A Cross-national Comparison Study of Metabolic Syndrome among Canadian and Korean Older Adults

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Background: Metabolic syndrome (MetS) is a clustering of traditional cardiovascular risk factors including central obesity, dyslipidemia, insulin resistance, and hypertension. The prevalence of MetS increases risk of cardiovascular disease and type 2 diabetes and increases with age.

Purpose: To compare prevalence and correlates of MetS (and components) in Canadian and Korean older adults.

Methods: This study consisted of secondary data analysis, using data from the Canadian Health Measures Survey (CHMS) (cycle 1) and the Korea National Health and Nutrition Examination Survey (cycle 4). The study sample included adults aged 60 to 79 years and who provided fasting blood samples. To compare prevalence of MetS between countries, the same diagnostic criteria (Harmonizing definition) were used. Similar measures of potential explanatory variables for MetS, such as physical activity, dietary patterns, comorbidity, gender, household income adequacy, education, marital status, alcohol consumption, smoking, psychological distress, and duration of sleep were also used where possible. Univariate and multiple logistic regression models were used to examine the cross-sectional relationship between these study variables and MetS. Principal component and cluster analyses were conducted to derive dietary patterns.

Results: Included were 550 (weighted N=4,886,039) and 3,040 (weighted N=4,267,182) Canadians and Koreans aged 60 to 79 years, respectively. The prevalence of MetS was 42.0% and 52.2% in the Canadian and Korean sample, respectively ($p<.0001$). The prevalence of MetS in Korean women was 60.5% and explained the overall increased prevalence in the Korean sample. Results of the descriptive analysis, as well as the univariate and multiple logistic regression analyses indicated that the prevalence and pattern or joint distribution of explanatory variables differed across the two populations. In the Canadian sample, the final multivariate model comprised household income, marital status, alcohol consumption and psychological distress, with evidence of an interaction between adequacy of household income and marital status. In the Korean sample, the final multivariate model comprised comorbidity, gender, education, marital status, physical activity, and dietary pattern, with evidence of an interaction between comorbidity and marital status and between gender and education.

Conclusions: Findings of this study provided insight into possible underlying mechanisms that might lead to between-country differences in prevalence of MetS and to inconsistent measures of association between MetS and an individual factor like physical activity or dietary intake across studies.

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CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The metabolic syndrome (MetS) is a clustering of traditional cardiovascular risk factors, including central obesity, dyslipidemia, insulin resistance, and hypertension (Alberti et al., 2005). Compared to those without the syndrome, individuals with MetS have an elevated risk of type 2 diabetes (T2DM) and cardiovascular disease (CVD), with relative risks ranging from 1.7 to 3.0 (Laaksonen et al., 2002; Ford, 2005; Mottillo et al., 2010). Studies worldwide have consistently shown that prevalence of MetS increases with age. Using data from the National Health and Nutrition Examination Survey (NHANES) (2003-2006), Ervin (2009) reported that 52% and 54% of American men and women aged 60 years and over had MetS, relative to 41% and 37% of men and women aged 40-59 years. Recent data from the Canadian Health Measures Survey (CHMS) also showed that approximately 40% of adults aged 60 years or older had MetS, while 27% of adults aged 50-59 years had the syndrome (Riediger & Clara, 2011). Older adults in Asian countries also have a higher prevalence of MetS than their younger counterparts. A nationwide Japanese study showed that 27% of elderly women aged 65 years or over had MetS compared with 9.0% of middle-aged women (Arai et al., 2010). Data from the 2005 Korea National Health and Nutrition Examination Survey (KNHANES III) indicated that individuals aged 70 and over had the highest prevalence of MetS (52.7%) of all age groups (Korean Ministry of Health Welfare, 2006). Using KNHANES 2001 to 2007 data, Lim et al. (2011) reported that women aged 60 to 79 years had a higher prevalence of MetS (ranging from 55% to 65%) compared with men (ranging from 37% to 40%). Several studies have suggested that the higher prevalence of MetS in older adults may be associated with age-related central obesity, muscle mass loss, increase in insulin resistance and glucose tolerance, and age-related alterations in vascular structure and function (Scuteri et al., 2004; Guillet & Boirie, 2005; Sahyoun et al., 2006; Lee & Oh, 2010; Yang et al., 2012).

Public health strategies to prevent MetS in older adults have primarily focused on modifiable risk factors such as physical activity and dietary intake (Ross & Després, 2009; Petrella et al., 2005; Katzmarzyk et al., 2003; Lutsey et al., 2008; Rumawas et al., 2009). However, there are few empirical studies that have examined the link between physical activity, diet, and MetS in older adults (Sahyoun et al., 2006; Wannamethee et al., 2006). Further, the results of population-based studies that have examined the association between physical activity, diet, and MetS have been inconsistent. Using data from NHANES (1999-2000 and 2001-2002), a recent study found that self-reported physical activity, participation in resistance training, and moderate intensity physical activity were unrelated to presence of MetS among American adults aged 50 years and older (Sénéchal et al., 2012). By contrast, population-based studies in Korea and Poland have shown an inverse relationship between level of physical activity and prevalence of MetS among older adults (Choi et al., 2013; Sygnowska et al., 2012). Similarly, a prospective study conducted in the United States (U.S.) reported that the consumption of fresh fruits, vegetables, and fish was unrelated to MetS (Lutsey et al., 2008), while results from the KNHANES (cycle 2001 and 2005) showed an inverse relationship between grain, vegetables, and fish dietary pattern, once adjusting for major covariates (Kim & Jo, 2011). Two additional American studies also reported conflicting findings. Zhu et al. (2004) found that carbohydrate intake was associated with MetS among men only, while Sénéchal et al. (2012) found no statistically significant association between carbohydrate intake and MetS among women and men.

The primary objectives of this study were : 1) to compare prevalence of MetS (and individual components) between Canada and Korea in adults aged 60 years or over, using the same diagnostic criteria; 2) to compare prevalence of physical activity, dietary patterns, and other known risk factors for MetS between Canada and Korea, using comparable measures where possible; 3) to examine whether the pattern or interrelationships among MetS and physical activity, dietary pattern, and other risk factors vary between countries.

In this thesis, Chapter 2 will review the evolution of MetS and the literature on potential risk factors of MetS, and Chapter 3 will provide the rationale and study aims and hypotheses. Next, Chapter 4 and 5 will present the study methodology and results, respectively. This will then be followed be a discussion of the findings in Chapter 6. Final conclusions are given in Chapter 7.

CHAPTER 2 LITERATURE REVIEW

This literature review explored the evolution of metabolic syndrome and its associated effects on CVD and T2DM. Three broad categories of factors that may be associated with MetS were also reviewed. These categories were biomedical, biosocial, and psychosocial and adapted from this thesis's guiding conceptual framework, the Concentric Biopsychosocial Model of Health Status (Hoffman & Driscoll, 2000), the guiding conceptual framework of this thesis.

2.1 Evolution of Metabolic Syndrome (MetS)

2.1.1 Definitions of MetS

In 1988 Reaven introduced Syndrome X, described as a cluster of symptoms and signs, including glucose intolerance, insulin resistance, hyperinsulinemia, dyslipidemia, and hypertension. In 1998, the World Health Organization (WHO) proposed the first operational definition of Syndrome X (WHO, 1999), and changed the name Syndrome X to MetS. The WHO definition included insulin resistance, obesity, hypertension, reduced high-density lipoprotein cholesterol (HDL-C), elevated glucose level and triglyceride, and microalbuminuria. The presence of insulin resistance plus two or more of the other five factors met the diagnostic criteria for MetS (Table 1). In 1999, the European Group for Study of Insulin Resistance (EGIR) modified the WHO definition (Balkau & Charles, 1999). The EGIR changed the name from MetS to insulin resistance syndrome (IRS) and suggested the following revised set of criteria: insulin resistance plus two of 5 other factors, including central obesity, hypertension, reduced HDL-C, and elevated glucose and triglyceride level (Balkau & Charles, 1999) (Table 1).

While both WHO and EGIR definitions emphasized insulin resistance, the EGIR included waist circumference in place of Body Mass Index (BMI) or waist-to-hip ratio (WHR) for obesity. The EGIR considered waist circumference to be a better indicator of abdominal adiposity (Balkau & Charles, 1999). The EGIR also excluded microalbuminuria from the criteria because there was inconclusive evidence demonstrating the association between microalbuminuria and insulin resistance (Balkau & Charles, 1999). Further, the EGIR definition of IRS excluded individuals with T2DM, whereas the WHO definition of MetS included both diabetic and nondiabetic populations. In 2001, the National Cholesterol Education Programs Adult Treatment Panel III (NCEP ATP III) proposed another definition of MetS, where no single factor was necessary for diagnosis (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). The NCEP ATP III diagnostic criteria for MetS were the presence of three or more of the following conditions: abdominal obesity, elevated triglyceride, reduced HDL-C, elevated blood pressure, and elevated fasting glucose. Compared to the WHO and EGIR definitions, the NCEP ATP III proposed different cut-off points for high blood pressure (i.e., systolic blood pressure: SBP ≥ 130 mmHg; diastolic blood pressure: DBP ≥ 85 mmHg), HDL-C (i.e., < 1.0 mmol/L in men; < 1.3 mmol/L in women), and waist circumference (i.e., ≥ 102 cm in men; ≥ 88 cm in women) (Table 1).

Shortly thereafter, two additional diagnostic criteria for MetS were proposed by the American Heart Association/ the National Heart, Lung, and Blood Institute (AHA/NHLBI) (Grundy et al., 2005) and the International Diabetes Federation (IDF) (Alberti et al., 2005), respectively (Table 1). Consistent with the EGIR and NCEP ATP III criteria, both the AHA/NHLBI and IDF criteria recommended the use of fasting plasma glucose, but lowered the cut-off point (i.e., ≥ 6.1 mmol/L to ≥ 5.6 mmol/L). These two definitions also proposed to include individuals who were excluded from previous definitions, that is, those treated for glucose, triglyceride, or HDL-C abnormalities (Table 1). Another major difference was that both the AHA/NHLBI and IDF criteria adopted racial/ethnic-specific thresholds for waist circumference. The AHA/NHLBI criteria established separate thresholds for Asian American men and women (i.e., ≥ 90 cm in men; ≥ 80 cm in women) (Table 2), whereas the IDF criteria established separate thresholds for several ethnic groups such as Europids, South Asians, Chinese, and Japanese (Table 2). It should be noted that the IDF and AHA/NHLBI definitions differed in terms of the importance of central obesity to the diagnosis of MetS (Alberti et al., 2005). According to the IDF definition of MetS, central obesity is a necessary component, along with two or more of the other factors (i.e., elevated glucose, high blood pressure, elevated triglycerides, reduced HDL-C) (Alberti et al., 2005).

Most recently, attempts have been made to unify the diagnostic criteria for MetS by 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 in 2009 (Alberti et al., 2009). According to the new joint interim statement, all components of the so-called ‘Harmonizing Definition’ of MetS were identical to those included in the AHA/NHLBI and IDF definitions. However, central obesity is not a necessary component. In other words, waist circumference has an equal weight as other factors. For the definition of MetS, one must meet three or more of five criteria. Of further note, the thresholds for waist circumference for certain countries as well as ethnic-specific thresholds have been updated (Table 2).

Table 1 Definitions of metabolic syndrome (MetS)*

	WHO - 1998	EGIR - 1999	NCEP ATP III - 2001	AHA/NHLBI - 2005	IDF - 2005	Harmonizing Definition - 2009
Glucose	T2DM, IGT or IFG	FPG ≥6.1 mmol/L	FPG ≥6.1 mmol/L	FPG ≥5.6 mmol/L	FPG ≥5.6 mmol or previously diagnosed T2DM	FPG ≥5.6 mmol/L or treatment
Insulin resistance	Glucose uptake below lowest quartile	IR or fasting hyper-insulinemia (Top 25%)	–	–	–	–
Blood pressure	SBP ≥140, DBP ≥90 mmHg	SBP ≥140, DBP ≥90 mmHg	SBP ≥130, DBP ≥85 mmHg	SBP ≥130, DBP ≥85 mmHg or treatment	SBP ≥130, DBP ≥85 mmHg or treatment	SBP ≥130, DBP ≥85 mmHg or treatment
Dyslipidemia	TG ≥1.7 mmol/L and/or HDL-C <0.9 mmol/L(M), <1.0 mmol/L (F)	TG> 2.0 mmol/L or HDL-C <1.0 mmol/L or treatment	–	–	–	–
Triglycerides	TG ≥1.7 mmol/L	TG> 2.0 mmol/L or treatment	TG ≥1.7 mmol/L	TG ≥1.7 mmol/L or treatment	TG ≥1.7 mmol/L or treatment	TG ≥1.7 mmol/L or treatment
HDL-C	–	–	<1.0 mmol/L (M), <1.3 mmol/L (F)	<1.0 mmol/L (M), <1.3 mmol/L (F) or treatment	<1.0 mmol/L (M), <1.3 mmol/L (F) or treatment	<1.0 mmol/L (M), <1.3 mmol/L (F) or treatment
Abdominal obesity	WHR >0.90 (M), >0.85 (F) and/or BMI >30 kg/m^2	WC ≥94 cm (M) ≥80 cm (F)	WC ≥102 cm (M), ≥88 cm (F)	WC ≥40.2 cm (M), ≥88 cm (F) Asian American ≥90 cm (M), ≥80 cm (F)	Racial/Ethnic specific**	Racial/Ethnic Specific**
Micro-albuminuria	UAER ≥20μg/min or ACR ≥ 20mg/g	–	–	–	–	–

Continued on next page

Table 1 Definitions of metabolic syndrome (MetS)* - continued

	WHO - 1998	EGIR - 1999	NCEP ATP III - 2001	AHA/NHLBI - 2005	IDF - 2005	Harmonizing Definition - 2009
Criteria for diagnosis	Glucose intolerance and/or IR plus ≥ 2 of other factors	IR or fasting hyper-insulinemia plus ≥ 2 of other factors	≥ 3 of 5 factors	≥ 3 of 5 factors	Abdominal obesity plus ≥ 2 of other 4 factors	≥ 3 of 5 factors
Inclusion of diabetic patients	Yes	No	Yes	Yes	Yes	Yes

* The definition of the National Heart, Lung, and Blood Institute/American Heart Association (NHLBI/AHA) (Grundy et al., 2004) was not listed since components included in the definition and the thresholds for all individual components are identical with those defined by NCEP ATP III criteria, except for the cut-off point for glucose (i.e., FPG ≥ 100 mg/dL).

* The American Association of Clinical Endocrinologists (AACE) (American College of Endocrinology, 2003) was not listed since components and the thresholds for all components are identical with those defined by the NCEP ATPIII criteria; however, diagnosis can be made with the presence of at least one of the following factors: diagnosis of CVD, hypertension, polycystic ovary syndrome, non-alcoholic fatty liver disease, or acanthosis nigricans; family history of type 2 diabetes mellitus (T2DM), hypertension, or cardiovascular disease (CVD); history of gestational diabetes or glucose intolerance; non-Caucasian ethnicity; sedentary lifestyle; age >40 years, and the presence of at least two components that are identical with those defined by NCEP ATP III criteria. The AACE excludes pre-existing diabetes from the definition.

** See Table 2 for racial/ethnic-specific thresholds provided by the IDF and Harmonizing Definition.

WHO, World Health Organization; EGIR, European Group for Study of Insulin Resistance; NCEP ATP III, National Cholesterol Education Programs Adult Treatment Panel III; AHA/NHLBI, American Heart Association/the National Heart, Lung, and Blood Institute; IDF, International Diabetes Federation; IGT, impaired glucose tolerance; IFG, impaired fasting glucose; FPG, fasting plasma glucose; IR, insulin resistance; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein-cholesterol; WHR, waist-to-hip ratio; BMI, body mass index; WC, waist circumference; UAER, urinary albumin excretion rate; ACR, albumin-creatinine ratio; M, male; F, female

Table 2 Current recommended waist circumference* thresholds for abdominal obesity by ethnicity

	IDF** - 2005		Harmonizing Definition - 2009	
Ethnic/population	Men	Women	Men	Women
Europids	≥ 94	≥ 80	≥ 94	≥ 80
Caucasian	–	–	≥ 102	≥ 80
United States	–	–	≥ 102	≥ 88
Canada	–	–	≥ 102	≥ 88
European	–	–	≥ 102	≥ 102
Asian	≥ 90	≥ 80	≥ 90	≥ 80
Japanese	≥ 85	≥ 90	≥ 85	≥ 90
Chinese	≥ 90	≥ 80	≥ 85	≥ 80
Middle East, Mediterranean	Use European data until more specific data are available		≥ 94	≥ 80
Sub-Saharan African	Use European data until more specific data are available		≥ 94	≥ 80
Ethnic Central and South American	Use south Asian recommendations until more specific data are available		≥ 90	≥ 80

* Unit of waist circumference: cm
**IDF: International Diabetes Federation

2.1.2 Ongoing issues related to diagnostic criteria for MetS

Debate about the utility of a formal diagnosis of MetS and drawbacks of the use of different definitions of MetS were posed by the Joint Statement from the American Diabetes Association and the European Association for the Study of Diabetes (Kahn et al., 2005). One identified drawback was that estimates of prevalence of MetS will vary, depending on the definition used (Eckel et al., 2005; Cornier et al., 2008; Kassi et al., 2011). Results of a population-based study in the U.S. (Carlsson et al., 2009) reported that estimates of prevalence of MetS defined by the EGIR, IDF, and NCEP ATPIII were 23.5%, 38.4%, and 31.8%, respectively. In addition, when selecting definition of MetS, characteristics such as gender and race/ethnicity of the population investigated should be considered in order to estimate prevalence of MetS accurately (Kassi et al., 2011). In a study by Kim et al. (2004) ethnic-specific thresholds for waist circumference were applied in a Korean population and the prevalence of MetS in Korean adults was found to be higher than in American white adults. This finding suggested that the use of Europid cut-off points for waist circumference (Table 2) in Korean populations may underestimate the prevalence of MetS (Kim et al., 2004).

Moreover, the predictive power of MetS for subsequent development of CVD and T2DM may depend on the definition used (Cornier et al., 2008). Results from the San Antonio Heart Study reported that the IDF, NCEP ATP III, and WHO definitions demonstrated similar abilities to predict incident CVD and T2DM (Lorenzo et al., 2007). In contrast, a Japanese study (Sone et al., 2005) showed that the WHO definition had a greater predictive ability for incidence of CVD than the NCEP ATP III definition (hazard ratio [HR] = 3.2 (95% CI, 1.6-6.5) and 1.4 (95% CI, 0.8-2.5), respectively) among women. This may be due to the fact that the cut-off points for high blood pressure in the WHO criteria are higher than those of the NCEP ATP III criteria. A 5-year follow-up study in China examined the ability of four different definitions of MetS for predicting incident T2DM (Wang et al., 2004). The AACE definition had the highest predictive ability in both men and women (i.e., 61% and 58%, respectively). The predictive ability of the WHO definition was 53% in men and 42% in women, whereas the predictive ability of the NCEP ATP III was 27% in men and 41% in women. The EGIR predicted only 28% of the incident T2DM in both men and women. This may underestimate the significance of MetS on risk of developing T2DM.

2.1.3 Discussion

Despite ongoing debate about the MetS entity, it should be noted that the prevalence of MetS is high, ranging from 40% to 53%, and still rising in many countries, possibly associated with the worldwide obesity epidemic (Ervin, 2009; Riediger & Clara, 2011; Korean Ministry of Health Welfare, 2006; Kassi et al., 2011; Hollman & Kristenson, 2008; Eckel et al., 2005). In addition, some researchers believe that it is worthwhile to consider MetS as a diagnostic syndrome, rather than focus on individual components of MetS. This will encourage a broad approach to prevention of CVD or T2DM, including both lifestyle interventions and pharmacologic treatments (Johnson & Weinstock, 2006; Pratley, 2007). Researchers have also recognized that the definition of MetS is still evolving (Pratley, 2007; Alberti et al., 2009). Over the past two decades, several operational definitions of MetS have been updated by major public health and professional organizations in order to diagnose MetS more accurately or to reflect diversity of race/ethnicity (Balkau & Charles, 1999; Grundy et al., 2005; Alberti et al., 2005; Alberti et al., 2009). Even the most recent definition, the Harmonizing Definition, continues to struggle with establishing racial/ethnic specific thresholds (Alberti et al., 2009). Also, there is a remaining question about whether country of origin racial/ethnic specific thresholds or country of adoption thresholds should be used (Alberti et al., 2009). Further research is required in terms of both accurate diagnosis of MetS and precise estimation of prevalence of MetS (and its individual components) to inform public health strategies to reduce risk of CVD and T2DM.

2.2 MetS, Cardiovascular Disease, and Diabetes

2.2.1 Impact of MetS on cardiovascular disease

The underlying mechanisms linking MetS and CVD are not well understood, but are believed to involve insulin resistance and abdominal obesity. These, in turn, influence proinflammatory and prothrombotic states which predispose to CVD (Johnson & Weinstock, 2006; Cornier et al., 2008; Grundy, 2012). Since there has been ongoing controversy about the value of MetS, especially to predict further development of CVD, a number of epidemiological studies have been conducted to examine this issue (Cornier et al., 2008).

Using data from the Diabetes Epidemiology Collaborative Analysis of Diagnostic Criteria in Europe (DECODE study), Hu et al. (2004) investigated the association between MetS and CVD. In this meta-analysis, 11,512 non-diabetic men and women participants of 11 prospective cohort studies were followed approximately 8.8 years. A modified WHO definition was used to identify the presence of MetS. The results of this meta-analysis found that the hazard ratio for CVD mortality associated with MetS was 2.26 (95% confidence interval [95% CI], 1.61-3.17) in men and 2.78 (95% CI, 1.57-4.94) in women, after adjusting for age, HDL-C, and smoking.

