—
Non-Caucasian	16.6[E]	5.4–27.7	< .001	2.66	1.29–5.45
Men					
Age[b]					
20–39 (ref)	8.0[E]	4.4–11.5	—	1	—
40–59	14.5[E]	6.7–22.4	.05	1.48	0.67–3.26
60–80	26.9	21.3–32.5	.012	3.33	2.07–5.34
Smoking status[a,b]					
Current	6.6[E]	2.0–11.1	.01	0.65	0.23–1.86
Former	24.1	15.5–32.7	.12	1.54	0.66–3.61
Never (ref)	11.4[E]	5.6–17.3	—	1	—
LTPA[a,b]					
Active (ref)	12.0	8.5–15.6	—	1	—
Inactive	16.9[E]	10.0–23.9	.001	1.39	0.69–2.78
BMI, kg/m^2 [a]					
< 25 (ref)	—[F]	—	—	1	—
25–29	15.8	10.4–21.2	< .001	—[F]	—
≥ 30	38.6	25.5–51.8	< .001	—[F]	—
Women					
Age[b]					
20–39 (ref)	—[F]	—	—	1	—
40–59	18.7[E]	11.7–25.7	.003	3.67	1.20–11.17
60–80	31.5	24.3–38.6	< .001	7.43	2.62–21.05
Smoking status[a,b]					
Current	21.1	13.6–28.5	.71	3.15	1.63–6.07
Former	21.3[E]	10.8–31.8	.38	2.06	0.93–4.59
Never (ref)	11.0	8.7–13.3	—	1	—

Discussion

Prevalence of metabolic syndrome

Comparing prevalence for MetS using the same rNCEP definition, the age-adjusted rate in Canada is less than half that reported in the United States (14.9% vs. 34.4%),[14] but similar to previously published findings for the Canadian population.[34] Using newly suggested IDF definitions, which take into account variations in waist circumference for different ethnic groups, or the Harmonized definition, the age-adjusted prevalence of MetS in Canada is higher than with the rNCEP (22.3% and 19.1%, respectively), showing that the choice of definition for MetS does appear to matter.

We chose to use the rNCEP definition for MetS in our study to facilitate comparisons with previously published epidemiological data.[14] The rNCEP definition was reasonably accurate in representing the ethnic composition of our study population (84% Caucasian; Table 1). While sample size limitations did not allow us to explore variations in MetS prevalence based on self-reported ethnic origin, when this information was used to apply the IDF definition of MetS, it appears as though more people are being included as having MetS.[15]

Risk factors and metabolic syndrome

Our findings indicate that the prevalence of MetS in Canada is associated with age, ethnicity, BMI and leisure time physical activity. Older age was significantly associated with MetS, but the patterns of prevalence varied by age and sex. Prevalence was higher in men than in women in the 30- to 39-year age group. Thereafter, the prevalence of MetS increases steadily in women, exceeding the prevalence of MetS in men, from age 40 through 60 to 74 years, after which time it levels off. In men, the steady increase in prevalence seems to occur after the age of 40. Tjepkema[35] suggested that this transition reflects the marked increase in rates of obesity in men after age 45 years. In the same study, Tjepkema[35] also showed that obesity rates increase steadily in women until age 65

TABLE 2 (continued)
Metabolic syndrome prevalence and odds ratios according to population characteristics, CHMS 2007–2009

Characteristics	Prevalence			Odds Ratios	
	%	95% CI	*p* value	OR	95% CI
LTPA[a,b]					
Active (ref)	10.5[E]	6.6–14.5	—	1	—
Inactive	20.2	15.4–25.0	< .001	1.76	1.13–2.73
BMI, kg/m² [a]					
< 25 (ref)	—[F]	—	—	1	—
25–29	22.9	16.1–30.0	< .001	—[F]	—
≥ 30	43.2	34.2–52.2	< .001	—[F]	—

Source: Canadian Health Measures Survey, 2007–2009, clinic dataset.

Abbreviations: BMI, Body Mass Index; CHMS, Canadian Health Measures Survey; CI, confidence interval; IDF, International Diabetes Federation; LTPA, leisure time physical activity; ref, reference; rNCEP ATP, revised National Cholesterol Education Program Adult Treatment Panel III.