Galassi et al. (2006) also conducted a meta-analysis to examine the association between MetS and risk of CVD. A total of 21 prospective studies using either the WHO or NCEP ATPIII definition were included. Eleven of these studies were conducted in the U.S. and 10 in Europe. Subjects with T2DM and/or history of CVD and subjects who were free of both conditions at baseline were included. When all 21 studies were included in the analyses, subjects with MetS were found to have 61% increased risk of CVD (Relative Risk [RR], 1.61, 95% CI, 1.42-1.83). Among the 14 studies that adjusted for a wide range of major risk factors for CVD (i.e., gender, race/ethnicity, cigarette smoking, or physical activity), the relative risk was 1.54 (95% CI, 1.30-1.81). Six studies investigated CVD mortality and reported that MetS was associated with an increased risk of CVD mortality (RR, 1.74, 95% CI, 1.29-2.35). Studies using the WHO definition showed a higher relative risk of CVD mortality (RR, 1.82, 95% CI, 1.27-2.61) than the studies that adopted the NCEP-ATP III definition (RR, 1.61; 95% CI, 1.42-1.83). Also, among patients with no history of CVD, people with MetS and T2DM were more likely to have an increased risk of CVD (RR, 1.70, 95% CI, 1.41-2.04), compared with people with MetS alone (RR, 1.58, 95% CI, 1.35-1.73).

Gami et al. (2007) also conducted a systematic review and meta-analysis based on 36 published studies, including 43 prospective cohorts that examined the association between MetS and risk of developing

CVD. A total of 172,537 participants with or without T2DM and/or history of CVD at baseline were included in the analysis. For individuals with MetS, the overall relative risk for incident cardiovascular events and death was 1.78 (95% CI, 1.58-2.00). Studies that examined gender-specific risk showed that women had a higher risk of incident cardiovascular events and death than men (RR, 2.63 vs. 1.98, p=0.09). The relative risks of cardiovascular events and death varied depending on the definitions of MetS used. Studies using the WHO definition reported that MetS was more predictive of cardiovascular events and death compared with the NCEP ATP III definition (RR, 2.06 vs. 1.67). This might be due to the fact that the use of higher cut-offs for high blood pressure and lower cut-offs for HDL-C and inclusion of insulin resistance and micro-albuminuria in the WHO definition. Furthermore there was some evidence that the magnitude of the association between MetS and cardiovascular events and death varied by population characteristics. Subgroup analysis by T2DM showed that studies with only diabetic patients showed a somewhat lower risk of cardiovascular events and death related to MetS compared with studies with only non-diabetic patients (RR= 1.51 vs. 1.69, respectively), whereas the relative risk of cardiovascular events and death for those with history of coronary heart disease showed a higher risk of cardiovascular events and death than those without the history (RR, 2.68 vs. 1.94, respectively).

A more recent meta-analysis was conducted by Mottillo et al. (2010) in order to investigate the cardiovascular risk associated with MetS. Eighty-seven studies using the NCEP ATP III definition or a revised NCEP ATP III definition were ascertained, with a total of 951,083 participants. When the NCEP ATP III definition of MetS was adopted, the relative risk of incident CVD and CVD mortality was 2.51 (95% CI, 1.38-4.55) and 1.85 (95% CI, 1.42-2.41), respectively, while studies using the revised NCEP ATP III definition reported that the relative risk of incident CVD and CVD mortality was 1.93 (95% CI, 1.56-2.40) and 2.91 (95% CI, 1.85-4.58), respectively. When pooling all data, MetS was associated with an increased risk of CVD (RR, 2.35; 95% CI, 2.02-2.73) and CVD mortality (RR, 2.40; 95% CI, 1.87-

3.08). A subgroup analysis for studies including only participants without T2DM showed that MetS was still associated with an increased risk of CVD mortality (RR, 1.75, 95% CI, 1.19-2.58).

There are, however, studies that did not find an increased risk of CVD associated with MetS. A longitudinal study of 1,565 Italian older adults with T2DM found no association between MetS and cardiovascular mortality (Bruno et al., 2004). In another study that included two elderly cohorts (i.e., participants aged 70 to 82 years from the Prospective Study of Pravastatin in the Elderly at Risk (PROSPER) and participants aged 60 to 79 years from the British Regional Heart Study (BRHS)), there was no evidence of a statistically significant association between MetS and risk of incident CVD in the PROSPER cohort (HR, 1.07, 95% CI, 0.86-1.32), but a weak association in the BRHS cohort (HR, 1.27, 95% CI, 1.04-1.56) (Sattar et al., 2008).

2.2.2 Impact of MetS on type 2 diabetes mellitus

It has been recognized that excess visceral adipose tissue produces excess free fatty acids and adipocytokines such as C-reactive protein (CRP), plasma resistin, and tumor necrosis factor alpha (TNF-α) (Cornier et al., 2008; Deng & Scherer, 2010). This, in turn, appears to increase insulin resistance and risk of T2DM (Cornier et al., 2008; Deng & Scherer, 2010). Although the pathophysiology of the link between insulin resistance and individual components of MetS is unclear, insulin resistance can be considered as a major feature of MetS and prediabetes (Grundy, 2012). One Italian study (Bianchi et al., 2011) revealed that 74% of people with prediabetes measured by impaired fasting glucose (IFG) and impaired glucose tolerance (IGT) had MetS, based on the NCEP ATP III criteria, while only 19% of people with normal glucose tolerance had MetS.

To examine whether MetS was associated with an increased risk of developing T2DM, Ford et al. (2008) conducted a meta-analysis that included 16 cohort studies and a total of 42,419 participants. There was variation in the magnitude of association due to study heterogeneity. For instance, studies using the WHO, NHLBI/AHA, or AHA/NHLBI definitions reported stronger associations between MetS and incident T2DM (RR, 5.17, 95% CI 3.99-6.69; RR, 5.16, 95% CI, 4.43-6.00; RR, 5.12, 95% CI, 3.26-8.05, respectively) compared with those using the EGIR, IDF, or NCEP ATP III definitions (RR, 4.45, 95% CI, 2.41-8.22; RR, 4.42, 95% CI, 3.30-5.92; RR, 3.53, 95% CI, 2.84-4.39, respectively). The relationship between MetS and incident T2DM also varied depending on study population. North American and European populations showed a higher magnitude of association (RR, 4.12, 95% CI, 3.16-5.40) compared with Asian and Mauritius cohorts (RR, 3.53, 95% CI, 2.96-4.20) and with Native American cohorts (RR, 1.98, 95% CI, 1.69-2.32).

Researchers have also examined whether or not the joint presence of MetS and other risk factors such as insulin resistance adds to the risk of T2DM. Meigs et al. (2007) examined whether MetS increases risk of incident T2DM in the presence of insulin resistance, using the data from the Framingham Offspring study. It was found that people with MetS and insulin resistance had a greater risk of incident T2DM (RR, 6.9, 95% CI, 3.7-13.0) than those with either MetS or insulin resistance alone (RR, 3.6, 95% CI, 1.9-6.8 and RR, 1.5, 95% CI, 0.5-4.1, respectively). A Japanese prospective cohort study (Mukai et al., 2009) also found that the ability of both MetS (defined by NCEP ATP III criteria) and IFG to predict incident T2DM was greater than that of either MetS or IFG alone (HR, 6.76, 95% CI, 4.75-9.61); however, in this study IFG was a better predictive than MetS (HR, 3.49 95% CI, 2.57-4.74 versus HR, 2.37, 95% CI, 1.45-3.88).

2.2.3 Discussion

The evidence from four meta-analyses suggests that MetS is associated with an increased risk of CVD and CVD mortality. The most recent meta-analysis reported a two-fold increased risk of cardiovascular outcomes (Mottillo et al, 2010), although the estimated magnitude of increased risk varies depending on definition of MetS and population characteristics such as age, gender, and co-existing comorbidity (Kim et al., 2004; Cornier et al., 2008; McNeill et al., 2005; Alexander et al., 2003; Meigs et al., 2006; Bruno et al., 2004; Sattar et al., 2008). Future studies will be needed to examine whether or not the predictive power of MetS is significantly greater than that of the individual components of MetS. This remains a subject of debate (Kahn et al., 2005; Grundy, 2006; Cornier et al., 2008). Moreover, further prospective studies that minimize attrition bias are needed, since dropouts may be more likely to have CVD, and this may alter the association between MetS and CVD risk (Gami et al., 2007). Similarly, the evidence suggests that MetS is associated with an increased risk of developing T2DM. This increased risk appears to be greater than that reported for CVD (Cornier et al., 2008; Grundy, 2012). There is, however, no consensus regarding whether the prognostic value of MetS for developing T2DM exceeds that of other individual risk factors, for instance insulin resistance (Ford et al., 2008). Meigs et al. (2007) reported that people with MetS alone were more likely to have incident T2DM than those with insulin resistance alone, whereas other studies showed insulin resistance alone is better predictor of T2DM risk than MetS alone (Cameron et al., 2008; Mukai et al., 2009). Mukai et al. (2009) suggested that MetS might have lower prognostic value compared to insulin resistance in certain ethnic groups where obesity is infrequent. Although researchers recognize the need to test the ability of MetS to predict T2DM relative to that of the existing T2DM risk prediction models such as the Diabetes Risk Score (Stern et al., 2004; Ford et al., 2008; Cameron et al., 2007), few studies have been conducted. Stern at al. (2004) found that the Diabetes Risk Score was superior to the NCEP ATP III definition for MetS to predict incident T2DM, while Cameron et al. (2008) reported the Finish Diabetes Risk Score was inferior to the NCEP ATP III and IDF definitions. Further research is, therefore, required to identify if the diagnose of MetS has better predictive ability for T2DM than other published diabetes prediction models.

2.3 Biomedical Factors Associated with MetS

2.3.1 Age

Older adults have a higher prevalence of MetS compared with their younger counterparts (Cornier et al., 2008). This is likely due to the higher prevalence of insulin resistance and visceral fat (Lechleitner, 2008; Barzilai et al., 2012). The age-related increase of visceral fat and sarcopenia are associated with secretion of adipokines, inflammatory markers, and free fatty acids, leading to insulin resistance (Lechleitner, 2008; Evans et al., 2010; Barzilai et al., 2012). Moreover, insulin resistance also appears to exacerbate sarcopenia including the decline in muscle quantity and quality (Guillet & Biorie, 2005; Dominguez & Barbagallo, 2007; Evans et al., 2010).

Studies worldwide have shown that prevalence of MetS increases with age. Based on data from NHANES 2003-2006 (Ervin, 2009), the prevalence of MetS in US males and females aged 60 years and over was 52% and 54%, respectively, relative to 41% and 37% of males and females aged 40-59 years, respectively. Using data from the CHMS, Riediger and Clara (2011) reported approximately 40% of Canadian adults aged 60 years or older had MetS, while 27% of adults aged 50-59 years had the syndrome. A nationwide Japanese study showed that 27% of elderly women aged 65 years or over had MetS compared with 9.0% of middle-aged women (Arai et al., 2010). Korean older adults also had the highest prevalence of MetS (52.7%) among all age groups (Korean Ministry of Health Welfare, 2006).

2.3.2 Comorbidities

Non-alcohol fatty liver disease (NAFLD) involves fat accumulation in hepatocytes and is strongly associated with obesity, insulin resistance, and other components of MetS (Souza et al., 2012). NAFLD has therefore been recognized as the hepatic manifestation of MetS, although underlying mechanisms linking NAFLD and MetS are not fully understood (Cornier et al., 2008; Moore, 2010; Souza et al., 2012). In epidemiological studies, there is evidence to suggest that NAFLD is strongly associated with

MetS, even in non-diabetic and non-obese individuals (Kim et al., 2004). The amount of liver fat is 4-fold higher in people with MetS compared with those without the condition (Kotronen et al., 2007), and in the presence of MetS, the incidence of NAFLD was increased 4-fold in men and 11-fold in women (Hamaguchi et al., 2005).

The role of MetS in the etiology and progression of certain types of cancer is not yet fully understood (Cornier et al., 2008). However, researchers have pointed out that key components of MetS such as obesity, dyslipidemia, and hyperinsulinemia may play an important role in increasing risk of certain types of cancer (Braun et al., 2011; Siddiqui & Palmer, 2011). The association between MetS and cancer has been reviewed in a recent meta-analysis (Esposito et al., 2012). Based on data from 43 published studies with cohort, case-control, and mortality study design, the authors reported that several types of cancer were associated with MetS. Colorectal cancer was significantly associated with MetS in both men (RR, 1.25, 95% CI, 1.19-1.32) and women (RR, 1.34, 95% CI, 1.09-1.64). MetS was also associated with a significantly increased risk of liver cancer in men (RR, 1.43, 95% CI, 1.23-1.65) and pancreatic cancer in women (RR, 1.58, 95% CI, 1.35-1.84) relative to other types of cancer.

Chronic kidney disease (CKD) is another condition that may be associated with MetS (Schelling & Sedor, 2004). Several studies have reported that individual components of MetS and insulin resistance might be risk factors for development of CKD (Schelling & Sedor, 2004; Tanner et al., 2012). Using data from the third NHANES (Chen et al., 2004) and the KNHANES-2001 (Choi, 2008), it was reported that MetS was significantly associated with CKD. Choi (2008) reported that the adjusted odds ratio of CKD in participants with MetS compared with those without MetS was 1.65 (95% CI, 1.29-2.12), while Chen et al. (2004) found that the adjusted odds ratio of CKD in the presence of MetS was 2.60 (95% CI, 1.68-4.03). In both studies the individual components of MetS that were found to be associated with CKD were elevated triglycerides, high blood pressure, and abdominal obesity. Reduced HDL-C was shown to be related with CKD in the U.S. data only. A recent meta-analysis (Thomas et al., 2011) also found that MetS was significantly associated with incident CKD (OR, 1.55, 95% CI, 1.34-1.80) and reported that all components of MetS were associated with increased risk of CKD. Further findings from two cross-sectional studies and from the meta-analysis of prospective studies indicated that the association between MetS and CKD increased as number of individual components of MetS increased (Chen et al., 2004; Choi, 2008; Thomas et al., 2011).

Polycystic ovarian syndrome (PCOS) is common in women with MetS (Cornier et al., 2008), since anthropometric and metabolic abnormalities of PCOS such as obesity, dyslipidemia, insulin resistance overlap with the components of MetS (Ehrmann et al., 2006). A recent meta-analysis reported that women with PCOS had increased prevalence of MetS (OR, 2.88, 95% CI, 2.40-3.45 in BMI-unmatched studies; OR, 2.20, 95% CI, 1.36-3.56 in BMI-matched studies) (Moran et al., 2010). In addition, women with both conditions may be at higher risk of CVD and T2DM compared with those with either PCOS or MetS (Cornier et al., 2008; Moran et al., 2010).There is also evidence to show that erectile dysfunction and male hypogonadism are often found in men with MetS (Corona et al., 2009). Like PCOS, obesity and insulin resistance are thought to play an important role in the link between erectile dysfunction and/or male hypogonadism and MetS (Corona et al., 2009). In their meta-analysis, Corona et al. (2011) found that MetS was significantly associated with lower testosterone after adjustment for other known risk factors (r=-0.752, p<.001), and that lower testosterone was significantly associated with increased risk of developing MetS.

Psoriasis has also been shown to increase risk of MetS (Langan et al., 2011). This may be due to the systematic chronic inflammation of psoriasis, along with the elevated rates of obesity associated with psoriasis, leading to insulin resistance and abnormalities in lipid metabolism (Cohen et al., 2007; Alsufyani et al., 2010). A recent meta-analysis reported that the pooled odds ratio for MetS in people with psoriasis was 2.26 (95% CI, 1.70-3.01) compared with those without psoriasis (Armstrong et al., 2013). A dose-response relationship between psoriasis severity and prevalence of MetS was also observed in a population-based study conducted in the United Kingdom (U.K.) (Langan et al., 2011). The odds ratios for MetS were 1.22 (95% CI, 1.11-1.35) in mild psoriasis, 1.56 (95% CI, 1.38-1.76) in moderate psoriasis, and 1.98 (95% CI, 1.62-2.43) in severe psoriasis, respectively (Langan et al., 2011).

2.3.3 Discussion

Age and comorbidities were selected as two biomedical factors that may influence prevalence of MetS. Other possible biomedical factors such as genetic predisposition and physiological aspects (e.g., neuro-hormonal activity and inflammatory process) (Hoffman & Driscoll, 2000) were not considered in this review, simply because the data sources for the current study did not provide information on these factors.

The evidence suggests that age is associated with increased prevalence of MetS. In addition, with an increased focus on MetS worldwide, growing attention has been focused on the various comorbidities associated with MetS, including NAFLD, certain types of cancer, CKD, PCOS, erectile dysfunction, male hypogonadism, and psoriasis. Obesity and insulin resistance, leading to dyslipidemia and high blood pressure, are considered to play a key role in the initiation and progression of MetS and comorbidities studied, although the underlying mechanisms linking MetS and these comorbidities are unknown.

2.4 Biosocial Factors Associated with MetS

2.4.1 Gender

Gender differences in prevalence of MetS vary across population-based studies. Based on 2003-2006 NHANES data, Ford et al. (2010) reported that American men had a higher prevalence than American women after adjustment for multiple variables such as age, race/ethnicity, smoking, and physical activity (OR, 1.24, 95% CI, 1.11-1.37), whereas in a nationally representative sample of 15,540 Chinese adults, Gu et al. (2005) found that the age-adjusted prevalence of MetS in women was higher than in men (17.8% vs. 9.8%, respectively). Mabry et al. (2010) conducted a systematic review to examine gender differences among adults in Member States of the Gulf Cooperative Council (GCC; Bahrain, Kuwait, Oman, Qatar, Saudi, Arabia and the United Arab Emirates), and reported that in studies using the NCEP ATP III definition, prevalence of MetS in men ranged from 20.7% to 37.2% and in women ranged from 32.1% to 42.7%. Studies using the IDF definition also reported that women had a higher prevalence. Prevalence estimates in women ranged from 36.1% to 45.9% versus 29.6% to 36.2% in men, respectively.

Changes in fat distribution with increasing age may be one factor that contributes to gender-associated differences in prevalence of MetS (Regitz-Zagrosek et al., 2006; Razzouk & Muntner, 2009). Central obesity is more frequently occurred in postmenopausal women, whereas peripheral obesity such as subcutaneous fat accumulation is more frequently developed in premenopausal women (Regitz-Zagrosek et al., 2006; Razzouk & Muntner, 2009). Comparing the prevalence of MetS between 40- and 66-year-old Korean adults, Lim et al. (2012) reported that among 40-year-old adults the prevalence of MetS in women was lower than in men (OR, 0.57, 95% CI, 0.56-0.59), whereas among 60-year-old adults women had a higher prevalence of MetS than men (OR, 1.28, 95% CI, 1.26-1.31). However, in a Canadian population-based study there was no association between gender and MetS in adults aged 18 to 79 years (Riediger, & Clara, 2011).

Two meta-analyses showed that women with MetS had a higher CVD risk and mortality compared with men with MetS (Galassi et al., 2006; Gami et al., 2007). Galassi et al. (2006) reported that the pooled relative risk for CVD associated with MetS in women was higher than that in men (RR, 2.10, 95% CI, 1.79-2.45 versus RR, 1.57, 95% CI, 1.41-1.75). Similarly, Gami et al. (2007) found that the pooled relative risk of incident cardiovascular events and death in women was 2.63 and 1.98 in men ($p=0.09$). Using recent data from a multiethnic U.S. population, however, Hari et al. (2012) reported that men with

MetS had higher risk of CVD compared with women. This increased risk in men was observed across all the MetS definitions studied. For instance, when using the Harmonizing Definition, the hazard ratios for men and women were 2.92 (95% CI, 2.15-3.95) and 2.08 (95% CI, 1.37-3.14), respectively.

2.4.2 Race/ethnicity

Certain racial/ethnic groups may have higher risk for MetS than other racial/ethnic groups because of both genetics and environmental factors (Wulan et al., 2010). American studies suggested that race/ethnicity-associated differences in prevalence of MetS vary by gender (Cornier et al., 2008; Park et al., 2003; Ervin, 2009). Using the 1988-1994 NHANES data, Park et al. (2003) reported that the odds of MetS were lower in African-American men compared with that in non-Hispanic white men (OR, 0.5, 95% CI 0.3-0.6). There was no difference in prevalence of MetS in Hispanic men compared with non-Hispanic white men (OR, 1.1, 95% CI, 0.9-1.4). African-American women also had lower odds for MetS compared with non-Hispanic white women (OR, 0.7, 95% CI, 0.5-0.9), whereas Hispanic women had an elevated odds for MetS compared with non-Hispanic white women (OR, 1.5, 95% CI, 1.1-2.0). Using 2003-2006 NHANES data, Ervin (2009) reported findings in women that differed somewhat from the results of the study by Park et al. (2003). African-American women had higher odds of MetS compared with non-Hispanic white women (OR, 1.44, 95% CI, 1.05-1.98). Hispanic women still had elevated odds for MetS compared to non-Hispanic white women (OR, 1.55, 95% CI, 1.06-2.29).

In their population-based study, Rampal et al. (2012) reported ethnic differences in the prevalence of MetS. Among Malaysians under 40 years of age, the prevalence of MetS was significantly higher in Indian and Indigenous Sarawakians populations compared with ethnic Malays (OR, 1.42, 95% CI, 1.19-1.69 and OR, 1.37, 95% CI, 1.08-1.73, respectively), but significantly lower in the Chinese population (OR, 0.81, 95% CI, 0.67-0.96). Among those aged 40 years and over, a similar pattern was observed for the Indian and Chinese populations; however, there was no difference in prevalence of MetS between Indigenous Sarawakians and ethnic Malays.