Note: The adjusted prevalence estimate is age-adjusted to the Canadian Census information.

[a] Odds ratio adjusted for age.

[b] Odds ratio adjusted for BMI.

[c] Odds ratio adjusted for sex.

[E] Interpret with caution (coefficient of variation: 16.6%–33.3%).

[F] Cannot be reported (coefficient of variation: > 33.3%).

years. The changes in prevalence that we observed align with reported increased rates of MetS in peri- and post-menopausal women.[36]

The odds of MetS were significantly higher in non-Caucasian individuals, and we found greater risk of MetS in non-Caucasian Canadians than was found in Mexican American and non-Hispanic white individuals in the United States.[14] In addition to Hispanic and African Canadians, we included Filipino, Chinese, South Asian, Arab and other populations in our study. It is possible that the inclusion of these additional groups may account for the difference in the odds of MetS by ethnicity between the two studies. Previous findings using the rNCEP definition also showed higher prevalence rates in some of the ethnic groups included in our study relative to our overall population.[37,38]

Our results indicate that being physically active lowers the odds of MetS compared with being inactive, although this lower risk is only statistically significant in women. Our analysis clearly shows that rates of overweight and obesity are high in adults, with a prevalence of almost 57 %. This is of concern given the close association of obesity with MetS, as well as with pre-diabetes.[39]

MetS is commonly associated with pre-diabetes, wherein individuals have elevated plasma glucose levels as well as

FIGURE 2
Prevalence of metabolic syndrome by gender and by age group, CHMS 2007–2009
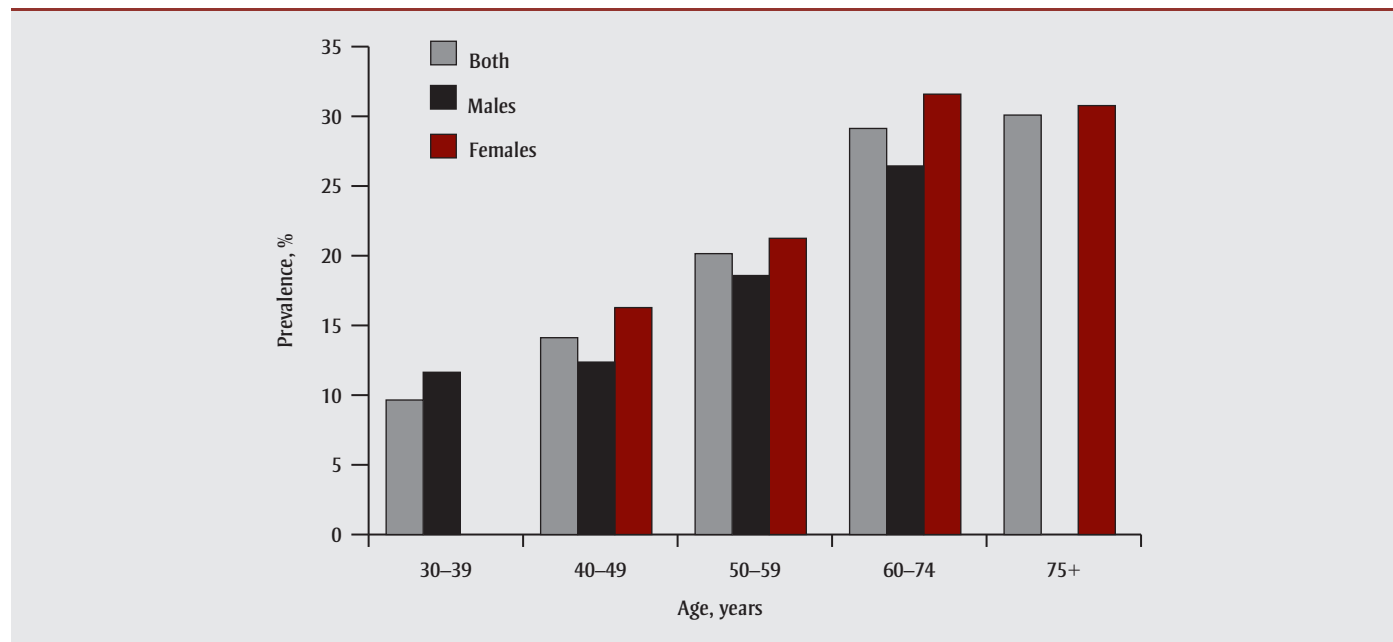
Source: Canadian Health Measures Survey, 2007–2009, clinic dataset.