A UK population-based cross-sectional study also reported ethnic-related difference in prevalence of MetS across European (n=2,346), South Asians (n=1,711), African-Caribbean (n=803) participants aged 40 to 69 years who resided in west London (Tillin, 2005). Based on age-adjusted prevalence estimates, South Asians had the highest prevalence (28.8% and 31.8% for male and female, respectively), whereas Europeans showed the lowest prevalence (18.4% and 14.4% for male and female, respectively). The prevalence of MetS among African-Caribbean participants was 15.5% and 23.4% for male and female, respectively. There was no significant difference in waist circumference between European and South Asian men (p=0.30). However, compared with European men, South Asian men had significantly higher prevalence of impaired glucose homeostasis (16.9% versus 30.0%, p<.0001), high BP (39.1% versus 53.4%, p<.0001), and dyslipidemia (44.5% versus 60.1%, p<.0001). African-Caribbean men had significantly lower prevalence of abdominal obesity (11.2% versus 16.2%, p=0.002) and dyslipidemia (28.4% versus 44.5%, p<.0001) compared with European men, but had a higher prevalence of impaired glucose homeostasis (31.2% versus 16.9%, p<.0001) and high BP (55.6% versus 39.1%, p<.0001) than European men. Compared with European women, South Asian women had significantly higher prevalence of high BP (30.2% versus 47.6%, p<.0001), dyslipidemia (33.4% versus 53.4%, p<.0001), and central obesity (22.0% versus 45.5%, p<.0001). Compared with European women, African-Caribbean women had a higher prevalence of high BP (30.2% versus 60.2%, p<.0001) and abdominal obesity (22.0% versus 46.3%, p<.0001), whereas European women had higher prevalence of dyslipidemia (33.4% versus 25.7%, p=.01). There was no significant difference in prevalence of impaired glucose homeostasis between European and African-Caribbean women (p=0.25).

2.4.3 Education and income

Several studies have investigated the association between MetS and socioeconomic status (SES), as measured by education and income. Using the third wave of NHANES (1988-1994) data, Park et al. (2003) found a negative association between household income and MetS in American women (OR, 1.5, 95% CI, 1.0-2.3), but not in American men. Level of education was unrelated to MetS in both men and women after adjusting for known risk factors such as age, race/ethnicity, smoking, physical activity, alcohol consumption, and menopausal status for women.

Loucks et al. (2007) also used the NHANES (1999-2002) data to examine the relationship between household income, education, and MetS. After adjusting for covariates, the association between household income and MetS was significant only in women, especially for those between 25-45 years of age (OR, 3.85, 95% CI, 1.99-7.45). There was no significant association between income and MetS in men across all age groups. In women aged 25-45 years old, those with lower education levels (i.e., 12 years or less) had a significant association with MetS, compared with those with over 12 years of education (OR, 2.42, 95% CI 1.11-5.25 and OR, 2.31, 95% CI, 1.15-4.64, respectively). In women aged 46-65 years old there was also a significant negative association between education and MetS (OR, 2.03, 95% CI, 1.07-3.85). The association between low level of education and MetS was not significant in men, except among 25-45 years old men (OR, 1.86, 95% CI, 1.05-3.30).

Findings from two Asian studies (Park et al. 2007; Zhan et al., 2012) were similar to those of the two American studies mentioned above (Park et al., 2003; Loucks et al., 2007). Using the 2001 KNHANES data, Park et al. (2007) found that after adjustment for multiple known risk factors, Korean women aged 20 to 79 years with higher levels of education and income were less likely to have MetS than those with lower levels of education and income. Similarly, Zhan et al. (2012) reported that Chinese women with a higher level of education and higher household income were less likely to have MetS. In both Korean and Chinese studies, no association between income and education and MetS was observed in men.

The findings from European studies have tended to show an association between education level and MetS. Using data from the Whitehall II study, Brunner et al. (1997) found a positive association between employment grade (i.e., grade 1: the highest range of annual salary to grade 6: the lowest range of annual salary) and prevalence of MetS in both men and women (OR, 2.2, 95% CI, 1.6-2.9 and OR, 2.8, 95% CI, 1.6-4.8, respectively). In a second study conducted in the U.K., Ramsay et al. (2008) examined a sample of older British men aged 60 to 79 years and found a significant association between adult social class (i.e., manual versus nonmanual) and MetS after adjusting for age, smoking, alcohol consumption, and physical activity (OR, 1.21, 95% CI, 1.02-1.43). Silventoinen et al. (2005) reported that both Finnish men and women with university education had significantly lower odds of developing MetS compared with those with only 9 years of education (OR, 0.41, 95% CI, 0.23-0.74 and OR, 0.46, 95% CI, 0.24-0.89, respectively), after adjusting for physical activity, alcohol use, smoking, marital status, daily consumption of fresh vegetables, berries or fruits. In a sample of Polish men and women, Sygnowska et al. (2012) reported that the association between education and MetS was significant in both men and women, after adjusting for age, marital status, place of residence, BMI, smoking, physical activity, alcohol use, and self-rated health (OR, 0.72, 95% CI, 0.55-0.95).

2.4.4 Marital status

The associations between marital status and MetS vary across three population-based studies. Using 2001 KNHANES data, Park et al. (2007) reported that the adjusted odds ratios for MetS were lower in single, never-married Korean men and women aged 20 to 79 years (OR, 0.70, 95% CI, 0.52-0.96 and OR, 0.49, 95% CI, 0.29-0.80, respectively), compared with married Korean men and women. The prevalence of MetS was not statistically significant in divorced or widowed men and women compared with married men and women (OR, 0.82, 95% CI, 0.57-1.17 and OR, 1.03, 95% CI, 0.84-1.26, respectively). Using data from the 2003-2005 National Multicentre Health Survey, Sygnowska et al. (2012) found that single Polish men compared with married Polish men had a lower prevalence of MetS (OR, 0.82, 95% CI, 0.68-0.97). There was no difference in prevalence of MetS by marital status in Polish women. On the other hand, based on the 1999-2006 NHANES cohort of African-American men and women, Bhaunshali et al. (2013) found that single women had significantly lower prevalence of MetS compared with married women (OR, 0.43, 95% CI, 0.43-0.99). There was no difference in MetS by marital status in men.

2.4.5. Discussion

In this study gender, race/ethnicity, education, income, and marital status were considered biosocial factors (Hoffman & Driscoll, 2000). Results of cross-sectional studies that have examined the association between gender and MetS are inconsistent (Razzouk & Muntner, 2009). One possible explanation for this relates to changing trends in obesity over time that differ for men and women (Regitz-Zagrosek et al., 2006; Razzouk & Muntner, 2009). For instance, Ford et al. (2004) investigated change in prevalence of MetS over time, using the NHANES III 1988-1994 and NHANES 1999-2000. In men the age-adjusted prevalence of MetS in 1988-1994 and in 1999-2000 was essentially unchanged in time (24.6% to 25.2%, p=0.831). By contrast, the change in the age-adjusted prevalence of MetS in women was statistically significant (23.5% to 29.0%, p=0.021). This may be associated with the fact that more women than men had obesity over this period (Steinbaum, 2004).

Race/ethnicity-associated differences in prevalence of MetS were often investigated in multi-racial/ethnic countries. Based on the findings, however, it has been difficult to identify which race/ethnic group was most vulnerable to MetS, since some racial/ethnic minorities were not included in the analysis or often grouped together due to small sample size (Park et al., 2003; Ervin, 2009). Certain racial/ethnic minorities may have higher risk for MetS than other major racial/ethnic groups (Wulan et al., 2010). For instance, Palaniappan et al. (2011) showed that compared with non-Hispanic whites, Asian Americans had higher prevalence of MetS in spite of lower BMI and lower prevalence of overweight/obesity. Wulan et al. (2010) also noted that Asians have higher abdominal obesity, higher intramyocellular lipid, and a higher liver fat content, compared with Caucasians of similar BMI. This might increase risk for insulin resistance and MetS.

In terms of SES, several studies conducted in Korea, America, Poland, and China have reported that women with low education or income appear to have a higher prevalence of MetS compared with women with higher levels of education or income (Park et al., 2003; Park et al., 2007; Loucks et al., 2007; Sygnowska et al., 2012; Zhan et al., 2012). In part this may be due to the fact that women with lower education were more likely to be lower paid or unemployed, leading to deprived living conditions (Loucks et al., 2007) and a greater degree of psychological stress or depression, known to be associated with MetS (Park et al., 2007; Zhan et al., 2012). By contrast, studies have reported only a weak association between SES and MetS in men.

Findings from population-based studies are inconsistent regarding the relationship between MetS and marital status (Park et al., 2007; Sygnowska et al., 2012; Bhanushali et al., 2013). This may, in part, be due to difference in study methods such as categorization of marital status or may reflect difference in role of gender or marriage across study populations (Park et al., 2007; Sygnowska et al., 2012).

2.5 Psychosocial Factors Associated with MetS

2.5.1 Physical activity

It has been demonstrated that physical activity induces favourable changes in metabolic profiles of individuals with MetS (Strasser, 2012). A recent meta-analysis of seven randomized controlled trials (Pattyn et al., 2013) reported that aerobic and/or resistance exercise led to statistically significant decreases in mean waist circumference (−3.4 cm, 95% CI, −4.9 - −1.8), blood pressure (systolic, −7.1, 95% CI, −9.03 - −5.2; diastolic, −5.2, 95% CI, −6.2 - −4.1), and low HDL-C (0.06, 95% CI, 0.03 - 0.09) among adults with MetS. A second meta-analysis based on 13 randomized controlled trials investigated the effect of resistance training on MetS (Strasser et al., 2010). The mean age of study participants in the 13 trials ranged from 46.8 to 67.6 years. The results indicated that resistance exercise significantly improved glycosylated haemoglobin (i.e., HbA1c) (− 0.48%, 95% CI, −0.76 - − 0.21), fat mass (−2.33 kg, 95% CI, −4.1 - −0.04), and systolic blood pressure (−6.18 mmHg, 95% CI, 1.00-11.38).

Observational studies have also been conducted to examine the association between physical fitness or physical activity and MetS. LaMonte et al. (2005) investigated the longitudinal association between cardiorespiratory fitness (measured by duration of a maximal treadmill exercise test) and incidence of MetS in American sample of 9,007 men and 1,491 women with a mean age 44±9 years. During a follow-up of 5.7 years, 1,346 men and 56 women developed MetS. The age-adjusted rate was 25.8 per 1000 person-years for men and 6.7 per 1000 person-years for women. Compared with men with the lowest level of cardiorespiratory fitness at baseline, men with middle and high level of fitness had a significantly decreased risk of developing MetS (HR, 0.74, 95% CI, 0.65-0.84 and HR, 0.47, 95% CI, 0.40-0.54, respectively). Similar patterns of association were observed in women (HR, 0.80, 95% CI, 0.44-1.46 for middle level; HR, 0.37, 95% CI, 0.18-0.80 for high level).

Using longitudinal data of the British Regional Heart Study with a 20-year follow-up, Wannamethee et al. (2006) investigated the effect of physical activity on MetS among 3,051 British men aged 60 to 79 years who were free from diabetes and coronary heart disease at baseline. Findings of the cross-sectional data showed that both moderate and moderate to vigorous levels of physical activity had significant inverse association with MetS (*p* for trend=.04), after adjusting for covariates including smoking, alcohol intake, dietary pattern, and energy intake of fat and carbohydrate. The longitudinal data with a mean observational period of 3 years showed that men who were continuously active had the lowest odds of MetS than those who were continuously inactive (OR, 0.73, 95% CI, 0.57-0.94). Men who became active also showed a lower odds of MetS than those who were continuously inactive although the association was not statistically significant (OR=0.76, 95% CI, 0.54-1.06).

Laursen et al. (2012) also examined the longitudinal association between physical activity and incident MetS, in a sample of 3,968 men and women aged 21-98 years without MetS at baseline. During the follow-up period of 10 years, 585 participants developed MetS. Volume and intensity of physical activity were assessed using a self-administered questionnaire. Volume of physical activity was defined by weekly leisure time physical activity, categorized into sedentary, light, moderate, and high physical activity, and by weekly hours of walking, while intensity of physical activity was measured by speed of walking and jogging. Intensity of physical activity was associated with a decreased risk of MetS, after adjusting for covariates. Specifically, participants who had average and fast/very fast walking speed were less likely to develop MetS compared with those with slow walking speed (OR, 0.64, 95% CI, 0.42-0.97 for average speed; OR, 0.51, 95% CI, 0.33-0.80 for fast/very fast speed, respectively). Participants who reported themselves as joggers were less likely to develop MetS during the follow-up compared with non-joggers (OR, 0.60, 95% CI, 0.37-0.95). Volume of physical activity was found to be unrelated to risk of MetS.

Using cross-sectional data from the 1999-2000 and the 2001-2002 NHANES, Sénéchal et al. (2012) examined the association between physical activity and severity of MetS (no-MetS vs. moderate-MetS vs. severe-MetS). Severe-MetS was defined with higher cut-off values for individual components of MetS than those used for moderate-MetS. For instance, the cut-off values of fasting glucose were 5.6 mmol/L and 7.0 mmol/L for moderate-MetS and severe-MetS, respectively. Physical activity was assessed by self-reported physical activity levels (minute/week), resistance training, moderate intensity exercise, and vigorous intensity exercise. No significant difference in self-reported physical activity was observed by severity of MetS. Among participants younger than 50 years of age, resistance training and moderate intensity exercise were inversely associated with severe-MetS ($p<.05$) while among participants aged 50 years or older, only vigorous intensity exercise was inversely associated with severe-MetS ($p<.05$).

Brien and Katzmarzyk (2006) also investigated the cross-sectional association between physical activity and MetS in a sample of 12,881 men and women aged 18 to 64 years who participated in the Canadian Heart Health Survey. Physically active was defined as participating in physical activity at least once a week for a period of at least 30 minutes over the past month, with physical activity causing sweating or heavy breathing for at least some of the time. Using the NCEP ATP III criteria, the authors reported that the prevalence of MetS in men and women was 17.5% and 11.2%, respectively. Physically active men were less likely to have MetS compared with inactive men (adjusted OR, 0.45, 95% CI, 0.29-0.69), whereas no statistically significant association between physical activity and MetS was observed in women (OR, 0.67, 95% CI, 0.44-1.02).

Using the 2007-2009 KNHANES data, Choi et al. (2013) investigated the association between physical activity assessed by a self-reported questionnaire and prevalence of MetS among Koreans aged 65 years and older. Older women had a higher prevalence of MetS than older men (54.4% versus 36.1%, respectively). Physically active women had a significantly lower odds of MetS compared with physically inactive women (OR, 0.67, 95% CI, 0.50-0.89). No statistically significant association between physical activity and MetS was observed among men.

Wagner et al. (2012) examined the association between sedentary behaviours, physical activity, and MetS, using cross-sectional data of 3,090 French subjects aged 35 to 64 years. Men who participated in leisure-time physical activity with the highest energy expenditure (24 or greater metabolic equivalent of task (MET) hour/week) showed a significantly lower odds of MetS (*p* for trend<.01), whereas no significant association between leisure-time physical activity and MetS in women (*p* for trend=.15), after adjusting for multiple covariates including age, SES, smoking, total calorie intake, and dietary patterns. In terms of sedentary behaviours, women who reported the greatest time spent sitting (9 hours or over/day) had a borderline significant association with MetS (*p* for trend=.06), whereas there was no significant association in men (*p* for trend=.15). Similarly, the inverse association between physical activity at work and MetS was significant in women (*p* for trend<.05) but not in men (*p* for trend=.17).

2.5.2 Dietary intake

Various dietary strategies for MetS have been investigated, with the majority emphasizing weight reduction through caloric restriction (Yu-Poth et al., 1999; Abete et al., 2010; Josse et al., 2008). However, caloric restriction is controversial since feelings of hunger increase, lowering compliance and long-term effectiveness in terms of weight maintenance (Abete et al., 2010). Therefore alternate strategies to manage body weight, body composition, or metabolic profiles have been investigated and involve manipulation of macronutrient distribution such as low-fat, low-carbohydrate, or high-protein diet (Josse et al., 2008; Abete et al., 2010). In addition, effects of low glycemic index (GI) foods, certain types of fatty acids, and micronutrients on MetS and/or its individual components have been examined (Feldeisen & Tucker, 2007; Abete et al., 2010). In this section a narrative summary or broad overview of the literature is provided. The summary of study results of the association between nutrient intake and MetS is presented in Table 3. Priority was given to results of intervention studies and prospective observational studies.

Table 3 Summary of study results of the association between nutrient intake and MetS

		Intervention studies	Observational studies
Macro-nutrient	Fatty acids	Short-term effect*	Vary by population characteristics
	- mono- & polyunsaturated		Inversely associated
	Protein	Short-term effect	Vary by population characteristics
	Carbohydrates	Short-term effect	Vary by population characteristics
	- Low- or High-GI		High-GI positively associated
Micro-nutrient	Calcium, Vitamin D, Vitamin E, Magnesium		Inversely associated
	Sodium		Positively associated

* 6 weeks to 12 months; GI: glycemic index

Macronutrients distribution

Intervention studies

The effect of low-carbohydrate versus low-fat diets on weight loss and cardiovascular risk factors has been investigated in several studies. Samaha et al. (2003) studied a sample of 132 obese participants (mean BMI of 43) with a prevalence of diabetes and MetS of 39% and 43%, respectively. It was found that participants in the 6-month low-carbohydrate diet group showed a significant decrease in body weight (p=.002), triglycerides (p=.001), and glucose level (p=.017) compared with those in the low-fat diet group. Using a crossover study design, Sharman et al. (2004) also compared the effects of a 6-week low-carbohydrate diet to that of a 6-week low-fat diet on fasting blood lipids and postprandial lipemia in 15 overweight but otherwise healthy participants. The macronutrient distribution for the low-carbohydrate diet was ~30% of energy from protein, ~60% of energy from fat, and ~10% of energy from carbohydrate. The distribution for low-fat diet was ~20% of energy from protein, ~25% of energy from fat, and ~55% of energy from carbohydrate. The 6-week low-carbohydrate diet showed a greater reduction in body weight (p<.05) and metabolic profiles such as fasting serum triglyceride, triglyceride/HDL-C ratio, glucose, and postprandial lipemia (p<.05), while the 6-week low-fat diet showed a significant reduction in serum low-density lipoprotein cholesterol (LDL-C) was observed (p<.05). In a randomized multi-centre intervention study, Petersen et al. (2006) also investigated the effects of two hypoenergetic (i.e., −600kcal/day) diets with either low-fat or high-fat diet on body weight, body composition, concentrations of fasting plasma lipids, glucose, and insulin. A total of 771 obese adults from eight sites in seven European countries participated. Dropout rate was higher in high-fat diet group than in low-fat diet (i.e., 18.3% vs. 13.6%). During a 10-week intervention, both diet groups showed similar reduction in mean body weight, but 21% in the low-fat group lost 10% or more of initial body weight compared with 15% in the high-fat group ($p=.02$). The low-fat diet also showed a greater degree of reduction in fasting plasma total cholesterol ($p=.06$), LDL-C ($p=.01$), and HDL-C ($p<.001$) compared with the high-fat diet. There were no group differences in plasma insulin and glucose concentration.

The effect of high-protein/low carbohydrate diet on body composition and metabolic profiles has also been investigated. Clifton et al. (2009) compared the effect of two hypoenergetic diets with either high-protein or standard-protein component. The macronutrients composition for high-protein diet was 27% of energy from protein, 44% of energy from carbohydrate, and 29% of energy from fat. For standard-protein diet, the composition of protein, carbohydrate, and fat was 16%, 57%, and 27%, respectively. A total of 215 overweight or obese participants completed a 12-week intervention, and a higher percent of dropouts were observed in standard-protein diet group than in high-protein diet group (i.e., 18% versus 12%, respectively). There was no between-group difference in weight loss and in total fat loss, but a significant reduction in triglycerides was observed in the high-protein diet group compared with the standard-protein group ($p<.001$). In a subgroup analysis that included participants with high levels of triglyceride (i.e., >1.54 mmol/L) at baseline, a greater degree of reduction in body weight ($p<.01$), total fat mass ($p<.01$), abdominal fat mass ($p<.01$), total cholesterol ($p<.01$), and triglyceride ($p=.05$) was observed in the high-protein diet group compared with the standard-protein group. Layman et al. (2009) also investigated both short-term (i.e., 4 months) and long-term (i.e., 8 months) effects of high-protein diet on body weight, body composition, and blood profiles in 130 obese participants. The macronutrient distribution for high-protein diet and low-protein diet was similar to that of the Clifton et al. study (2009). After completing the 4-month intervention, the high-protein diet showed a greater reduction in fat mass than the low-protein group ($p<.05$), but there was no between-group difference in body weight loss. More participants in the high-protein diet group completed the further 8-month intervention compared with low-protein diet group (64% versus 45%, $p<.05$), and the high-protein diet group showed a greater improvement in body composition ($p<.05$). However, between-group difference in body weight loss remained non-significant ($p=.18$). In a subgroup analysis of participants who lost ≥ 10% of initial body weight, the high-protein diet group showed a greater improvement in body weight loss ($p<.01$) and fat mass ($p<.01$) compared with the low-protein diet. At the 4-month assessment, serum cholesterol and LDL-C were significantly reduced in the low-protein diet compared with the high-protein diet, but this effect was no longer observed at the 8-month assessment. By contrast, at both 4-month and 8-month assessments, serum triglyceride, HDL-C, and triglyceride/HDL-C ratio were significantly reduced in the high-protein diet compared with the low-protein diet.