Abbreviation: CHMS, Canadian Health Measures Survey.

Note: For all reported age groups, except for ages 60–74 years, estimates should be interpreted with caution (coefficient of variation: 16.6%–33.3%). Estimates that could not be reported (coefficient of variation: > 33.3%) were not included in the figure.

TABLE 3
Prevalence of diagnosed and undiagnosed chronic conditions in the overall population and in individuals with obesity and with metabolic syndrome, CHMS 2007–2009

	Overall		Obesity			Metabolic Syndrome			p value[b]
	%	95% CI	%	95% CI	p value[a]	%	95% CI	p value[a]	
Hypertension									
Diagnosed	17.2	14.2–20.1	33.6	25.2–41.9	.001	36.1	29.0–43.1	< .001	.61
Undiagnosed	0.7[E]	0.2–1.1	—[F]	—	—	—[F]	—	—	—
Diabetes									
Diagnosed	3.4	2.4–4.5	8.0	5.2–10.8	.003	11.2[E]	6.7–15.6	.003	.07
Undiagnosed	1.1[E]	0.6–1.7	4.4[E]	1.5–7.2	.02	6.0[E]	2.2–9.8	.009	.27
Chronic Kidney Disease									
Diagnosed	1.9	1.4–2.4	—[F]	—	—	4.0[E]	1.2–6.8	.13	—
Undiagnosed	10.0	8.1–11.9	15.2[E]	9.0–21.5	.11	22.2	14.9–29.5	.002	.10
Dyslipidemia									
Diagnosed	29.4	26.5–32.3	37.0	31.3–42.6	.02	50.8	46.6–55.1	< .001	< .001
Undiagnosed	10.0	6.9–13.1	18.5	12.3–24.7	.006	28.3	22.5–34.1	< .001	.006

Source: Canadian Health Measures Survey, 2007–2009, clinic dataset.

Abbreviations: CHMS, Canadian Health Measures Survey; CI, confidence interval.

[a] These p values represent the significance of the difference between population subgroups and the overall population.

[b] This p value represents the significance of the difference between population subgroups.

[E] Interpret with caution (coefficient of variation: 16.6%–33.3%).

[F] Cannot be reported (coefficient of variation: > 33.3%).

systemic inflammation. It is also associated with characteristics such as pro-thrombotic state and dyslipidemia, which may account for its link to cardiovascular risk.[40] The increased risk of type 2 diabetes and of a fatal CVD event in individuals with MetS is thus not surprising, given the research demonstrating these associations.[5,41] The proportion of individuals identified as being at risk of developing diabetes in the next 10 years, relative to those without MetS, indicates the role of MetS as a potential chronic disease indicator. These findings are corroborated by a 2010 study that estimated risk of diabetes for Canadians at 8.9%.[42] When considering the projections for CVD, which estimate the risk of a fatal event, the concern is clear.

We need to be aware of a possible overlap in definitions for chronic disease risk factors and for MetS. In the case of dyslipidemia, this overlap may contribute to the high rates of abnormal lipid levels in those with MetS. The risk marker of low HDL cholesterol was prevalent in 75% of the population with MetS, but it is worth noting that the definition of dyslipidemia was based on a high total cholesterol to HDL cholesterol ratio combined with elevated LDL levels. Similarly, MetS is defined based on waist circumference, not BMI, which makes both populations distinct but potentially related.

Public health impact of metabolic syndrome

Independent of race/ethnicity, age, sex and health status, evidence shows an increased risk of developing certain chronic diseases with each additional MetS risk marker.[41] Reaven[43] suggests that even though an individual may not meet the number of risk markers (3 or more) necessary to be diagnosed with MetS, they may still be at risk of future disease and should therefore not be overlooked. We found that 50% the study population had one or two MetS risk markers, by no means a small proportion.