Macronutrients distribution

Observational studies

Two prospective cohort studies have shown inconsistent findings regarding the association between carbohydrate intake and incidence of MetS. Results from the British Regional Heart Study showed that higher intake of carbohydrate was positively associated with incident MetS in a sample of 3,051 older men aged 60 to 79 years (Wannamethee et al., 2006). In addition, the high carbohydrate/low fat pattern showed an increased risk of MetS compared with the low carbohydrate/low fat pattern (OR, 1.37, 95% CI, 1.07-1.76). However, Carnethon et al. (2004) reported that carbohydrate intake was not significantly associated with incident MetS in 4,192 young American men and women aged 18 to 30 years who participated in the Coronary Artery Risk Development in Young Adults (CARDIA) study.

Findings from cross-sectional studies tend to vary by population. Skilton et al. (2008) investigating 1,626 French adults with mean age of 52.1 years reported an inverse association between high intake of carbohydrate and prevalence of MetS (OR, 0.83, 95% CI, 0.78-0.88) in a multivariable-adjusted model. Using data from the third NHANES data, Zhu et al. (2004) found that compared with high intake of carbohydrate, low intake of carbohydrate was significantly associated with a decreased prevalence of MetS (OR, 0.41, 95% CI, 0.24-0.67 for low intake; OR, 0.44, 95% CI, 0.25-0.77 for moderate intake) in American men but not in women. In 910 middle-aged Korean adults with mean age of 57.9 years, Kim et al. (2008) also found a positive association between carbohydrate intake and prevalence of MetS, but the association was significant only in women.

Similarly, the results of studies investigating the association between MetS and fat intake have been inconsistent. A prospective cohort of older British men aged 60-79 years showed that there was no association between quartiles of total fat intake and incident MetS (Wannamethee et al., 2006). Another prospective study (i.e., the CARDIA study) showed that compared with moderate intake of total fat (i.e., 36-39% energy), the highest quartile of total fat intake (i.e., 42-59% energy) was significantly associated with incident MetS in both African-American and white young men (RR, 2.15, 95% CI, 1.08-4.31 and RR, 2.09, 95% CI, 1.12-3.87, respectively), but not in young women (Carnethon et al., 2004). A cross-sectional study conducted in France (Skilton et al., 2008) reported that high intake of total fat was positively associated with the prevalence of MetS (OR, 1.13, 95% CI, 1.06-1.21), whereas no significant association between fat intake and MetS was observed in the middle-aged participants in the Whitehall II study conducted in the U.K. (OR, 0.97, 95% CI, 0.77-1.23 in men and OR, 1.35, 95% CI, 0.94-1.93 women) (Brunner et al., 2001).

Skilton et al. (2008) found a positive association between protein intake and the prevalence of MetS (OR, 1.41, 95% CI, 1.24-1.60) in middle-aged French adults. Using data from the middle-aged adults of the

Whitehall II study, Brunner et al. (2001) reported that the highest tertile of protein intake showed an increased odds ratio of 1.43 (95% CI, 1.13-1.80) in men, but not in women (OR, 1.13, 95% CI, 0.80-1.62). However, in a Korean cross-sectional study (Kim et al., 2007) the highest quartile of protein intake was inversely associated with prevalence of MetS in women aged 60 years and older (OR, 0.35, 95% CI, 0.18-0.69), but not in older men (OR, 1.8, 95% CI, 0.62-5.6).

Glycemic index

Glycemic index (GI) was developed as a measure of carbohydrate quality (Abete et al., 2011). It has been shown that by reducing postprandial insulin secretion and by maintaining insulin sensitivity, low-GI diets have a beneficial effect on MetS and CVD risk (Josse et al., 2008). Results of intervention studies, however, are inconclusive. Shikany et al. (2009) conducted a randomized crossover intervention study with two diets including a low GI and a high GI diet. A total of 24 overweight or obese but healthy American men completed two 4-week interventions with a 4-week washout period. Both diets showed a favourable change in body composition including body weight, BMI, fat mass, and lean mass, whereas the high-GI diet showed greater improvement in fat mass (p=.024) and lean mass (p=.018) than the low-GI diet. Glucose and insulin levels were decreased in both diets but no between-group difference was observed. Similarly, there was no between-group change in inflammatory markers and coagulation factors. Of lipoprotein/lipids markers, high-GI diet showed a greater decrease in total cholesterol (p=.0013) and LDL-C (p=.0019) than low-GI diet; however, HDL-C level was significantly lowered in high-GI diet relative to low-GI diet (p=.045). Using data from 202 Norwegian participants with at least one component of MetS (65% of sample had MetS), Klemsdal et al. (2010) also examined the effect of low-GI diet versus low-fat diet on individual components of MetS. At 12 months, both low-GI and low-fat diets showed favourable changes in body weight, waist circumference, and waist-to-hip ratio, but the change in waist circumference (p=.03) and waist-to-hip ratio (p=.009) was less in low-GI diet group than in low-fat diet group. Compared with low-fat diet, low-GI diet significantly lowered diastolic blood pressure (*p*=.016) and LDL-C (*p*=.05).

Finley et al. (2010) investigated the cross-sectional association between GI and MetS (and individual components) in American sample of 9,137 men and 1,775 women. The prevalence of MetS in men and women was 24% and 9%, respectively. In men, the energy-adjusted GI quartiles were significantly and positively associated with elevated triglyceride, low HDL-C, elevated fasting glucose and prevalence of MetS. In women, the energy-adjusted GI quartiles were positively associated with large waist circumference, elevated triglycerides, and low HDL-C after adjusting for age, examination year, smoking, alcohol intake, protein intake, total fat intake, energy intake adjusted fiber, energy intake, and cardiorespiratory fitness.

Using cross-sectional data from 910 Korean adults aged 20 years and older, Kim et al. (2008) reported a significant positive association between carbohydrate intake and prevalence of MetS, especially in women. Data on the amount of dietary carbohydrate, GI, and glycemic load (GL: the amount of carbohydrate x GI) were collected using a food frequency questionnaire. Higher intake of carbohydrate, GI, and GL had significant association with MetS (*p* for trend=.03, .03, and .02 for carbohydrate, GI, and GL, respectively). All three indicators were significantly associated with increased odds of HDL-C abnormality (*p* for trend <.0001, 01, <.0001, for carbohydrate, GI, and GL, respectively).

Sahyoun et al. (2006) investigated the association between whole-grain intake and MetS, using cross-sectional data of 535 American older adults aged 60 to 98 years. After adjusting for covariates including age, SES, smoking, alcohol intake, exercise, energy intake, percentage saturated fatty acid intake, use of medication for hypertension or lipid abnormality, higher intake of whole grain was inversely associated with MetS (*p* for trend=.005). In contrast, higher intake of refined grain was positively associated with MetS (*p* for trend=.01).

Fatty acids

It has been suggested that the type of fatty acids may be more important for MetS than the amount of fatty acids consumed (Riccardi et al., 2004; Feldeisen & Tucker, 2007). Evidence from intervention studies supports that polyunsaturated fatty acids and monounsaturated fatty acids have a beneficial effect on insulin sensitivity and MetS (and its individual components), while saturated fatty acids and trans fatty acids impede glucose and lipids metabolism (Riccardi et al., 2004). Appel et al. (2005) conducted a randomized, crossover study, the OmniHeart randomized trial of 164 American adults with mean age of 53.6 years. Results showed that compared with a carbohydrate diet, a diet rich in monounsaturated fatty acids significantly lowered systolic and diastolic blood pressure (*p*=.005 and .02, respectively) and improved total cholesterol (*p*=.04), HDL-C (*p*=.03), and triglycerides (*p*=.02). Omega-3 fatty acids (a key family of polyunstaturated fatty acids) have been also recommended to prevent and treat MetS (Abete et al., 2010). Carpentier et al. (2006) suggested potential benefits of omega-3 fatty acids on: lowering insulin resistance in muscle and adipose tissue; decreasing serum triglyceride; increasing HDL-C; reducing blood pressure; and improving endothelial function, inflammatory status and cell antioxidant defenses. Although there is evidence that omega-3 fatty acids slightly increase LDL-C, omega-3 fatty acids reduce small, dense lipoprotein particles which are highly associated with an increased risk of CVD (Carpentier et al., 2006). Two cross-sectional studies (Brunner et al., 2001; Skilton et al., 2008), however, reported no association between intake of monounsaturated and polyunsaturated fatty acids and MetS.

Micronutrients

Several studies have reported that high intake of calcium and vitamin D is associated with a reduced prevalence of MetS. Dairy products are considered the major source of both calcium and vitamin D

(Feldeisen & Tucker, 2007). Based on data from 10,066 middle-aged and older women in the U.S., Liu et al. (2005) reported an inverse association between quintiles of total calcium intake and prevalence of MetS (p for trend<.0003), after adjusting for smoking, exercise, alcohol consumption, multivitamin use, parental history of myocardial infarction. No association between vitamin D intake and the prevalence of MetS was observed (Liu et al., 2005). In the third NHANES dataset of 8,421 American men and women aged 20 years and older, Ford et al. (2005) found an inverse association between vitamin D intake and prevalence of MetS (p for trend<.001). Results from a French prospective study of 3,435 subjects aged 39 to 65 years (Fumeron et al., 2011) showed that high intake of cheese, other dairy products, and calcium density was inversely associated with incident MetS (OR, 0.88, 95% CI, 0.77-1.00; OR, 0.88, 95% CI, 0.79-0.97; OR, 0.86, 95% CI, 0.78-0.95, respectively). American data from the Atherosclerosis Risk in Community (ARIC) study, including 9,514 participants with mean age of 54.4 years and 53.1 years for men and women, respectively also found that diary consumption was inversely associated with incidence of MetS after adjusting for a wide range of covariates (Lutsey et al., 2008).

Magnesium is known to be a cofactor in various key enzymatic reactions including muscle contraction, neurotransmitter release and the regulation of ion channels (Feldeisen & Tucker, 2007). Several studies investigated the role of magnesium in MetS. Based on data from 11,686 middle-age and older American women, Song (2005) reported an inverse association across quintiles of magnesium intake and the prevalence of MetS (p for trend=.002). In contrast, using data from 2,504 participants aged 18 to 74 years in the Tehran Lipid and Glucose Study, Mirmiran et al. (2012) found no association between magnesium intake and prevalence of MetS in all participants (p=.061), but observed an inverse association in obese participants (p=.035). Moreover, intake of magnesium was inversely associated with fasting blood glucose (p=.006), triglycerides (p=.009), and waist circumference (p=.006). He et al. (2006) investigated the longitudinal association between magnesium intake and incidence of MetS over 15-years among young Americans aged 18 to 30 years. In a multivariable-adjusted model, an inverse association between quartiles of magnesium intake and incidence of MetS was found (*p* for trend<.01), and the hazard ratio for incident MetS in the highest quartile of magnesium intake was 0.69 (95% CI, 0.52-0.91).

The effect of anti-oxidative macronutrients including catorenoides, polyphenolic antioxidants, vitamins, and minerals on obesity and cardiovascular risks has been investigated (Abete et al., 2011). A prospective study of 5,285 American men and women with mean age of 61.8 years examined the association between antioxidants such as magnesium, β-carotene, vitamin C, and vitamin E and incident MetS (de Oliveira Otto et al., 2012). Of these antioxidants, vitamin E was inversely associated with incident MetS (*p*=.01). Using the dietary total antioxidant capacity (TAC) assessment tool, Bahadoran et al. (2012) reported that high TAC scores were inversely associated with incident MetS (*p* for trend=.001), obesity (*p* for trend=.01), and hypertension (*p* for trend=.001) after a 3-year follow-up.

Several studies have investigated the association between MetS and sodium intake. Räisänen et al. (2012) investigated the association between daily sodium intake and MetS (and its individual components) in 716 Finnish adults aged 40 to 59 years. The authors found that the highest tertile of sodium intake was positively associated with prevalence of MetS (OR, 1.94, 95% CI, 1.23-3.05). After adjusting for age, gender, study group, and BMI, sodium intake was positively associated with waist circumference (*p*<.001) and fasting glucose (*p*<.001), whereas systolic and diastolic blood pressure, HDL-C, and triglycerides were not significantly associated with sodium intake.

In a sample of 766 middle-aged Venezuelan adults, Hoffman and Cubeddu (2009) found that there was significant difference in 24-hour urinary sodium excretion (used as an index of dietary natrium) between those with and without Mets in both men (*p*<.001) and women (*p*<.01). The urinary sodium excretion was positively associated with waist circumference (*p*=.007), systolic blood pressure (*p*=.05), and diastolic pressure (*p*=.024), whereas no significant association was observed in other components of MetS such as fasting glucose, HDL-C, and triglycerides.

Shin et al. (2013) used KNHANES (2008-2009) data of 11,883 Korean adults aged 20 to 64 to investigate the association between dietary pattern and metabolic abnormalities. High intake of traditional dietary pattern including vegetables, fishes, seaweeds, shell fish, tofu, potatoes, radish, and cabbage (Kimchi) was significantly associated with high intake of salt ($p<.0001$). However, high intake of traditional dietary pattern had a significant association with increased mean DBP (*p* trend=.002), and had no significant association with other lipid abnormalities such as total cholesterol, HDL-C, LDL-C, and triglycerides.

Dietary pattern

In examining the association between diet and disease, the traditional approach has been used to assess a single or a group of nutrients or foods based on existing knowledge of nutritional health (Newby & Tucker, 2004). One limitation of this traditional approach is that it fails to reflect actual and overall dietary intake since people consume meals including many foods and nutrients in combination (Hu, 2002; Newby & Tucker, 2004). Many researchers have applied dietary pattern analysis (also called food or eating pattern) to provide a picture of overall diet quality and to account for how foods or nutrients act in combination (Newby & Tucker, 2004). Based on data typically collected through food frequency questionnaires or 24-hour recall methods, statistical methods such as factor or cluster analysis are used to derive optimal (healthy) and suboptimal (unhealthy) dietary patterns (Hu, 2002).

In terms of MetS, the “Mediterranean” diet is thought to be the ideal dietary pattern to prevent and treat MetS, at least in Western or European countries (Feldeisen & Tucker, 2007). This dietary pattern is characterized by high intake of whole grain cereals, vegetables, fruits, low-fat dairy products, and monounsaturated fatty acids, mainly from olive oil, moderate intake of fish and red wine, and low intake of red meat and sweets (Abete et al., 2010). A recent meta-analysis that included 35 clinical trials, 2 prospective, and 13 cross-sectional studies investigated the effect of the Mediterranean dietary pattern on MetS (and individual components) (Kastorini et al., 2011). The studies included in this meta-analysis were conducted in Mediterranean, American, European, and Australian populations. The pooled effect of the findings from the clinical trials and prospective studies indicated that Mediterranean dietary pattern was highly protective for MetS (log-hazard ratio, −0.69, 95% CI, −1.24- −1.16). Compared with "control" dietary patterns, Mediterranean diet had a beneficial effect on individual components of MetS including waist circumference (mean difference between groups, −0.42, 95% CI, −0.82- −0.02), HDL-C (1.17, 95% CI, 0.38-1.96), triglycerides (−6.14, 95% CI, −10.35- −1.93), systolic blood pressure (−2.35, 95% CI, −3.51- −1.18), diastolic blood pressure (−1.58, 95% CI, −2.02- −1.13), glucose (−3.89, 95% CI, −5.84- −1.95), and the homeostasis model assessment - estimated insulin resistance (HOMA-IR) (−0.45, 95% CI, −0.74 - −0.16). However, the pooled effect of findings from the 13 cross-sectional studies was not statistically significant (log-hazard ratio, −0.16, 95% CI, −0.49-0.17).

Heidemann et al. (2011) performed a cross-sectional study to investigate the association between MetS and two derived dietary patterns - processed foods versus health-conscious foods - in a sample of 4,025 German adults. The processed food pattern was characterized by a high intake of refined grains, processed meat, red meat, high-sugar beverages, eggs, potatoes, beer, sweets and cakes, snacks and butter, whereas the health-conscious food pattern reflected a high intake of vegetables, vegetable oils, legumes, fruits, fish and whole grains. The odds of MetS, hypertension, triglycerides, and glucose homeostasis were higher among participants in both the lowest quintile of the health-conscious pattern and the highest quintile of the processed foods pattern compared with those in both the highest quintile of health-conscious pattern and the lowest quintile of processed foods pattern (OR, 2.26, 95% CI, 1.33-4.16; OR, 2.55, 95% CI, 1.49-4.36; OR, 2.36, 95% CI, 1.33-4.17; and OR, 2.60, 95% CI, 1.03-4.56, respectively).

In a 9-year prospective study, Lutsey et al. (2008) also investigated the effects of two dietary patterns - Western and prudent diet - on incident MetS in sample of 9,514 U.S adults aged 45 to 64 at baseline. The Western dietary pattern was characterized by high intake of refined grains, processed meat, fried foods, and red meat, whereas the prudent dietary pattern reflected high consumption of vegetables, fruit, fish, and poultry. Results of multivariable-analyses showed that the association between quintiles of Western dietary pattern and incident MetS was statistically significant (p for trend=0.03); however, there was no significant association between incident MetS and quintiles of prudent dietary pattern. Further analysis for individual food groups showed that intake of meat was positively associated with incident MetS (*p* for trend<.001), while consumption of dairy products was inversely associated with incident MetS (*p* for trend=.006). Intake of fruit and vegetable, whole grains, and refined grains were not statistically associated with incident MetS.

In Asian countries especially Korea, there have been growing concerns about the increasing rates of MetS, and the possible link between MetS and the high-GI traditional diet, along with an increase in consumption of a westernized diet (Kim et al., 2008; Kim & Jo., 2011; Ahn et al., 2013; Baik et al., 2013). In one Korean study, Kim and Jo (2011) examined the association between four derived dietary patterns and MetS in a Korean sample of 9,850 adults aged 19 years and older. The four dietary patterns were: 1) Korean traditional dietary pattern of 'white rice and Kimchi (fermented cabbage)'; 2) 'meat and alcohol'; 3) 'high fat, sweets, and coffee'; and 4) 'grains, vegetables, and fish'. The high intake of two food patterns, 'white rice and Kimchi' and 'grains, vegetables, and fish' showed an inverse relation to prevalence of MetS, whereas the other two patterns, 'meat and alcohol' and 'high fat, sweets, and coffee' were positively associated with prevalence of MetS. High intake of 'meat and alcohol' was positively associated with hypertriglyceridemia (*p* for trend=0.01) and elevated blood pressure (*p* for trend=0.01), while high intake of 'grains, vegetables, and fish' was inversely associated with hypertriglyceridemia (*p* for trend=0.0002).

Based on KNHANES 2008-2010 data of 11,883 Korean adults aged 20 to 64 years, Shin et al. (2013) investigated the association between three derived dietary patterns, namely 'traditional', 'Western', and 'dairy and carbohydrate' and three individual components of MetS (i.e., BP, TG, and HDL-C). The traditional dietary pattern consisted of green and white vegetables, mushroom, white flesh fish, blue-back fish, brown seaweeds, dried laver, shellfish, anchovy, cuttlefish, salted fish, tofu, fruits, potatoes, cabbage, radish, eggs, cereal, and beans. The Western pattern was characterized by high intake of ham, sausage, fast food, fat oils, carbonated beverage, instant noodle, chicken, pork, beef, boiled fish, noodles, and alcohol. The dairy and carbohydrate pattern was characterized by high intake of bread, snack, dairy products, rice cake, and sweet potatoes, and less intake of coffee. When adjusting for other covariates such as age, gender, education, income, smoking, physical activity, energy intake, higher intake of the traditional dietary pattern was significantly associated with higher level of DBP (*p* for trend=.002), but unrelated with TG or HDL-C. Higher intake of the Western dietary pattern was significantly associated with increased risk of BP, TG, and HDL-C (*p* for trend=.0001 for the three measures). In contrast, higher intake of the dairy and carbohydrate pattern were significantly associated with lower risk of BP and TG, but increased risk of low HDL-C (*p* for trend=.0001).

Song & Joung (2012) also examined the association between dietary patterns and MetS by comparing three derived dietary patterns based on the KNHANES III data consisting of 4,730 Korean adults aged 20 years and older. The first dietary pattern was labeled as traditional and characterized by high consumption of rice and Kimchi. The second pattern was labelled as healthy and consisted of rice, vegetables, grains, fruit, eggs, fish, and milk. The third pattern was characterized by high intake of meat and its products and alcohol, and therefore labeled as meat and alcohol. Compared with the traditional pattern, the healthy and meat and alcohol patterns were not significantly associated with MetS, after controlling for other covariates. However, compared with the traditional pattern, the healthy and meat and alcohol patterns had lower odds of abnormal levels of HDL-C (OR, 0.77 and 0.87, respectively) and the associations were statistically significant. In contrast, compared with the traditional pattern, the meat and alcohol pattern was significantly associated with increased risk of TG and fasting blood glucose (OR, 1.21 and 1.33, respectively).