We compared MetS with a well-studied chronic disease risk factor, obesity. Our findings demonstrated a higher prevalence of chronic disease in individuals with MetS compared with those with obesity (shown in Table 3), although the differences were not statistically significant. A previous study has described MetS as more predictive of future disease than obesity alone.[44] The greater association between chronic disease and MetS in our study may, therefore, further signify a public health utility for MetS as a key indicator of disease risk.

Limitations

Working with the CHMS data, sample size proved to be a limiting factor in providing reportable estimates for key covariates, such as for sociodemographic characteristics, and limited the scope of the study to a national viewpoint, since it is not built to produce regional estimates. Further, the use of self-reported information for activities such as smoking or leisure time physical activity may have proven to be a limitation. Due to the lack of pertinent variables to measure undiagnosed diabetes, our definition is limited in scope and interpretations should be made with caution. To limit the effects of confounders, BMI, age and sex were all controlled for in multivariate analyses. The removal of missing values may have contributed to a downward bias in our diabetes risk projections since the proportion of missing

FIGURE 3
Ten-year projections for the cumulative incidence of diabetes[a] and mean percent risk of a fatal CVD[b] event in individuals with or without MetS,[c] CHMS 2007–2009
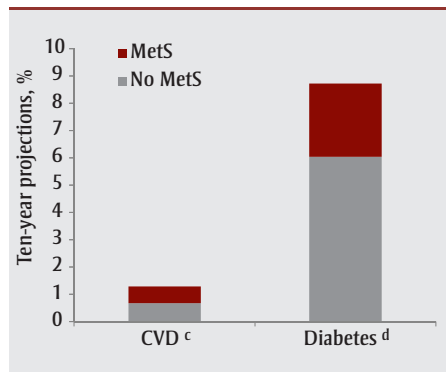
Source: Canadian Health Measures Survey, 2007–2009, clinic dataset.

Abbreviations: CVD, cardiovascular disease; CHMS, Canadian Health Measures Survey; CI, confidence interval; MetS, metabolic syndrome.

Note: Given the identified population prevalence of MetS among Canadian adults (85.1% without MetS, 14.9% with MetS), this suggests a projected 10-year risk of a fatal CVD event as 1.29%, and a projected 10-year cumulative incidence of diabetes as 8.7% (95% CI: 7.5–9.9).

[a] Estimated using the Diabetes Population Risk Tool (DPoRT).[32]

[b] Calculated using the lipid-based Framingham 10-year risk calculator.[33] The population subset for CVD projections was restricted to adults aged 30–74 years who have no previous history of a CVD event.

[c] Projections: With MetS = 4.1% (95% CI: 2.3–6.0), $p < .01$; without MetS = 0.8% (95% CI: 0.6–1.0), $p < .01$.

[d] Projections: With MetS = 18.0% (95% CI: 15.3–20.7), $p < .01$; without MetS = 7.1% (95% CI: 6.2–8.1), $p < .01$.

values for BMI tends to be higher among females. However, since missing values for women only represent a small proportion of all responses for BMI among females, their removal should not skew our results.

Conclusion

MetS represents a condition that is strongly associated with factors such as obesity, ethnicity and leisure time physical activity. Our study demonstrates the differential pattern by which MetS affects specific subpopulations and indicates an association between MetS and major chronic conditions.[45] Since Canadians with MetS have significantly higher rates of undiagnosed chronic diseases than the overall population and higher predicted rates of

future chronic disease, it may be of value for clinicians to include MetS, in addition to obesity, as an indicator for chronic disease and useful for public health policy-makers to consider MetS when directing preventive population health efforts.

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References

1. Morgan MW, Zamora NE, Hindmarsh MF. An inconvenient truth: a sustainable healthcare system requires chronic disease prevention and management transformation. Healthc Pap. 2007;7:6-23.

2. Mirolla M. The cost of chronic disease in Canada. Ottawa (ON): The Chronic Disease Prevention Alliance of Canada; 2004.

3. Rapoport J, Jacobs P, Bell NR, Klarenbach S. Refining the measurement of the economic burden of chronic diseases in Canada. Chronic Dis Can. 2004;25:13-21.

4. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation. 2002;106:3143-421.

5. Mottillo S, Filion KB, Genest J, et al. The metabolic syndrome and cardiovascular risk a systematic review and meta-analysis. J Am Coll Cardiol. 2010;56:1113-32.