Using the KNHANES (2007-2008) data of 3,871 Korean adults aged 30 to 65 years, Song et al. (2012) reported that higher levels of intake of whole grains and beans were negatively associated with insulin resistance (*p* trend=.013) while there was no significant association between a pattern of white rice and Kimchi and insulin resistance (*p* trend=.398). Ahn et al. (2013) examined the association between rice-eating pattern and MetS using the Korean Genome and Epidemiology Study data of 26,006 Korean adults aged 40 to 69 years. Four types of rice eating were assessed including white rice, eating rice with beans, eating rice with multi-grains, and eating rice in mixed (of these three types). Among men participants, none of the rice eating patterns was significantly associated with MetS and components of MetS, except for the mixed group. Men with mixed rice eating pattern were more likely to have higher waist circumference compared with men with white rice group (OR, 1.18, 95% CI, 1.02-1.36). However, in postmenopausal women, women who had rice with multi-grains and rice in mixed patterns were less likely to have MetS (OR, 0.85, 95% CI, 0.73-0.98; OR, 0.74, 95% CI, 0.62-0.89, respectively) and HDL-C abnormality (OR, 0.87, 95% CI, 0.76-0.99; OR, 0.82, 95% CI, 0.70-0.97, respectively) compared with those with white rice pattern. Rice with beans and rice with multi-grains patterns had significantly lower odds of high waist circumference (OR, 0.78, 95% CI, 0.66-0.92; OR, 0.83, 95% CI, 0.73-0.94) compared with women with white rice pattern. Rice with beans pattern were less likely to have fasting glucose abnormality (OR, 0.75, 95% CI, 0.61-0.92) compared with women with white rice pattern.

2.5.3 Smoking

Smoking is a major risk factor for MetS (Cena et al., 2011). A recent meta-analysis (including 13 prospective studies and a total of 56,691 participants) investigated the longitudinal association between smoking and MetS (Sun et al., 2012). The pooled relative risk of MetS among smokers compared with non-smokers was 1.26 (95% CI, 1.10-1.44) in all participants, 1.19 (95% CI, 1.00-1.42) in men, and 0.85 (95% CI, 0.60-1.21) in women. The relative risk of MetS in light smokers (i.e., < 20 cigarettes/day) and heavy smokers (i.e., ≥ 20 cigarettes/day) was 1.10 (95% CI, 0.90-1.35) and 1.42 (95% CI, 1.27-1.59), respectively. This increased risk was observed in Asian, Europe and American studies, although not statistically significant in the American studies.

Bradshaw et al. (2013) investigated the cross-sectional association between smoking habits, weight, and prevalence of MetS in 14,663 American adults aged 45 to 64 years. Compared with non-smokers, current smokers in all three BMI categories (i.e., normal, overweight, obese) showed a positive association with MetS (OR, 1.56, 95% CI, 1.23-1.97 for normal; OR, 1.32, 95% CI, 1.14-1.53 for overweight; OR, 1.51, 95% CI; 1.26-1.81 for obese). However, among former smokers, obese subjects had a greater odds for MetS compared with obese non-smokers (OR, 1.24, 95% CI, 1.06-1.44), whereas normal and overweight subjects had no significant association with MetS (OR, 1.06, 95% CI, 0.82-1.38 and OR, 0.99, 95% CI, 0.87-1.14, respectively).

In another cross-sectional study conducted in the U.S., Zhu et al. (2004) found that, non-smokers had a significantly lower odds of MetS compared with current smokers (OR, 0.63, 95% CI, 0.45-0.90 in men; OR, 0.58, 95% CI, 0.41-0.81 in women). However, there was no significant association between former smokers and prevalence of MetS in both men and women, after adjusting for a wide range of covariates such as age, race, education, income levels, menopausal status for women, physical activity, and alcohol consumption. Another study (Bhanushali et al., 2013) investigated the association between smoking and prevalence of MetS in African-American men and women and found no association.

In a Japanese cross-sectional study of 5,697 men, Matsuchita et al. (2011) found that smokers had an elevated odd of MetS compared to non-smokers (OR, 1.18, 95% CI, 0.97-1.42), but this difference did not achieved statistical significance. Former smokers also had greater odds of MetS than non-smokers. The relationship between visceral fat area and smoking habits was also examined. Compared with current smokers, former smokers had significantly greater visceral fat area. There was no significant difference in visceral fat area between current smokers and non-smokers. In further analyses, current smoking status was positively associated with elevated triglycerides (OR, 1.39, 95% CI, 1.21-1.60) and low HDL-C (OR, 1.76, 95% CI, 1.40-2.20). Former smokers with 10-14 years of smoking cessation had an increased odds of elevated triglycerides (OR, 1.36, 95% CI, 1.03-1.79) and hyperglycemia (OR, 1.43, 95% CI, 1.07-1.91). Former smokers with 5-9 years of smoking cessation had an increased odds of hyperglycemia (OR, 1.47, 95% CI, 1.17-1.85), while former smokers with ≤ 4 years of smoking cessation had an increased odds of elevated triglycerides (OR, 1.29, 95% CI, 1.04-1.59) and hyperglycemia (OR, 1.47, 95% CI, 1.17-1.83). Interestingly, current smokers had a significantly lower odds of hypertension than non-smokers (OR, 0.71, 95% CI, 0.64-0.86).

2.5.4 Alcohol consumption

Previous studies have suggested that light to moderate alcohol consumption would decrease risk of MetS, and this might be explained by increase in HDL-C concentration (De Oliveira e Silva et al., 2000; Brinton, 2012; Shimomura & Wakabayashi, 2013). Alkerwi et al. (2009) conducted a meta-analysis to examine the association between alcohol consumption and prevalence of MetS. Data were derived from 7 cross-sectional studies involving 17,202 men and 22,233 women aged 20 years and older from the U.S., the U.K., Sweden, Portugal, and Korea. Alcohol consumption was categorized into four groups: 1) non-drinkers; 2) responsible drinking (i.e., 0.1-19.99g/day for women and 0.1-39.99g/day for men); 3) hazardous drinking (i.e., 20-39.99g/day for women and 40-59.99g/day); and 4) harmful drinking (i.e., ≥ 40g/day for women and ≥ 60g/day for men). The pooled odds ratios for MetS in responsible drinkers compared with non-drinkers was 0.84 (95% CI, 0.75-0.94) in men and 0.75 (95% CI, 0.64-0.89) in women, respectively. The pooled odds ratio for MetS with hazardous drinking was 0.95 in men, but this association was not statistically significant (95% CI, 0.83-1.09). For women with hazardous drinking, data were not available due to small numbers. Harmful drinking was not associated with MetS in both men (OR, 0.99, 95% CI, 0.71-1.38) and women (OR, 0.81, 95% CI, 0.57-1.14), perhaps due to insufficient sample size.

Several studies have investigated the longitudinal association between alcohol consumption and incident MetS. Stoutenberg et al. (2013) tested this association in 7,483 Caucasian American men (mean age of 43.4 years). During an average of 6.0 years of follow-up, 1,578 incident cases of MetS were observed. The level of alcohol consumption was based on frequency of drinks per week, with a drink being defined as 360 mL of beer, 150 mL of wine, or 22.5 mL of liquor. Participants were categorized into five groups: non-drinkers; light drinkers (i.e., 1-3 drinks/week); moderate drinkers (i.e., 4-7 drinks/week); moderate to heavy drinkers (i.e., 8-13 drinks/week); and heavy drinkers (i.e., ≥ 14 drinks/week). The hazard ratio for MetS in light, moderate, moderate to heavy and heavy drinkers was 0.81 (95% CI, 0.68-0.95), 0.68 (95% CI, 0.57-0.80), 0.70 (95% CI, 0.59-0.83), and 0.78 (95% CI, 0.66-0.91), respectively. Among individual components of MetS, fasting glucose was positively associated with moderate (HR, 1.28, 95% CI, 1.11-1.48), moderate to heavy (HR, 1.22, 95% CI, 1.05-1.42), and heavy drinking (HR, 1.56, 95% CI, 1.35-1.81), whereas low level of HDL-C was inversely associated with all levels of alcohol consumption.

In their prospective study, Wilsgaard & Jacobsen (2007) examined the longitudinal association between alcohol consumption and incident MetS in 17,014 Norwegian men and women aged 20 to 56 years who participated in the population-based Tromsø Study. During an average of 13.8 years of follow-up, 13% of men and 11.4% of women were newly diagnosed with MetS. Based on reported monthly frequency, alcohol consumption was classified into four categories: 0-1, 2, 3-5, and > 6 times/month. For women, the hazard ratio for incident MetS for second, third, and fourth quartile of alcohol intake was 0.80 (95% CI, 0.66-0.97), 0.72 (95% CI, 0.59-0.88), and 0.72 (95% CI, 0.58-0.89), respectively. Alcohol intake was inversely associated with waist circumference (HR, 0.91, 95% CI, 0.86-0.97), HDL-C (HR, 0.87, 95% CI, 0.83-0.92), and triglycerides (HR, 0.91, 95% CI, 0.87-0.96). In men none of the quartiles of alcohol intake was significantly associated with incident MetS, and only HDL had an inverse association with incident MetS (HR, 0.93, 95% CI, 0.88-0.98).

Using the Framingham Offspring Study (1991-2001) data of 2,879 healthy adults (mean age of approximately 54 years), Imamura et al. (2009) also found the inverse association between alcohol intake and risk of developing T2DM, indicating that compared with lifetime non-drinkers, drinkers showed lower HRs of T2DM (HR, 0.78, 95% CI, 0.48-1.27 for 0.1-1.0 times/week; HR, 0.91, 95% CI, 0.60-1.38 for 1.1-3.4 times/week; HR, 0.58, 95% CI, 0.36-0.94 for 3.5-8.9 times/week; HR, 0.45, 95% CI, 0.27-0.75, respectively). Further, the authors found that the inverse association between alcohol intake and risk of T2DM was stronger when adjusting for dietary patterns (HR adjusted/HR unadjusted ratio, 0.60, 95% CI, 0.43-0.83) and suggested that if dietary pattern is not adjusted when assessing the effect of alcohol intake on T2DM, the association between alcohol intake and T2DM would not be clearly captured since alcohol intake is significantly associated with dietary pattern.

In contrast, Baik and Shin (2008) also investigated the association between alcohol intake and incident of MetS in a sample of 3,833 Korean men and women aged 40 to 69 years. During the 4-year follow-up, incidence of MetS was 5.7%. Participants were categorized into 5 alcohol intake groups: 1) non-drinkers; 2) very light (i.e., 0.1-5g/day); 3) light (i.e., 5.1-15g/day); 4) moderate (i.e., 15.1-30g/day); 5) and heavy drinkers (i.e., > 30g/day). In terms of frequency of alcohol intake, participants were classified into 3 categories: those who consumed <1; 1-2; and ≥ 3 drinks days per week. In a multivariable-adjusted model, the relative risk for incident MetS in heavy drinkers was 1.63 (95% CI, 1.02-2.62). There was no evidence of an association between the other drinking categories and incident MetS. A stratified analysis by type of alcohol beverage showed that among heavy drinkers, only liquor was positively associated with incident MetS (RR, 1.70, 95% CI, 1.04-2.80). A BMI-stratified analysis showed that among heavy drinkers, individuals with a BMI ≥ 25 kg/m^2 had an increased risk of MetS (RR, 2.15, 95% CI, 1.18-3.91). There was no evidence of an association between frequency of alcohol intake and incident MetS. Heavy drinking was positively associated with high triglycerides (OR, 1.60, 95% CI, 1.28-2.00), high blood pressure (OR, 2.19, 95% CI, 1.70-2.82), and high glucose (OR, 2.37, 95% CI, 1.50-3.73). Moderate drinking was positively associated with high triglycerides (OR, 1.31, 95% CI, 1.04-1.66) and high blood pressure (OR, 2.21, 95% CI, 1.71-2.86). HDL-C, however, was inversely associated with alcohol intake across all categories.

Data from a sample of Italian seniors aged 65-84 years (517 older men and 231 older women) showed no association between alcohol consumption and incident MetS (Buja et al., 2010). Over an average 3.5 years of follow-up, the incidence of MetS in men and women was 10.6% and 26%, respectively. Based on their reported total daily alcohol intake, participants were categorized into 5 groups, non-drinkers and those drinking ≤ 12g/day, 13-24g/day, 25-47g/day, or ≥ 48g/day. In both men and women, daily amount of alcohol intake was unrelated to incident MetS (and its individual components).

2.5.5 Psychological conditions

The underlying etiological mechanism for the association between psychological conditions and MetS is complex. One prevailing hypothesis focuses on the endocrine system response to stress, including the activation of the sympathetic nervous system (SNS) and the sensitization of the hypothalamic-pituitary-adrenal (HPA) axis (Holmes et al., 2010; Lambert & Lambert, 2011). Hypertension and obesity have been known to be associated with increased activation of the SNS (Lambert & Lambert, 2011). Dysregulation of the HPA axis as a result of chronic stress exposure increases production of glucocorticosteroid hormones such as cortisol (also called a stress hormone) (Holmes et al., 2010; Lambert & Lambert, 2011). The increased level of cortisol is associated with weight gain, insulin resistance, and lipids abnormalities (Lambert & Lambert, 2011). Furthermore, it has been suggested that deficiency of catecholamine caused by chronic stress is associated with depression (Cowen, 2002). Stress-induced elevated level of cortisol is also associated with decreased brain serotonin function, which in turn induces depression (Cowen, 2002; Pompili et al., 2010). Thus, depression and MetS may share several common traits such as obesity, hypertension, and blood lipids abnormalities that are associated with dysregulation of endocrine systems in response to a stressful life event or chronic stress exposure. Alternatively, depression may increase risk of unhealthy lifestyle choices and ultimately MetS (Bonnet et al., 2005). In addition, the use of medications for depression can affect MetS (Chokka et al., 2006).

A recent meta-analysis investigated the association between depression and MetS (Pan et al., 2012). Data from 27 cross-sectional and 14 prospective studies were included. The majority of studies used the NCEP ATP III diagnostic criteria for MetS. Two types of assessment methods were used for the diagnosis of depression. One was a structured or semi-structured clinical diagnostic interview and the other was self-reported symptom scales. Based on the cross-sectional studies only, the odds of MetS was higher in depressed participants compared with those without depression (pooled OR, 1.42, 95% CI, 1.28-1.57). Of the 14 prospective studies, 10 investigated the association between MetS and incident depression, while 4 examined the association between depression and incident MetS. The pooled odds ratio for the association between MetS and incident depression was 1.49 (95% CI, 1.19-1.87), while the pooled odds ratio for association between depression and incident MetS was 1.52 (95% CI, 1.20-1.91). Further analyses showed that the magnitude of association varied depending on both the method used to diagnose depression (clinical diagnosis versus self-reported symptoms) and the operational definition of MetS (i.e., NCEP ATP III versus IDF criteria). Additionally, European prospective studies reported a weaker association between depression and MetS than prospective studies conducted in other countries (OR, 1.31, 95% CI, 1.03-1.67 versus OR, 1.69, 95% CI, 1.15-2.49) (p=0.04). Gender also appeared to modify the relationship, with the magnitude of the association between depression and MetS being stronger in men versus women (OR, 2.15, 95% CI, 1.59-2.93 versus OR, 1.66, 95% CI, 1.07-2.57, respectively) (p=0.006). Moreover, a significant level of heterogeneity across studies was observed. Pan et al. (2012) used the I^2 statistic to assess heterogeneity across studies. Values of 25, 50, and 75% were interpreted as low, medium, and high degree of heterogeneity. Cross-sectional studies conducted in European studies showed higher degree of heterogeneity (i.e., I^2=70.5), whereas studies conducted in other countries showed a modest level of heterogeneity (i.e., I^2=66.7). In prospective studies, especially studies examining depression as the outcome showed a higher degree of heterogeneity (i.e., I^2=56.8) than studies using incident MetS as the outcome (i.e., I^2=0). Furthermore, a significant heterogeneity was found across studies investigating elderly participants (i.e., ≥ 60 years old). The value of I^2 statistic was 83.5, relative to 30.6 in participants aged less than 60 years old.

The association between perceived stress and individual components of MetS has also been investigated. In a sample of 106 Italian elderly men and women (i.e., mean age 79.5 ± 3.8 years old), Bove et al. (2010) investigated the cross-sectional association between perceived stress and components of MetS. Perceived stress was measured by the Perceived Stress Scale (PCS) (Cohen et al., 1983) that asks how often the participants felt symptoms of stress in the last month. MetS-related biological measures were assessed, including total cholesterol, triglycerides, HDL-C, LDL-C, uric acid, glycaemia, fibrinogen, waist circumference, BMI, and blood pressure. Results of multiple-regression analysis showed that only triglycerides was significantly associated with perceived stress (p=.02). Using the same PCS, Räikkönen et al. (2007) investigated the association between perceived stress and incident MetS in 523 American middle-aged women enrolled in the Healthy Women Study, a prospective study with a 15-year follow-up. The frequency and severity of stressful life events during the past 6 months was also assessed. In the final multivariable-adjusted model, the relative risk for MetS in women having a high level of perceived stress was 1.54 (95% CI, 1.07-2.32). The relative risk for MetS in women having at least one very severe stressful life event was 2.19 (95% CI, 1.08-4.45).

2.5.6 Sleep

Similar to depression, it has been suggested that sleep deprivation may be lead to dysregulation of the SNS and HPA axis, increasing catecholamine levels and stress hormones such as cortisol. This, in turn, leads to an elevated risk for abnormal metabolic profiles (Van Cauter et al., 2008). Given this shared pathway, people with sleep restriction tend to have higher rate of depression compared with those with normal sleep pattern (i.e., an appropriate duration and a sufficient level of slow wave sleep) (Mezick et al., 2011). Similarly, people with depression are more likely to have sleep disorders such as insomnia than those without the condition (Mezick et al., 2011). In addition, another important hormone that is associated with sleep is the growth hormone (GH) and the release of GH is increased during slow wave sleep (Van Cauter et al., 2008). Reduction in either total sleep or slow wave sleep hours decreases release of GH and a corresponding increase in cortisol release and risk for abnormal metabolic profiles (Van Cauter et al., 2008). Sleep deprivation is also associated with ghrelin which is a hormone involved in appetite regulation (Spiegel et al., 2004). Compared with people with a moderate level of sleep duration, those with limited sleep are more likely to have an increased level of ghrelin, whereas level of insulin (i.e., having an effect on inhibition of food intake) is decreased. Hence, sleep-deprived individuals are more likely to experience hunger and to consume more foods such as calorie-dense foods compared with people with sufficient duration of sleep. Sleep deprivation may therefore increase obesity (Spiegel et al., 2004; Van Cauter et al., 2008).

Hung et al. (2013) reported the cross-sectional association between self-reported sleep quality and MetS in a sample of 3,435 Taiwanese individuals (mean age: 50.8 and 43.5 years for subjects with MetS and without MetS, respectively). The prevalence of MetS in this cohort was 26.2%. The authors found that people with MetS were more likely to report poor sleep quality than those without MetS (OR, 1.48, 95% CI, 1.25-1.74). Another cross-sectional study conducted in Iran investigated the association between sleep duration and MetS (Najafian et al., 2011). The prevalence of MetS was 23.5%. The odds of MetS in those with either ≤ 5 or 6 hours of sleep per day were greater than that among those with 7 to 8 hours of sleep per day (OR, 1.52, 95% CI, 1.33-1.74 and OR, 1.20, 95% CI, 1.07-1.35, respectively). A further analysis showed that among participants aged < 60 years, participants with either ≤ 5 or 6 hours of sleep per day had greater odds of MetS (OR, 1.70, 95% CI, 1.46-1.99 and OR, 1.23, 95% CI, 1.08-1.39) compared with those with 7 to 8 hours of sleep per day. Participants with ≥ 9 hours/day had lower odds of MetS (OR, 0.84, 95% CI, 0.70-1.00). Among participants aged ≥ 60 years, there was no significant association between MetS and participants with either ≤ 5 or 6 hours of daily sleep compared with those with 7 to 8 hours of daily sleep. Participants with ≥ 9 hours/day, however, had lower odds of MetS (OR, 0.61, 95% CI, 0.40-0.92). By contrast, in a Portugese sample of 832 men and 1, 332 women aged 18 to 92 years (Santos et al., 2007), compared with participants with ≥ 9 hours/day of sleep duration, women with ≤ 6, 7, and 8 hours of daily sleep duration had lower odds of MetS (OR, 0.46, 95% CI, 0.28-0.72; OR, 0.50, 95% CI, 0.33-0.76; OR, 0.58, 95% CI, 0.41-0.84), indicating that longer duration of sleep (i.e., ≥ 9 hours/day) increased risk of MetS.

Choi et al. (2011) examined the longitudinal association between sleep duration and MetS in a Korean cohort of 1,107 men and women aged 40-70 years old. During an average 3-year follow-up, the incidence of MetS was 18.4% (i.e., 21.2% for men and 16.9% for women). After adjusting for multiple covariates including age, BMI, physical activity, smoking, alcohol use, and menopausal status, women with < 6 and ≥ 10 hours/day of sleep duration had higher odds of incident MetS compared with women who reported 6 to 7.9 hours of daily sleep. (OR, 1.80, 95% CI, 1.06-3.05 and OR, 1.66, 95% CI, 0.71-3.88, respectively). Women with 8 to 9.9 hours of sleep per day had similar odds of MetS than that of women who reported 6 to 7.9 hours of daily sleep. There was no significant association between sleep duration and incident MetS in men.

2.5.7 Discussion

Physical activity

Findings from intervention studies have shown the evidence of protective effect of physical activity on development of MetS. Two meta-analyses (Pattyn et al., 2013; Strasser et al., 2010) found that physical activity intervention improved at least some of components (i.e., waist circumference, blood pressure, and HDL-C) and certain physiological indicators (i.e., fat mass and HbA1c) of MetS. Longitudinal studies have also supported the protective effect of physical activity (i.e., high level of cardiovascular fitness and high intensity of physical activity) on incident MetS (LaMonte et al., 2005; Wannamethee et al., 2006; Laursen et al., 2012) and incident CHD and CVD (Broekhuizen et al., 2011; Stensvold et al., 2011). Cross-sectional studies have also shown that vigorous intensity physical activity rather than moderate intensity physical activity was inversely associated with presence of MetS in both middle-aged and older adults (Sénéchal et al., 2012; Brien & Katzmarzyk, 2006; Choi et al., 2013). However, this protective association between vigorous intensity physical activity and MetS appears to vary by gender and age. For instance, based on results from two nationally representative cross-sectional surveys of Canadians and Koreans mentioned earlier (Brien & Katzmarzyk, 2006; Choi et al., 2013), physically active middle-aged (50-64 years) Canadian women did not show a significant association with presence of MetS, whereas physically active Korean older women (65-74 years) had significant lower odds of MetS. By contrast, the inverse association between vigorous intensity physical activity and MetS was found in middle-aged (50-64 years) Canadian men but not in Korean older men (65-74 years). Given the very limited evidence, however, it is hard to conclude that there exists age- or gender-related variability on the association between physical activity and MetS. Also, the discrepancies of findings may in part due to differences in study methods such as unadjusted covariates or the definition of MetS used (Sénéchal et al., 2012; Brien

& Katzmarzyk, 2006; Choi et al., 2013). Further, it may be difficult to establish a clear temporal sequence in cross-sectional studies, since participants who have been diagnosed with MetS may alter their physical activity levels.

Dietary intake

Intervention studies have manipulated macronutrient distribution by increasing either fat or protein intake while decreasing carbohydrate intake. The results in general suggest that both higher-fat and higher-protein diets have a favourable short-term effect (i.e., 6 weeks to 12 months) on metabolic profiles, body composition, or MetS (Samaha et al., 2003; Sharman et al., 2004; Clifton et al., 2009; Layman et al., 2009) although there is a lack of evidence to support long-term effects (e.g., over 1 year). However, as researchers suggested, higher-fat diet may be less recommendable than high-protein diets for individuals with MetS since high-fat diets may have adverse health outcomes including increased levels of ketone bodies, constipation, or headache which may be barriers to maintain body weight loss after diet (Abete et al., 2011).

Findings from observational studies that examined the association between macronutrients intake and MetS vary by study population characteristics, such as age, gender, and country. High intake of carbohydrates was positively associated with MetS in older British adults (Wannamethee et al., 2006), middle-aged American men (Zhu et al., 2004), and middle-aged Korean women (Kim et al., 2008), while no significant association was observed in young American adults (Carnethon et al., 2004). In middle-aged French adults, an inverse association was observed (Skilton et al., 2008). Fat intake was positively associated with MetS in young American adults (Carnethon et al., 2004) and middle-aged French adults (Skilton et al., 2008), whereas no association was found in both older and middle-aged adults in two UK studies (Wannamethee et al., 2006; Brunner et al., 2001). Two studies from the UK and France showed a positive association between protein intake and MetS in middle-aged adults, whereas older Korean women had an inverse association with MetS (Kim et al., 2007).

The protective effects of low-GI and mono- and poly-unsaturated fatty acids on MetS have been shown in intervention studies. Low-GI diet had favourable changes in metabolic profiles in a 3-month intervention study (Klemsdal et al., 2010), but not in a 4-week intervention study (Shikany et al., 2009). In addition, high-GI diet showed a positive association with MetS and its components in a cross-sectional study (Finley et al., 2010; Sahyoun et al., 2006). In a randomized trial (Appel et al., 2005), a beneficial effect of a diet rich in monounsaturated fatty acids on blood pressure, HDL-C, and triglycerides was reported. Although a statistical significance was not achieved, an inverse association between poly- and mono-unsaturated fatty acids diets and MetS was observed in cross-sectional studies (Brunner et al., 2001; Skilton et al., 2008).

Results from studies investigating the association between several micronutrients and MetS and its individual components are consistent. Several micronutrients such as calcium, vitamin D, vitamin E, and magnesium were inversely associated with MetS or several individual components of MetS (Liu et al., 2005; Ford et al., 2005; Fumeron et al., 2011; Song et al., 2005; Mirmiran et al., 2013; He et al., 2006; de Oliveira Otto et al., 2011). By contrast, intake of sodium was positively associated with the prevalence of MetS (Hoffman & Cubeddu, 2009; Räisänen et al., 2012).

The evidence from Western countries also suggested that Mediterranean dietary pattern or a dietary pattern rich in whole grains, vegetables, legumes, fruits, fish, and dairy products was inversely associated with MetS and its individual components, whereas high intake of process foods, red meat, high-sugar beverages, sweets, and refined grains was positively associated with the condition (Lutsey et al., 2008; Malik et al., 2010; Kastorini et al., 2011; Kim & Jo, 2011; Heidemann et al., 2011). However, there have been some inconsistent findings on dietary patterns, especially a dietary pattern labelled 'health-conscious' or 'prudent'. For instance, Heidemann et al. (2011) found a significant inverse association between a health-conscious pattern and MetS, whereas Lutsey et al. (2008) did not observe an association between prudent pattern and MetS.

One of the dietary patterns consistently derived from Korean data is the traditional dietary pattern, characterized by high consumption of rice and Kimchi. Since the traditional dietary pattern is predominant in Koreans especially in older age groups, the dietary pattern has been examined to identify whether the dietary pattern has beneficial or adverse effects on metabolic risks (Kim et al., 2008; Ahn et al., 2013). The results have suggested that the traditional dietary pattern had an inverse or no association with prevalence of MetS (Kim & Jo, 2011; Song & Joung, 2012), but had significant association with higher DPB and lower HDL-C (Shin et al., 2013; Song & Joung, 2012). In terms of rice eating pattern, recent studies (Song et al., 2012; Ahn et al., 2013) have shown that rice with beans or whole grains rather than white rice alone had beneficial effect on MetS and/or its components.

When interpreting the results of dietary pattern analyses conducted in both Western and Asian studies, there is one issue that needs to be discussed. Inconsistent findings across studies regarding a certain dietary pattern may be due to study differences in food or nutrient components of the particular pattern (Newby & Tucker, 2004). For instance, Heideman et al. (2011) observed that the 'prudent' dietary pattern was negatively associated with MetS, whereas the 'prudent' dietary pattern derived by Lutsey et al. (2008) had no significant association with MetS. Although the two studies derived a dietary pattern that was labeled as 'prudent', there were differences in food components of the 'prudent' dietary pattern between the two studies. The food items loaded on the derived 'prudent' dietary pattern in the Heideman et al. (2011) study included vegetables, vegetable oils, legumes, fruits, fish, and whole grains, whereas the 'prudent' dietary pattern in Lutsey et al. (2008) study included only vegetables, fruits, fish, and poultry (i.e., no grains or legumes). Similarly, both Kim & Jo (2011) and Shin et al. (2013) derived 'traditional' dietary patterns but reported somewhat different results. The traditional dietary pattern in Kim & Jo (2011) study was characterized by rice and Kimchi only, whereas the pattern derived by Shin et al. (2013) included vegetables, fishes, tofu, beans, and fruits. Thus, when comparing the effect of a certain dietary pattern across studies, food items loaded on a dietary pattern should be examined to identify whether they have different components of foods, even though they have the same label (Newby & Tucker, 2004). The discrepancy in food items of a certain dietary pattern (e.g., prudent) across studies might show a real difference in the dietary pattern across study populations; however, these discrepancies may also be due to differences in data collection methods, in researchers' subjectivity when interpreting data results of dietary pattern analysis, and in characteristics of study populations such as elderly versus younger populations (Newby & Tucker, 2004). Again, it may be difficult to establish a clear temporal sequence in cross-sectional studies, since participants who have been diagnosed with MetS may alter their dietary intake.

Smoking

In a meta-analysis (Sun et al., 2012) a significant association between smoking and MetS was found in men but not in women. This might be due to the fact that women were more likely to consume less daily cigarettes than men, and thus the effect of smoking on MetS might be weaker in women than that of men (Sun et al., 2012). Although findings from cross-sectional studies examined the association between smoking and MetS seem to be mixed, a significant positive association between smoking and MetS was observed in current smokers (Bradshaw et al., 2013; Zhu et al., 2004) and former smokers with obesity (Bradshaw et al., 2013; Matshchita et al., 2011) compared with non-smokers.

Alcohol consumption

Results of meta-analysis and several prospective and cross-sectional studies have shown that alcohol intake was either unrelated or inversely associated with MetS (Alkerwi et al., 2009; Wilsgaard & Jacobsen, 2007; Stoutenberg et al., 2013; Buja et al., 2010). By contrast, one Korean study (Baik & Shin, 2008) reported that only heavy drinkers, especially liquor drinkers were positively associated with MetS and some of its components.

Psychological conditions

The results of a recent meta-analysis (Pan et al. , 2012) provided evidence of a cross-sectional association between depression and MetS, as well as a bidirectional and significant association between depression and MetS over time (Pan et al., 2012). Perceived stress also appeared to be significantly associated with MetS. In the study by Bove et al. (2010), perceived stress was associated with triglyceride levels, while Räikkönen et al. (2007) found a significant association between perceived stress, stressful life events, and diagnosis of MetS.

Sleep

Findings from cross-sectional and prospective studies were contradictory. However, one consistent finding was that sleep duration and MetS tend to be related in women (Santos et al., 2007; Choi et al., 2011). Specifically, women with a longer duration of sleep (e.g., ≥ 9 hours/day) had greater odds of MetS compared with those with shorter duration of sleep, whereas this association was not observed in men (Santos et al., 2007; Choi et al., 2011). This gender-associated difference is possibly due to differences in social or household roles, or sex hormones such as estrogen, or presence of depression and high perceived stress (Choi et al., 2011).

2.6 Summary

In chapter two, the evolution of MetS was discussed with emphasis on differences in existing definitions of MetS. Ongoing debate exists about the value of MetS as a diagnostic entity. From a public health perspective it seems potentially useful as it encourages a comprehensive approach to early prevention of CVD or T2DM, including policy development, lifestyle interventions, and pharmacologic treatment. Based on the literature, several biomedical, biosocial and psychosocial factors have been shown to be associated with MetS and might prove useful in identifying high risk groups in the population and targeting modifiable risk factors.

CHAPTER 3 RESEARCH RATIONALE, AIMS, AND HYPOTHESES

3.1 Rationale

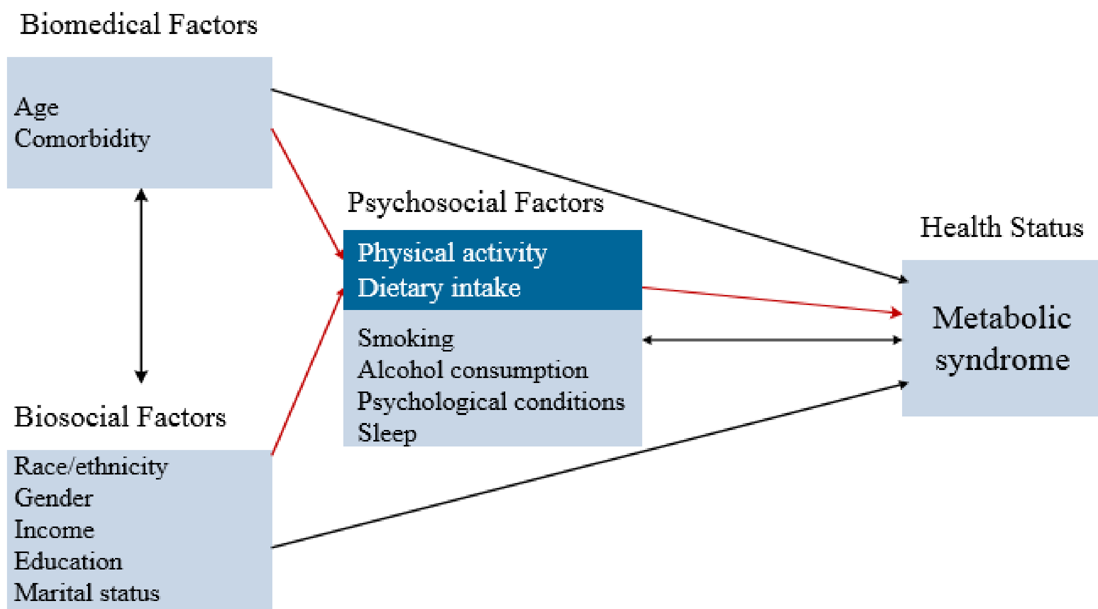
Public health strategies to prevent MetS in older adults have primarily focused on modifiable risk factors such as physical activity and dietary intake (Ross & Després, 2009; Petrella et al., 2005; Katzmarzyk et al., 2003; Lutsey et al., 2008; Rumawas et al., 2009). However, there are few empirical studies that have examined the link between physical activity, diet, and MetS in older adults (Sahyoun et al., 2006; Wannamethee et al., 2006). Further, the results of population-based studies that have examined the association between physical activity, diet, and MetS have been inconsistent. This inconsistency of findings may relate to use of different measurement methods for physical activity or diet intake, use of different diagnostic criteria for MetS, or 'real" variability in physical activity levels and dietary intake, in addition to other known risk factors for MetS (e.g., gender, income, education, smoking, alcohol consumption, and co-existing comorbidities) across study populations (Wahba & Mak, 2007; Pothiwala et al., 2009; Gremese & Ferraccioli, 2011; Sygnowska et al., 2012). As noted by others (Rothman, 1986; Schwartz & Carpenter, 1999), the effect size for any risk factor is dependent on the prevalence and pattern of other risk factors in a given population.

Cross-national studies have the potential to examine the extent to which the magnitude and direction of the association between MetS and individual risk factors such as physical activity or dietary intake are influenced by population differences in physical activity and dietary patterns, as well as prevalence and joint distribution of other known risk factors. Naturally this assumes comparable definitions and measures of key variables, including MetS, physical activity, dietary factors, and other relevant variables. Few studies, however, have compared the prevalence of MetS between countries (Park et al., 2008; Agyemang et al., 2012), and to the author's knowledge there are no cross-national studies comparing prevalence of both MetS and potential risk factors among older adults.

On this basis it was decided to conduct a cross-national comparison of MetS in Canadian and Korean adults aged 60 to 79 years. These two populations differ in dietary intake, with the Canadian diet largely being meat based (Western) and the Korean diet largely being plant based (Asian). In addition, it was expected that between-country differences in history, life experiences and sociocultural norms have led to differences in the magnitude and direction of relationships between MetS, physical activity, dietary pattern, and other known risk factors. The primary objectives of this study therefore were : 1) to compare prevalence of MetS (and individual components) between Canada and Korea in adults aged 60 years or over, using the same diagnostic criteria; 2) to compare prevalence of physical activity, dietary patterns, and other known risk factors for MetS between Canada and Korea, using comparable measures where possible; and 3) to examine whether the pattern or interrelationships among MetS and physical activity, dietary pattern, and other risk vary between countries.

The study's guiding conceptual framework was based on the Concentric Biopsychosocial Model of Health Status, developed to explain the impact of multiple biomedical, biosocial, and psychosocial factors on health status (Hoffman & Driscoll, 2000). Given the range of known risk factors for MetS, this general framework seemed appropriate. Hoffman & Driscoll (2000) defined biomedical factors to represent inherited or fixed characteristics such as genetics or biological processes which may be difficult to modify. Biosocial factors reflected social, economic, ethical, and legal contexts which shape and constrain health status, for instance, gender or poverty. Psychosocial factors represented psychological and social variables such as sedentary lifestyles, depression, and social support which often serve as mediating or moderating influences the association between biomedical and biosocial variables and health status. It was assumed that three broad factors (i.e., biomedical, biosocial, and psychosocial) contributed to MetS. Further, it was assumed that psychosocial factors (i.e., physical activity, dietary intake, smoking, alcohol consumption, psychological conditions, sleep) could mediate the association between biomedical (i.e., age, comorbidity) and biosocial factors (gender, income, education, marital status) and MetS (Figure 1).

Figure 1. Conceptual framework of the biopsychosocial model of metabolic syndrome (MetS) among Canadian and Korean older adults



3.2 Research Aims and Hypotheses

Aim 1: To compare prevalence of MetS (and individual components) between Canadian and Korean adults aged 60 to 79 years. On the basis of the literature, it was predicted that the prevalence will be higher in Korea than in Canada, especially among women. Further, it was hypothesized that differences in life experiences and sociocultural norms have led to important differences in education levels, gender roles, and lifestyle behaviours such as smoking or dietary pattern.

Aim 2: To compare the univariate measures of association between MetS and biomedical, biosocial, and psychosocial factors across Canadian and Korean adults aged 60 to 79 year.

Aim 3: To examine whether physical activity and dietary pattern mediated or moderated the observed measures of association between MetS and biomedical and biosocial factors in Canadian and Korean adults aged 60 to 79 years.

Aim 4: To identify the biomedical, biosocial, and psychosocial factors jointly associated with MetS in Canadian and Korean adults aged 60 to 79 years.

In terms of Aims 2 to 4, it was also hypothesized that between-country differences in history, life experiences and sociocultural norms have led to differences in the magnitude and direction of relationships between MetS, physical activity, dietary pattern, and other biomedical, biosocial, and psychosocial factors.

CHAPTER 4 METHODOLOGY

In this chapter the research methods including data sources, study eligibility criteria, response and explanatory variables, statistical methods, and ethics approval are described.

4.1 Data Sources

The CHMS (cycle 1) and KNHANES (cycle 4) were used to test the study hypotheses. The sources of information for section 4.1.1 and 4.1.2 (see below) were the 'Data User Guide: Cycle 1' (Statistics Canada, 2010) and 'Korea Health Statistics 2009: Korea Health and Nutrition Examination Survey (KNHANES IV-3)' (Korea Centers for Disease Control and Prevention (KCDC), 2009, 2012).

4.1.1 CHMS (cycle 1)

The CHMS (cycle 1) was a cross-sectional, national survey conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada. Data were CHMS (cycle 1 collected over a two-year period beginning in March 2007 and ending in February 2009. Compared with other Canadian national health surveys, the unique features of the CHMS included: 1) investigation of selected health conditions, characteristics and environmental risk factors based on direct health measures; 2) identification of associations between risk factors including health promotion and protective factors and health conditions; and 3) establishment of a biorepository of biospecimens such urine, blood, and DNA from a representative sample of Canadians.

The survey content of the CHMS (cycle 1) consisted of data from a household interview, and data obtained at a clinic visit. Information on socio-demographic and health-related factors was collected via an in depth, computer-based health questionnaire administered in respondents' home, using a computer-assisted personal interview (CAPI) where the interviewer uses a computer to record participants' responses. The household questionnaire contained 722 questions with 6 theme areas and 46 modules

(Appendix A). This interview took 60 to 90 minutes. After completing the household interview, respondents visited a mobile examination centre (MEC) (i.e., one day to six weeks later), where physical and laboratory measures such as blood and urine were collected. A total of 12 areas of physical measures were collected in MEC (Appendix A).

The target population of the CHMS (cycle 1) was the population living at home and residing in the 10 provinces and three territories, representing 96.3% of the Canadian population aged 6 to 79 years. Persons living on reserves or in other Aboriginal settlements in the provinces, institutional residents, certain remote areas, areas with a low population density, and full-time members of the Canadian Forces were excluded. To achieve an adequate sample size at the national level, at least 5,000 persons over the two-year period were needed, with at least 500 individuals allocated to each gender and 5 age groups (i.e., 6-11, 12-19, 20-39, 40-59, and 60-79).

The CHMS (cycle 1) sampling strategy included three stages. The first stage selected collection sites (i.e., defined as a geographic area with a population of at least 10,000 and a maximum respondent travel distance of 50 and 100 kilometers for an urban and rural area, respectively), whereas the second and third stage selected dwellings and individual respondents, respectively. In the first stage, the Labour Force Survey (LFS) sampling frame was used to create collection sites. A total of 257 collection sites were created based on LFS frame clusters, that is, geographic units including approximately 200 dwellings. The 257 collection sites were then stratified by 5 regions (i.e., the Atlantic Provinces – Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick; Quebec; Ontario; the Prairies- Alberta, Saskatchewan, Manitoba including Yellowknife; and British Columbia including Whitehorse). Due to logistical and cost constraints, a total of 15 sites were decided as the final collection sites. In each region, the collection sites were classified as a census metropolitan area (CMA: an area having one or more adjacent municipalities with a center of an urban core) versus non-CMA area. The collection sites were selected systematically with probability of selection proportional to their population size. Through this method, the allocated 15 sites by region were: 1 site in the Atlantic Provinces, 4 sites in Quebec, 6 sites in Ontario, 2 sites in Prairies, and 2 sites in British Columbia. On average 350 respondents were selected for each site.

In the second stage, dwellings were selected based on data from the 2006 Census, providing a list of dwelling address and information on the age and gender of residents. Within each site, dwellings were grouped into 5 strata by age groups (i.e., 6-11, 12-19, 20-39, 40-59, and 60-79). For instance, stratum 1 refers to dwellings with at least one person aged 6- to 11-year-old. The dwellings were then selected using a stratified simple random sampling.

In the third stage, selected dwellings were asked to provide a list of current household members. One or two respondents in a list were randomly selected. If there was one person aged 6-11 years in the household, a second person aged 12-79 years was selected randomly. This was done so children would have an accompanier when visiting the MEC. If there were two people aged 6-11 years, one of them was selected randomly. If there was no person aged 6-11 years, only one aged 12-79 years was selected randomly. If there were multiple people in the same age group in one dwelling, the weight vector was used for an equal probability of selection of all age groups.

A sub-sample of respondents was randomly selected to measure exposure to environmental contaminants and for this test, only one person per dwelling was selected. Before visiting the MEC, all respondents were randomly allocated into two groups by appointment times to avoid selection bias. Morning appointments required fasting, while afternoon appointments did not. Pregnant women, diabetic patients, and other special cases were not allocated to the fasted group.