6. Ford ES, Li C, Sattar N. Metabolic syndrome and incident diabetes: current state of the evidence. Diabetes Care. 2008;31:1898-904.

7. Esposito K, Chiodini P, Colao A, Lenzi A, Giugliano D. Metabolic syndrome and risk of cancer: a systematic review and meta-analysis. Diabetes Care. 2012;35:2402-11.

8. Chen J, Muntner P, Hamm LL, et al. The metabolic syndrome and chronic kidney disease in US adults. Ann Intern Med. 2004;140: 167-174.

9. Bonora E, Targher G, Formentini G, et al. The metabolic syndrome is an independent predictor of cardiovascular disease in type 2 diabetic subjects. Prospective data from the Verona Diabetes Complications Study. Diabet Med. 2004;21:52-8.

10. Cameron AJ, Shaw JE, Zimmet PZ. The metabolic syndrome: prevalence in worldwide populations. Endocrinol Metab Clin North Am. 2004;33:351-75.

11. Magliano DJ, Cameron A, Shaw JE, Zimmet PZ. Epidemiology of metabolic syndrome. In: Ekoé JM, Rewers M, Williams R, Zimmet P, editors. Epidemiology of diabetes mellitus. 2nd ed. Chichester (UK): Wiley-Blackwell; 2008. p. 31-49.

12. Grundy SM. Does a diagnosis of metabolic syndrome have value in clinical practice? Am J Clin Nutr. 2006;83:1248-51.

13. Riediger ND, Clara I. Prevalence of metabolic syndrome in the Canadian adult population. CMAJ. 2011;183:E1127-34.

14. Ervin RB. Prevalence of metabolic syndrome among adults 20 years of age and over, by sex, age, race and ethnicity, and body mass index: United States, 2003–2006. Natl Health Stat Report. 2009;13:1-7.

15. Alberti KG, Zimmet P, Shaw J. Metabolic syndrome - a new world-wide definition. A consensus statement from the International Diabetes Federation. Diabet Med. 2006;23:469-80.

16. Alberti KG, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009;120:1640-5.

17. Grundy SM. Metabolic syndrome: a multiplex cardiovascular risk factor. J Clin Endocrinol Metab. 2007;92:399-404.

18. Hivert MF, Grant RW, Shrader P, Meigs JB. Identifying primary care patients at risk for future diabetes and cardiovascular disease using electronic health records. BMC Health Serv Res. 2009;9:170.

19. Statistics Canada. Canadian Health Measures Survey data user guide: cycle 1. [Internet]. Ottawa (ON): Statistics Canada; 2011 [cited Jun 2012]. Available from: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/5071_D2_T1_V1-eng.htm

20. Statistics Canada. Canadian Health Measures Survey: definitions, data sources and methods - Appendix 9 Response rates [Internet]. Ottawa (ON): Statistics Canada; 2011 [cited Dec 2012]. Available from: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/chms-ecms-guide/app-ann9-eng.htm

21. Giroux S. Canadian Health Measures Survey: sampling strategy overview. Health Rep. 2007;18 Suppl:31-6.

22. Statistics Canada. Canadian Health Measures Survey (CHMS), cycle 01: Derived Variable (DV) Specifications [Internet]. Ottawa (ON): Statistics Canada; 2010 [cited Jun 2012]. Available from: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/5071_D3_T9_V2-eng.htm

23. Statistics Canada. Median Age - Age and Sex, 2006 counts for both sexes, for Canada, provinces and territories [Internet]. Ottawa (ON): Statistics Canada; 2010 [cited Dec 2012]. Available from: http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/hlt/97-551/pages/page.cfm?Lang = E&Geo = PR&Code = 01&Table = 2&Data = Count&Sex = 1&StartRec = 1&Sort = 2&Display = Page

24. Statistics Canada. Highest level of educational attainment for the population aged 25 to 64, 2006 counts for both sexes, for Canada, provinces and territories [Internet]. Ottawa (ON): Statistics Canada; 2010 [cited Dec 2012]. Available from: http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/hlt/97-560/pages/page.cfm?Lang = E&Geo = PR&Code = 01&Table = 1&Data = Count&Sex = 1&StartRec = 1&Sort = 2&Display = Page