A total of 8,772 dwellings were initially targeted for participation in the survey. Of these dwellings, 6,106 (69.6%) provided information on the composition of their household. This resulted in 7,483 persons being asked to participate in the survey. Of these, 6,604 (88.3%) persons participated in the household interview, and 5,604 (84.9%) visited the MEC for physical measurement. A combined response rate was 51.7% at the national level. Further, of the 7,483 persons asked to participate in the survey, 3,948 persons were assigned to the fasting sub-sample. Of these, 3,483 (88.2%) participated in the household interview, and 2,969 (85.2%) visited the MEC; however, only 2,634 (66.7%) actually fasted and provided blood. At the Canadian scale, a combined response rate was 46.3% (Statistics Canada, 2010 -'Data User Guide: Cycle 1', section 10.1).

The CHMS (cycle 1) provided a final weight to ensure participants were representative of the Canadian population. Specifically, three types of selection weights were applied in each stage of sample selection (i.e., collection sites, dwellings, and persons) to calculate the final weight. The selection weight for a dwelling was multiplied by the selection weight for the collection site, after adjusting for dwelling-level non-response. In the next stage, the person weights of the persons to be fasted were adjusted to account for the sampling weights of the fasted sub-sample. The selection weight for a person to be fasted was adjusted for non-response at the questionnaire level and the MEC level and the non-responses to the fasted sub-sample. In the final stage, after winsorization (i.e., data transformation by limiting extreme values or outliers) for aberrant person-level weights, the final weight for the fasted sub-sample (i.e., WGT_FAST) was made (Statistics Canada, 2010).

4.1.2 KNHANES (cycle 4)

The KNHANES was a nationwide cross-sectional survey conducted by KCDC in partnership with Ministry of Health & Welfare. Since 1998 the KNHANES has been conducted annually and the fourth cycle of the KNHANES was completed over a three-year period beginning in July 2007 and ending in

December 2009. The main objectives of the KNHANES were to: 1) produce a nationally representative statistics on health and nutrition status; 2) ascertain health indicators regarding health behaviours, prevalence of illnesses, and nutrition status; 3) produce fundamental data for the establishment or evaluation of public health policies, including health promotion programs and the National Health Promotion Plan; and 4) provide data to international organizations for cross-national comparison on health issues such as prevalence of smoking and obesity.

The KNHANES (cycle 4) consisted of three domains: 1) a health interview; 2) health examination; and 3) nutrition survey. Both the health interview and health examination were conducted in the MEC, while the nutrition survey was conducted in respondents' home. Health interview and nutrition data were collected via a face-to-face interview by trained interviewers, while data on health behaviours such as smoking habits or alcohol use were collected using a self-reported method. After respondents completed both health interview and health examination at the MEC, interviewers visited respondents' home to collect nutrition data. The health interview questionnaire included a total of 310 questions with 6 theme areas and 14 modules (Appendix A). A total of 14 areas of physical measures were collected in MEC (Appendix A). For the health examination, all respondents were required to fast and reported the hours of fasting.

The target population was the population living at home and residing in all areas of Korea (i.e., Seoul metropolis, 6 metropolitan cities, and 6 provinces), representing the entire Korean population. Persons living in institutional residences and full-time members of the Korean military were excluded. Using a rolling sampling survey, the KNHANES reported not only annual data but also cumulated estimates over three years.

The KNHANES (cycle 4) used a multistage sampling strategy based on information from the 2005 National Census Registry. The KNHANES (cycle 4) included three stages of sample selection. In the first stage, 11 geographic areas were created depending on the geographic characteristics such as population size. Within these 11 areas, a total of 29 strata were created based on population size by age, gender, and a dwelling type (i.e., apartment or a regular house). In each stratum, primary sampling units (PSUs) were created. In the second stage, a total of 500 segments (i.e., a cluster of households in a block or group of blocks within the PSUs) were selected by using proportional allocation to population sizes in strata to reflect characteristics of all PSUs, such as a dwelling type. In the third stage, the households within the segments were selected using a systematic sampling procedure. Approximately 20-23 households per segment were selected. All members in a household were asked to participate in the survey, except for a family member aged less than one year or living in other areas.

A total of 31,705 persons were targeted for the KNHANES (cycle 4) with 24,871 (78.4%) persons completing at least one of the three surveys. The response rate for persons who completed both health interview and health examination was 65.8% in 2007, 74.3% in 2008, and 79.2% in 2009, and the overall response rate was 74.5%. For the nutrition survey, the response rate was 80.6% in 2007, 82.0% in 2008, and 82.2% in 2009, and the overall response rate was 81.8%.

In order to ensure the KNHANES sample represented the Korean population, weights of the KNHANES (cycle 4) were produced on the basis of sampling fraction, response rate, and post-stratification adjustment to match the structure of the 2009 National Census registry population (i.e., strata by age groups, sex, and geographic area). After post-stratification adjustment, winsorization was conducted for aberrant weights and then the final weight was created. Furthermore, there were four types of weights for KNHANES data including weights for selected households, selected respondents, individual surveys (i.e., household interview, health examination, and nutrition survey), and multiple surveys (e.g., household interview + health examination + nutrition survey). Especially, when data from multiple interview or examination were simultaneously used in analysis, weights for multiple surveys (i.e., wt_tot) provided by the KCDC must be used.

4.2 Study Sample and Eligibility Criteria

For the current study, subsamples of both CHMS (cycle 1) and KNHANES (cycle 4) participants were included. The CHMS subsample included participants who completed both the household questionnaire and medical examination; were 60 to 79 years; and completed the fasting laboratory test (unweighted N=551; weighted N=4,886,039). The KNHANES (cycle 4) subsample included participants who 1) responded to health interview, medical examination, and nutrition survey; 2) were 60 to 79 years; and 3) reported at least 8-hour fast prior to providing a blood sample (Canadian Diabetes Association, 2008) (unweighted N=3,040; weighted N=4,267,182).

CHMS participants who did not complete either the household questionnaire or medical examination, who were not 60 to 79 year, and who did not complete fasting laboratory test were excluded. KNHANES participants who did not complete either the health interview, medical examination, or nutrition survey, who were not 60 to 79 years, and who reported less than 8-hour fast prior to providing a blood sample were excluded. In both samples, some diabetic patients were excluded since they did not meet fasting criteria. In the fasted or this study sample, the prevalence of diagnosed diabetes was 11.6% and 13.9% in the Canadian and Korean samples, respectively.

4.3 Response and Explanatory Variables

Study variables were divided into four domains: 1) MetS status; 2) biomedical; 3) biosocial; and 4) psychosocial. The description of study variables including the CHMS and KNHANES content codes, thresholds for MetS components, and response categories (labels & values assigned) are described in

Appendices B and C. The sources of this information were 'Data User Guide: Cycle 1' (Statistics Canada, 2010) and 'the KNHANES Data User Guide: Cycle 4 (2007-2009)' (KCDC, 2012).

4.3.1 Response variable

Prevalence of MetS was the response variable. The presence or absence of MetS was based on the 'Harmonizing Definition' (Alberti et al., 2009). According to this definition, one must meet three or more of the following five criteria: 1) fasting plasma glucose ≥ 5.6 mmol/L or treatment; 2) systolic blood pressure ≥ 130 mmHg and diastolic blood pressure ≥ 85 mmHg or hypertension treatment; 3) triglycerides ≥ 1.7 mmol/L or treatment; 4) HDL-C < 1.0 mmol/L in men and < 1.3 mmol/L in women or treatment; 5) waist circumference ≥ 102 cm in Canadian men, ≥ 88 cm in Canadian women, ≥ 90 cm in Korean men, and ≥ 80 cm in Korean women. The continuous data for each component were dichotomized based on the Harmonizing Definition of abnormal metabolism. The sum of abnormalities was used to classify participants as having or not having MetS (Appendix B).

Measurement of individual components of MetS in CHMS (cycle 1)

Fasting plasma glucose, triglycerides, and HDL-C information for the CHMS (cycle 1) participants were collected and analyzed in the following ways. A certified phlebotomist of MEC collected blood sample using a standardized venipuncture technique. The amount of blood taken from respondents aged 60 to 79 years was less than 80 mL. The plasma and serum separated from the whole blood by centrifuge were aliquoted into small tubes and stored in the refrigerator or the freezer at the MEC laboratory. For laboratory analysis, the plasma and serum stored were shipped to the Health Canada Laboratory in Ottawa.

Blood pressure (BP) was measured with the BpTRUtm BP-300 device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia) at MEC. Both SBP and DBP were measured six times with one-minute intervals and then the average of the last five measures was reported. Using a tapeline (SECA 200), WC was measured to the nearest 0.1 cm at the mid-point between the last floating rib and the top of the iliac crest at the end of a normal expiration. According to 'the Harmonizing Definition' of MetS, participants who were either taking medication for treatment of hypertension, T2DM, or lipid abnormalities or who were diagnosed with these conditions by a health professional were also considered to meet threshold for abnormality on the relevant component. In the household questionnaire of the CHMS (cycle 1), participants were asked to report if they had ever been diagnosed with hypertension or T2DM by a health professional. Furthermore, they reported the Drug Identification Numbers (DIN) of all prescription medications that the participants took in the past month, and then Statistics Canada coded the DIN using the Anatomical Therapeutic Chemical (ATC) classification system provided by the WHO Collaborating Centre for Drug Statistics (2012). In the present study, the ATC codes corresponding to abnormalities of blood pressures, triglycerides, HDL-C, and fasting glucose were also used to identify participants who met the threshold for abnormality on one or more components of MetS (Appendix B).

Measurement of individual components of MetS in KNHANES (cycle 4)

Participants' blood specimens collected at MEC were analyzed in two different laboratories, the Korea Medical Institute (July, 2007 to February 15, 2008) and the NEODIN Medical Institute (February 20, 2008 to December, 2009). The two labs used different analytic methods (i.e., elimination catalase versus selective inhibition), facilities (i.e., ADVIA 1650 – Simens, USA versus Hitachi 7600 – Hitachi, Japan), and reagents (i.e., HDL – Simens, USA versus CHOLESTEST, N HDL-DAIICHI, Japan). This resulted in differences especially in levels of HDL-C. The KCDC therefore participated in the Lipid Standardization Program of the U.S.A, conducting a comparison analysis at both the NEODIN Medical Institute and Center for Disease Control (CDC) in Atlanta, Georgia. Differences in HDL-C levels (i.e., 0.13 mmol/L) were found. This resulted in the KCDC using adjusted HDL-C scores rather than raw data. In the KNHANES (cycle 4), BP was measured with a mercury sphygmomanometer (Baumanometer, WA

Baum Co., New York, USA). BP was measured three times with 30-second intervals and then the average of the last two measures was reported. While checking the quality of data for BP, the KCDC found that there was variability among clinicians in vertical height of arm when measuring BP, potentially leading to measurement error. Thus, the KCDC adjusted the differences and recommended use of the adjusted measures for SBP and DBP (Appendix B). Both CHMS (cycle 1) and KNHANES (cycle 2) used a similar method to measure waist circumference. Similarly, in the KNHANES health interview, participants were asked to report if they ever had been diagnosed with hypertension or T2DM by a health professional or if they had used medications for hypertension, T2DM, and lipid abnormalities. For T2DM, participants were also asked to report if they had taken insulin injection.

4.3.2 Explanatory variables

Explanatory variables for the current study were categorized into three domains: 1) biomedical (age and comorbidity); 2) biosocial (gender, education, income, and marital status); and 3) psychosocial domain (physical activity, dietary pattern, smoking, alcohol consumption, psychological distress, and sleep duration). The original questions and response categories of these explanatory variables in both the CHMS (cycle 1) and KNHANES (cycle 4) data are presented in Appendix C.

Biomedical domain

Age was treated as continuous variable, ranging from 60 to 79 years old. The present study identified 7 health conditions that are associated with MetS, including cancer, non-alcohol fatty liver disease (NAFLD), chronic kidney disease (CKD), polycystic ovarian syndrome (PCOS), erectile dysfunction, male hypogonadism, and psoriasis (Appendix C). Another 14 health conditions were also considered since these comorbidities may be associated with other correlates of MetS, such as physical inactivity. The Functional Comorbidity Index (FCI) (Groll et al., 2005) provided a total of 18 conditions associated with physical function in middle and older adults. Of these health conditions, 14 were selected for the present study, including arthritis, osteoporosis, asthma, chronic obstructive pulmonary disease (COPD) (acquired respiratory distress syndrome or emphysema), angina, congestive heart failure (or heart disease), neurological disease (such as multiple sclerosis or Parkinson's), stroke, peripheral vascular disease, upper gastrointestinal disease (such as ulcer, hernia, reflux), visual impairment (such as cataracts, glaucoma, macular degeneration), hearing impairment (i.e., very hard of hearing, even with hearing aids), and degenerative disc disease (such as back disease, spinal stenosis, or severe chronic back pain). The remaining 4 conditions of the FCI were excluded since these conditions were incorporated in other domains. Specifically, diabetes (as measured by fasting blood glucose of 5.6 mmol/L or use of medication or insulin injection) and obesity (as measured by waist circumference) were included as components of MetS, while depression and anxiety (or panic disorder) were considered psychological distress within the psychosocial domain.

These 21 comorbid conditions were identified from both the CHMS and KNHANES data, using two stages. In the first stage, the majority of these health conditions were identified based on responses to the question asking about ever occurrence of a number of specific chronic conditions (Appendix C). In the next stage, for those health conditions not included in the list of specific conditions, a search was conducted, using ATC codes in the CHMS and the Korean Standard Classification of Disease and Causes of Death (KCD) (5th) codes (Statistics Korea, 2008) in the KNHANES data.

The prevalence of each comorbid condition retrieved is provided in Appendix D. As can be seen, prevalence estimates of some health conditions varied considerably between countries. For instance, prevalence of cataracts or glaucoma in Korean elderly was 26.2%, whereas the prevalence in Canadian elderly was only 3.4%. There were also significant differences in prevalence of PCOS, erectile dysfunction, or male hypogonadism between Canadian and Korean elderly (11.7 % versus 0.4%, respectively). These discrepancies might be due to differences in measurement methods used by each survey (e.g., reference period, use of medication information only versus use of information on hospitalization, hospital visit, and medication). The CHMS asked participants to report the DIN of all prescription medications that the participants took in the past month, whereas the KNHANES asked participants to report whether they had any health condition that required hospitalization in the past 1 year or hospital visits or prescription medications in the past 2 weeks. To ensure comparability of the data, the present study decided to use comorbidity data derived from the household questionnaire. Ten comorbidities were therefore included: asthma, emphysema, bronchiectasis, arthritis or rheumatism, back problem, COPD, heart disease (angina, myocardial infarction), stroke, hearing problem, and cancer. Comorbidity burden was classified into 4 categories: no comorbidity, 1 comorbid condition, 2 comorbid conditions, and 3 or more conditions.

Biosocial domain

Gender was coded as female (0) and male (1). In the CHMS, education was measured as the highest level of education achieved and then was coded as less than secondary school, secondary school, some post-secondary school, and post-secondary school graduation. Similarly, the KNHANES coded the levels of education as less than elementary school, elementary school graduation (i.e., grade 1-6), middle school graduation (i.e., grade 7-9), high school graduation (i.e., grade 10-12), and college or university graduation or higher. For this study, the level of education was coded into three levels: less than secondary graduation, secondary graduation, and post-secondary graduation. Both the CHMS and KHANES measured adequacy of household income. The adequacy of household income variable was recoded to have 4 response categories (i.e., lowest, lower middle, upper middle, and highest). Marital status was also recoded into 3 groups (i.e., married including common-law; separated, widowed, or divorced; and single or never-married).

Psychosocial domain

Physical activity

In the CHMS physical activity was defined as the occurrence of daily physical activity lasting over 15 minutes in the past 3 months. The list of physical activities included in the questionnaire were: walking for exercise, gardening or yard work, swimming, bicycling, popular or social dance, exercise class or aerobics, downhill skiing or snowboarding, bowling, baseball or softball, tennis, weight-training, fishing, volleyball, basketball, soccer, and others. The CHMS derived physical activity measure was coded as a binary variable (0=active; 1=inactive).

The KNHANES participants were asked to report whether they participated in a moderate level of physical activity for more than 30 minutes per day at least 5 days during the past week. Participants were provided with two responses options, 'participated' or 'did not participate'. Physical activities included in the questionnaire were: slow swimming, double-tennis, volleyball, badminton, table tennis, carrying light loads as a part of work or exercise. In contrast to the CHMS, walking was excluded from the list of physical activities. For the sake of comparability, the present study decided to incorporate responses to the KNHANES walking question. Similar to the CHMS, the KNHANES physical activity measure was coded as a binary variable (0=active; 1=inactive). Participants were classified as active if they reported participating in moderate level of physical activities or walking for more than 30 minutes per day at least 5 days in the past week. Otherwise they were reported as inactive.

Dietary intake

As shown in Appendix C, the CHMS included 37 specific food items. These items were grouped into the following 5 good categories: (1) meat, fish, nuts (i.e., red meat, liver, other organ meats, beef or pork hot dogs, sausage or bacon, salt water fish, fresh water fish, shellfish, eggs and egg dishes, cooked or dried beans, and peanuts, walnuts, seeds or other nuts); (2) grains, fruits, and vegetables (i.e., hot or cold cereal, brown bread including bagels, rolls, pita bread or tortillas, white bread including bagels and rolls, any kind of pasta, any kind of rice, instant, seasoned or wild rice, fruits, tomatoes or tomato sauce, lettuce or green leafy salad, spinach, mustard greens or collards, French fries, home fries or hash brown potatoes, other potatoes, and all other types of vegetables); (3) milk and dairy products (i.e., milk, cottage cheese, yogurt, and ice cream or frozen yogurt); (4) soft drink and water (i.e., soft drinks, diet soft drinks, sport drinks, fruit juices, fruit flavoured drinks, vegetable juices, water); and (5) dietary fat (i.e., fat salad dressing and fat potato chips, tortilla chips or corn chips). For each of the 37 items, respondents were asked about their annual consumption (i.e., the number of times per year), with responses ranging from 0 to 1,095 times per year. Participants were also asked about annual salt consumption (i.e., frequency of adding salt to food excluding during cooking, type of salt typically used, and frequency of adding ordinary table salt during cooking or preparation of foods). In the present study blood sodium level (measured as a part of the CHMS laboratory tests) was used. Biological assessment of sodium has been recognized as more accurate than indirect methods such as a self-reported food frequency questionnaire (Bentley, 2006).

The KNHANES included 63 specific food items to assess participants' annual dietary consumption. The present study selected 60 items grouped into the following 10 food categories: (1) meat (i.e., beef, poultry, pork, ham, eggs); (2) fish (i.e., mackerel, tuna, croaker, Pollack, anchovy, fish cake, squid, shellfish, salted fish); (3) grains (i.e., rice, multigrains, instant noodle, noodle, bread, rice cake, crackers); (4) beans and potatoes (i.e., tofu, legumes, soybean milk, potato, sweet potato); (5) fruits (i.e., tangerine, persimmon, pear, water melon, oriental melon, strawberry, grapes, peach, apple, banana, orange); (6) vegetables (i.e., Korean cabbage, radish, radish leaves, bean sprout, spinach, cucumber, hot pepper, carrot, squash, cabbage, tomato, mushroom); (7) seaweeds (i.e., seaweed and laver); (8) milk and dairy products (i.e., milk, yogurt, ice cream); (9) soft drink (i.e., soft drink, coffee, green tea); (10) others (i.e., hamburger, pizza, fried foods) (Appendix C). The response categories provided by the KNHANES were:

(1) not at all; (2) 6-11 times per year; (3) once a month; (4) 2-3 times per month; (5) once a week; (6) 2-3 times per week; (7) 4-6 times per week; (8) one time per day; and (9) three times per day (Appendix C). Data on the participants' salt consumption were collected through the 24-hour dietary recall interview since the question for salt consumption was not available in the food frequency questionnaire.

Smoking

In the present study, smoking status was coded using three categories (i.e., non-smoker, former smoker, current smoker). This coding scheme was adapted from the derived smoking variable of KNHANES. The six-category CHMS derived smoking variable was therefore recoded into the following 3 categories: 1) current smoker including daily smoker, occasional smoker (former daily), always an occasional smoker; 2) former smoker including former daily and former occasional smoker; and 3) lifetime non-smoker.

Alcohol consumption

CHMS respondents were asked to report frequency of alcohol consumption over past year. Respondents were categorized as regular drinker (i.e., 2 to 3 times a week, 4 to 6 times a week, and every day), occasional drinker (i.e., once a week, 2 to 3 times a month, and once a month), former drinker (i.e., never drank in the past 12 months), and never drank (i.e., lifetime abstainer). The KNHANES respondents also were asked about frequency of drinking in the past year; however, respondents were classified as 'lifetime abstainer', 'never drank in the past one year', 'less than one time per month', 'once per month', '2 to 4 times per month', '2 to 3 times per week', and 'more than 4 times per week'. In the present study, frequency of alcohol consumption for both CHMS and KNHANES was categorized as 'never drank' (i.e., lifetime abstainer), 'former drinker' (i.e., never drank in the past one year), 'occasional drinker' (i.e., less than once per month, once per month, 2 to 4 times per month), and 'regular drinker' (i.e., 2 to 3 times per week and more than 3 times per week).

Depression or severe psychological distress

Psychological status was assessed by measures of depression and perceived stress. The CHMS ascertained presence or absence of depression based on the following question: Do you have a mood disorder such as depression, bipolar disorder, mania, or dysthymia, which is expected to have already lasted 6 months or more and to have been diagnosed by a health professional? Similarly, the KNHANES asked respondents to report if they have been diagnosed with depression by a health professional. In the present study, the participants who reported 'the absence of a diagnosed depression' or 'not-yet-diagnosed with depression' were considered free of depression.