25. Statistics Canada. Age and sex, 2006 counts for both sexes, for Canada, provinces and territories [Internet]. Ottawa (ON): Statistics Canada; 2010 [cited Dec 2012]. Available from: http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/hlt/97-551/pages/page.cfm?Lang = E&Geo = PR&Code = 01&Table = 1&Data = Count&Sex = 1&StartRec = 1&Sort = 2&Display = Page

26. Statistics Canada. Ethnocultural portrait of Canada [Internet]. Ottawa (ON): Statistics Canada; 2010 [cited Dec 2012]. Available from: http://www12.statcan.ca/census-recensement/2006/dp-pd/hlt/97-562/pages/page.cfm?Lang = E&Geo = PR&Code = 01&Table = 1&Data = Dist&StartRec = 1&Sort = 2&Display = Page

27. Conference Board of Canada. Canadian income inequality: is Canada becoming more unequal? [Internet]. Ottawa (ON): Conference Board of Canada; 2013 [cited Dec 2012]. Available from: http://www.conferenceboard.ca/hcp/hot-topics/caninequality.aspx

28. Campbell NR, Joffres MR, McKay DW, et al. Hypertension surveillance in Canada: minimum standards for assessing blood pressure in surveys. Can J Public Health. 2005;96:217-20.

29. Bryan S, Saint-Pierre Larose M, Campbell N, Clarke J, Tremblay MS. Resting blood pressure and heart rate measurement in the Canadian Health Measures Survey, cycle 1. Health Rep. 2010;21:71-8.

30. Miller WG. Estimating glomerular filtration rate. Clin Chem Lab Med. 2009;47:1017-9.

31. SAS Enterprise Guide 4.1 [software]. Cary (NC): SAS Institute Inc., 2006.

32. Rosella LC, Manuel DG, Burchill C, Stukel TA; PHIAT-DM team. A population-based risk algorithm for the development of diabetes: development and validation of the Diabetes Population Risk Tool (DPoRT). J Epidemiol Community Health. 2010;65:613-20.

33. D'Agostino RB Sr, Vasan RS, Pencina MJ, et al. General cardiovascular risk profile for use in primary care: the Framingham Heart Study. Circulation. 2008;117:743-53.

34. Ardern CI, Katzmarzyk PT. Geographic and demographic variation in the prevalence of metabolic syndrome in Canada. Can J Diabetes. 2007;31:34-6.

35. Tjepkema M. Adult obesity. Health Rep. 2006;17:9-25.

36. Polotsky HN, Polotsky AJ. Metabolic implications of menopause. Semin Reprod Med. 2010;28:426-34.

37. Xu WH, Ruan XN, Fu XJ, et al. Prevalence of the metabolic syndrome in Pudong New Area of Shanghai using three proposed definitions among Chinese adults. BMC Public Health. 2010;10:246.

38. Rojas R, Aguilar-Salinas CA, Jimenez-Corona A, et al. Metabolic syndrome in Mexican adults: results from the National Health and Nutrition Survey 2006. Salud Publica Mex. 2010;52:S11-8.

39. Weiss R, Dziura J, Burgert TS, et al. Obesity and the metabolic syndrome in children and adolescents. N Engl J Med. 2004;350:2362-74.

40. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome - An American Heart Association/National Heart, Lung, and Blood Institute scientific statement. Circulation. 2005;112:2735-52.

41. Ford ES. The metabolic syndrome and mortality from cardiovascular disease and all-causes: findings from the National Health and Nutrition Examination Survey II Mortality Study. Atherosclerosis. 2004;173:309-14.

42. Manuel DG, Rosella LC, Tuna M, Bennett C. How many Canadians will be diagnosed with diabetes between 2007 and 2017? Assessing population risk. ICES Investigative Report. Toronto (ON): ICES; 2010.

43. Reaven GM. The metabolic syndrome: requiescat in pace. Clin Chem. 2005;51:931-8.

44. Kip KE, Marroquin OC, Kelley DE, et al. Clinical importance of obesity versus the metabolic syndrome in cardiovascular risk in women: a report from the Women's Ischemia Syndrome Evaluation (WISE) study. Circulation. 2004;109:706-13.

45. Starfield B. The hidden inequity in health care. Int J Equity Health. 2011;10:15.