Both CHMS and KNHANES participants were asked about perceived stress in daily life. The CHMS measure had five response options ((1) not at all stressful; (2) not very stressful; (3) a bit stressful; (4) quite a bit stressful; and (5) extremely stressful), whereas the KNHANES measure had only four response options ((1) not at all stressful; (2) not very stressful; (3) quite a bit stressful; and (4) extremely stressful). For sake of comparability, perceived stress was coded using the KNHANES categories ((1) not at all stressful, (2) not very stressful, (3) quite a bit stressful, and (4) extremely stressful. This meant that two CHMS response options - 'a bit stressful' and 'quite a bit stressful' were combined. In the present study, psychological distress was defined as 'ever been diagnosed with depression' or reporting daily life as 'quite a bit stressful' or 'extremely stressful'.

Duration of sleep

Both CHMS and KNHANES asked respondents about number of hours usually spent sleeping in a 24 hour period, excluding time spent resting. In the present study, responses were grouped into three categories: short (i.e., < 6 hours per day), moderate (i.e., 6-7 hours per day); and long (i.e., ≥ 8 hours per day) duration.

4.4 Statistical Methods

The analysis for the present study followed four stages. Briefly, in the first stage, data screening was conducted to explore the proportion of missing data or outliers. If a study variable had over 5% of data missing, multiple imputations were conducted (Yuan, 2011). In the second stage, using food frequency data, principal component analysis was conducted in order to reduce the number of dietary variables and to determine whether variables would cluster into separate domains based on the factor loadings (O'Rourke & Hatcher, 2013). A cluster analysis was then conducted to group participants into clusters that reflected similar dietary patterns. Factor scores for each participant (derived from the principal component analysis) were used in the cluster analysis (SAS Institute Inc., 2008). In the third stage, descriptive analysis was conducted to explore frequencies and distribution of data. To obtain a rough gauge of dependence between a particular explanatory variable and the outcome variable while conditioning on the remaining covariates, correlation and partial correlation analyses were also conducted. In the descriptive analysis stage, research aim 1 was also tested. In the fourth stage, univariate logistic regression analysis was conducted to examine the association between individual explanatory variables and MetS (aim 2). This was followed by mediation and moderation analyses to test the pathways of the proposed model regarding research aim 3. In the final stage, multiple logistic regression analysis was conducted to develop a parsimonious model to predict MetS for each country (aim 4).

A single dataset was created for all analyses by merging data from the CHMS (cycle 1) and KNHANES (cycle 4). In this merged dataset, new variables were created to reflect original information from each survey, including strata, clusters, survey weights, and country variable. All analyses were conducted using survey weights, wgt_fast for the CHMS (cycle 1) and wt_tot (and/or wt_ex, wt_itvex, wt_ntr) for the KNHANES (cycle 4) provided by Statistics Canada and KCDC, respectively. For univariate and multiple logistic regression analyses, survey weights of both CHMS and KNHANES were rescaled (or normalized) so that they sum to the actual sample size rather than population size, and new sets of weights including rescaled weights were then used for the analyses (Carle, 2009). Specifically, for each person in the study sample, their weights were adjusted by taking survey weights and dividing by the sample size. Using this approach, it is possible to avoid several issues caused by raw survey weights, including overestimation of the effective number of observations, underestimation of variability of estimators, and too many significant results (Hahs-Vaughn, 2005).

All statistical analyses were performed using SAS (version 9.2; SAS Institute Inc., 2009) and the SAS procedures to reflect complex survey design (e.g., PROC SURVEYMEANS, PROC SURVEYFREQ, and PROC SURVEYLOGISTIC) (Nadimpalli et al., 2012). Since bootstrap weights were not available in the KNHANES data, the variance estimation for univariate and multiple logistic regression analyses were calculated by the software using the Taylor series expansion method (Mukhopadhyay et al., 2008).

The reference categories of each study variable were: Canada (for the country variable), absence of MetS, absence of comorbidity, female, the lowest level of adequacy of household income, less than secondary school graduates, married or common-law, physically active, prudent dietary pattern, lifetime abstainer for smoking and alcohol consumption, absence of psychological distress, and short duration of sleep (i.e., > 6 hours per day).

4.4.1 Data screening

In the data screening step, the pattern of missing data and extreme observations were examined by analyzing skewness and kurtosis, using the SAS PROC CAPABILITIES procedure (Tabachnick & Fidell, 1989). If a study variable had greater than 5% of missing data, missing data were imputed using the SAS PROC MI and PROC MIANALIZE procedures (Yuan, 2010). All study variables had missing data (i.e., ‘do not know’) of less than 1.0%, except for adequacy of household income variable. Approximately 8% and 3% of CHMS and KNHANES participants, respectively did not report household income. The PROC

SURVEYLOGISTIC procedure and the PROC SURVEYFREQ procedure with chi-square test were used to examine whether there were differences in biomedical and biosocial factors between participants with and without household income data (Appendix E). There was no evidence of statistically significant between-group differences. The missing data of household income adequacy was imputed using the PROC MI and PROC MIANALIZE procedures. Missing data with less than 1% of the sample were imputed with an average value or a value in consideration of logical relations with other study variables (Appendices F-1 and F-2).

4.4.2 Dietary pattern analysis

Three stages of data analysis were conducted, including principal component analysis followed by cluster analysis. Discriminant function analysis was then done to test reproducibility of dietary clusters (Quatromoni et al, 2002). All food items were included in the principal component analysis without a prior food-grouping, since predefined food groups may affect the patterns derived (Newby & Tucker, 2004). For instance, it may not be true that all kinds of vegetables will appear in the same dietary pattern. This means that a certain vegetable may appear in a different dietary pattern when inputting those vegetables individually. The annual frequency of food consumption of 37 and 60 food items in the CHMS and KNHANES, respectively were used to identify dietary patterns of each country. Sodium intake was measured with the units of blood sodium (i.e., mmol/L) in the CHMS and sodium intake per day (i.e., mg) in the KNHANES.

In the first stage, principal component analysis with varimax (i.e., orthogonal) rotation was conducted to group food items into a smaller number of distinctive dietary groups or patterns based on intercorrelations among food items (Hu, 2002; Marjorie et al., 2006; Reedy et al., 2010). Four criteria were used to finalize the number of factors (i.e., dietary patterns): (1) the eigenvalue-one criterion; (2) scree test; (3) cumulative percent of variance account for; and (4) interpretability (O'Rourke & Hatcher, 2013).

Specifically, any factors with an eigenvalue greater 1 were retained according to the eigenvalue-one criterion known as the Kaiser criterion (Kaiser, 1960). In the present study, several sets of factor solution were examined with a range of eigenvalue from 1.0-2.2 in order to identify the optimal number of factors. The scree test (Cattell, 1966) provided a graph with the number of factors on the X axis and the corresponding eigenvalues on the Y axis. The scree test indentifies where there is an elbow (also called 'break') between declining eigenvalues and leveling off of eigenvalues, as number of factor increases. The identification of this elbow indicates the number of factors to be retained (Cattell, 1966). If there are too many elbows or the curve has no noticeable elbow, however, it may be hard to determine the number of factors retained (O'Rourke & Hatcher, 2013). The third criterion was to examine the cumulative percentage of variance accounted for, and this indicated the cumulative percentage of the total variance accounted for by the factors retained (O'Rourke & Hatcher, 2013). Although certain cut-off values such as 10% for individual factors and 70% - 80% for the combined factors retained have been used, researchers believe that the cut-off values are arbitrary and thus, may be inappropriate to determine the optimal number of factors (Marjorie et al., 2006; O'Rourke & Hatcher, 2013). The final criterion was interpretability (O'Rourke & Hatcher, 2013). O'Rourke and Hatcher (2013) provided specific rules to determine interpretability of factor solutions: (1) whether each retained factor had at least three variables (e.g., food items) with significant loadings; (2) whether the variables loading on a factor shared the same conceptual meaning (e.g., if apple, orange, and pear load on Factor A, it would be easy to interpret this factor as 'fruits'); (3) whether there were clear differences in conceptual meanings among factors (e.g., Factor A seemed to measure 'fruits' whereas Factor B included beef, pork, and poultry and seemed to measure 'meats'); and (4) whether the rotated factor had a simple structure. That is, variables that load on a given factor have relatively high factor loadings, but had relatively low factor loadings on other factors (e.g., apple, orange, and pear had high factor loadings on Factor A (e.g., fruits) but the factor loadings on Factor B (e.g., meats) were low). There is no consensus on the cut-off value regarding significant factor loading. For example, dietary pattern studies reported factor loadings with a range of 0.15 to 0.5

(Heidemann et al., 2011; Bouchard-Mercier et al., 2013). To extract factor solutions that can be testable in the further analysis (i.e., cluster analysis), all criteria listed above were applied, and the SAS PROC FACTOR procedure (O'Rourke & Hatcher, 2013) was used. All individuals were assigned factor scores on each factor extracted. If an individual had a high factor score on Factor A, this meant that the individual consumed the food items belonging to Factor A frequently.

Cluster analysis was then conducted using the derived factors scores. Before conducting the cluster analysis, all factor scores were standardized to reflect a z-score (ranged from -3 to 3) by using the SAS PROC SCORE procedure (SAS Institute Inc., 2008). While principal component analysis created food groups (e.g., fruits or meats), cluster analysis created groups of individuals with similar consumption patterns in terms of food groups that were derived by principal component analysis (Everitt, 1980; SAS Institute Inc., 2008). To derive dietary patterns, the present study used the SAS PROC FASTCLUS procedure with the K-means method of the cluster analysis (SAS Institute Inc., 1999). This method identified a cluster position based on the squared Euclidian distances between observations and the number of clusters *K* (e.g., Cluster 1, 2, …, Cluster *K*) (the mean of all observations involved in a cluster) (Maimon & Rokach, 2006). Using this method, it was possible to identify smaller variation (i.e., shorter distance) between observations within the same cluster and larger variation (i.e., longer distance) between observations in different clusters (Reedy et al., 2010). Since the clusters derived by this method were distinctive, participants were classified into one cluster only. This, in turn, enhanced interpretation of study results (Maimon & Rokach, 2006). For instance, if individuals in a cluster had high intake of food factors such as 'fruits', 'vegetables', and 'whole grains', the individuals in the cluster were considered as a 'healthy eater'. In addition, the values of cubic clustering criterion (CCC) were examined to decide the optimal number of clusters. The CCC values of greater than 2 are desired and those between 0 and 2 are fair. The CCC values below -30 are undesirable due to likelihood of outliers (Sarle, 1983). Based on these two criteria, the best solution with the optimal number of clusters was derived, and then each cluster was labeled (named) to reflect their conceptual meaning (e.g., healthy dietary pattern or traditional dietary pattern). To test the reproducibility and stability of the derived dietary pattern clusters, discriminant analysis was conducted (Bailey et al., 2006) using the SAS PROC DISCRIM procedure (SAS Institute Inc., 1999). Individuals were reassigned into new clusters via the discriminant analysis and then were examined whether there was discrepancy in the number of individuals between original and the new clusters (Bailey et al., 2006). All procedures to derive dietary patterns were conducted separately with each country dataset.

4.4.3 Descriptive analysis

The descriptive statistics were calculated for all study variables using survey weights, wgt_fast for CHMS (cycle 1) and wt_tot (and/or wt_ex, wt_itvex, wt_ntr) for KNHANES (cycle 4) datasets provided by Statistics Canada and KCDC, respectively. Using the PROC SURVEYFREQ procedure with chi-square option (An & Watts, 1998), difference in prevalence of biomedical, biosocial and psychosocial factors between Canadian and Korean older adults aged 60 to 79 years was examined. Between-country difference in prevalence of these factors by gender was also examined using 'Table' statement including the gender variable (e.g., tables country*gender*diet). The PROC SURVEYMEANS and PROC SURVEYREG procedures (An & Watts, 1998) were performed to estimate between-country difference in a continuous variable (i.e., age). For each survey dataset, correlation and partial correlation analysis were also conducted to obtain a rough gauge of dependence between a particular explanatory variable and the outcome variable and to identify whether multicollinearity between certain two explanatory variables existed. Only weighted data are presented in accordance with Statistics Canada rules. Further, if the sample size in an unweighted frequency cell was less than 10, then the weighted data were also supressed.

4.4.4 Research aim 1

This aim compared prevalence of MetS (and its components) between Canadian and Korean older adults aged 60 to 79 years. Between-country differences in both mean values of the individual components of MetS and total number of component abnormalities were also examined. For estimating mean values of individual components of MetS, the PROC SURVEYMEANS procedure was used with 'Domain' statement (i.e., Canadian versus Korean). The PROC SURVEYREG procedure (An & Watts, 1998) was then performed to identify between-country differences in mean values of individual components of MetS. Between-country difference in prevalence of MetS was estimated using the PROC SURVEYFREQ procedure with chi-square option and 'Table' statement including the country variable (i.e., CHMS=0 and KNHANES=1) for the domain analysis (i.e., tables country*MetS) (An & Watts, 1998). These between-country differences in prevalence of MetS (and individual components) were also examined by gender. Statistical significance was defined as p<.05.

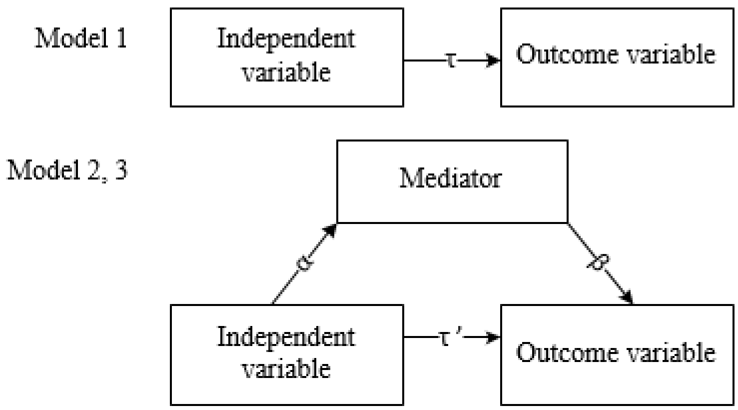
4.4.5 Research aim 2

This aim, first, examined univariate associations between MetS and biomedical, biosocial, and psychosocial across the two countries. The PROC SURVEYLOGISTIC procedure with 'Domain' statement was performed to provide univariate measures of association between these factors and MetS for each country dataset (An & Watts, 1998). Between-country differences in univariate associations were examined using the PROC SURVEYLOGISTIC procedure with an interaction term including 'Country' variable (e.g., Gender*Country). The p value cut-off for statistical significance was 0.05.

4.4.6 Research aim 3

Next, this aim tested whether there was evidence of between-country differences in mediation effects of physical activity and dietary pattern on observed association between MetS and biomedical and biosocial factors. The main reason for testing mediation is to understand the mechanism through which the independent variable affects the outcome variable (Baron & Kenny, 1986). For instance, age may have a direct and positive association with MetS. However, the association between age and MetS can be altered by a third variable (i.e., mediator) such as lifestyle factors (e.g., regular physical activity or healthy dietary pattern). According to Baron and Kenny (1986) and MacKinnon and Dwyer (1993), three regression models can be used to test mediation effects (Figure 2).

Figure 2 Simple model for testing mediation



The logistic regression models for this analysis were:

Model 1: $\text{Logit}(\Pr(\text{MetS} = \text{present}|X)) = \beta_1 + \tau X_p$

Model 2: $\text{Logit}(\Pr(\text{Mediator} = \text{reference}|X)) = \beta_2 + \alpha X_p$

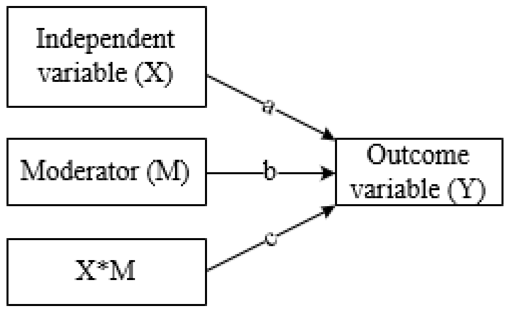
Model 3: $\text{Logit}(\Pr(\text{MetS} = \text{present}|X)) = \beta_3 + \tau' X_p + \beta X_m$

where β_1, β_2, and β_3 are the intercepts for Model 1, 2, and 3, respectively, X_p is the independent variable, X_m is the mediator, τ is the coefficient for the independent variable in Model 1, τ' is the coefficient for the independent variable after adjusting for the effect of mediator in Model 3, α is the coefficient for the independent variable in Model 2, and β is the coefficient of the mediator after adjusting for the effect of independent variable in Model 3.

For the present study, four steps were used to examine the mediation effect of physical activity or dietary pattern. In step 1, MetS was first regressed on each biomedical and biosocial factor (Model 1) to examine whether there was a statistically significant association between MetS and individual biomedical or biosocial factors (i.e., significance of τ). This was the first necessary condition for testing mediation (Baron & Kenny, 1986; Rucker et al., 2011). In Step 2, the potential mediator (i.e., physical activity or dietary pattern) was then regressed on the individual biomedical or biosocial factor (Model 2) to see if there was a statistically significant association between the two variables (i.e., significance of α). In Step 3, both the individual biomedical or biosocial factor and mediator were entered simultaneously in Model 3 to see if the mediator was significantly associated with MetS after adjusting for the impact of the individual biomedical or biosocial factor (i.e., significance of β). In step 4, the same regression model employed in Step 3 was used to identify the association between MetS and the individual biomedical or biosocial factors after controlling the effect of possible mediator (i.e., magnitude and significance of τ'). If τ and τ' are similar in magnitude, it can be considered that there was no mediating effect (Rucker et al., 2011). Mediation analysis was conducted separately for each country dataset using the PROC SURVEYLOGISTIC procedure using a 'Class' statement for categorical variables and 'link=glogit' option especially when dietary pattern (i.e., the outcome with 3 levels in Model 2) was the mediator (SAS Institute Inc., 2008).

Then this aim was to explore whether physical activity and dietary pattern moderated the association between MetS and biomedical and biosocial factors, and whether there were between-country differences in these moderation effects. The basic concept of moderation is shown in Figure 3, where path 'a' represents the association an independent variable (X) (e.g., gender) and the outcome (Y) (e.g., MetS). Path 'b' represents the association between possible moderator (M) (e.g., physical activity) and the outcome (Y) (MetS). Path 'c' reflects the impact of the interaction (or product) between X and M (Baron & Kenny, 1986). If the path 'c' is statistically significant, there is evidence of an interaction between X and M. In other words, the magnitude and direction of the association between Y and X is changed in the presence of M (Baron & Kenny, 1986).

Figure 3. Simple model for testing moderation



In this study, a logistic regression model was used to test for possible moderating influences of physical activity and dietary pattern on the association between MetS and individual biomedical and biosocial factors. The logistic model included the individual biomedical or biosocial factor (X) (e.g., gender), moderator (M) (e.g., physical activity), country (Canada versus Korea), three 2-way interaction terms (e.g., gender*physical activity, gender*country, and physical activity*country), and one 3-way interaction term (e.g., gender*physical activity*country) and the outcome of MetS. A logistic regression model for this is:

$$\text{Logit}(\Pr(\text{MetS} = \text{present}|X)) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1 * X_2 + \beta_5 X_1 * X_3 + \beta_6 X_2 * X_3 + \beta_7 X_1 * X_2 * X_3$$

where α is the intercept for the model, X_1, X_2, and X_3 are main effects, β_1, β_2, and β_3 are the coefficients of X_1, X_2, and X_3, respectively, X_1*X_2, X_1*X_2, and X_2*X_3 are 2-way interaction terms, β_4, β_5, and β_6 are the coefficients of the three 2-way interaction terms, $X_1*X_2*X_3$ is an 3-way interaction term, and β_7 is the vector of coefficient of the 3-way interaction term (Le & Johnson, 2008).

When the 3-way interaction term was significant at *p*<.05, it was considered that between-country difference in moderation effect of physical activity or dietary pattern) on the association between MetS and a biomedical (or biosocial) factor and MetS existed. When a significant 3-way interaction was observed in the constructed models, domain analysis (i.e., separate analysis for each country) was conducted to identify how the moderator worked differently depending on country.

All moderation analyses were performed using the PROC SUREYLOGISTIC procedure using a 'Class' statement for categorical variables (SAS Institute Inc., 2008).

4.4.7 Research aim 4

This aim identified the biomedical, biosocial, and psychosocial factors jointly associated with MetS in Canadian and Korean adults aged 60 to 79 years. For the first step, all explanatory variables were entered into the first model simultaneously, and the least significant variable was then identified. After removing the least significant variable from the model, the second model was tested to determine whether there was meaningful change in the variance explained in the analysis (i.e., as indicated by changes in the value of Likelihood ratio). Using this approach, an iterative process was continued until the most parsimonious model was identified. In the parsimonious model all explanatory variables were required to be statistically significant (SAS Institute Inc., 2008). Interaction terms were then created with the variables that remained in the parsimonious model and entered into the model to examine if there were any significant interaction terms. Thus, the final parsimonious model included all explanatory variables and interaction terms that predicted MetS. All analyses were performed using the PROC SURVEYLOGISTIC (An & Watts, 1998).

4.4.8 Power considerations

These calculations were done using the formula for calculating power of a study to detect a two-tailed difference in proportions for a cross-sectional study (Kelsey et al., 1996) (Table 4). The Korean and

Canadian sample size was 3,040 and 551, respectively. The prevalence of MetS in the Korean sample aged 60 to 79 years is anticipated to be 50% or greater (Korean Ministry of Health Welfare, 2006; Lim et al., 2011) and to be 40% in the Canadian sample (Riediger & Clara, 2011). Therefore the expected difference was 10%; however power calculations were done for smaller differences (Table 4). The study was underpowered for differences less than 7%. Gender-specific calculations were also done, since Korean women aged 60 to 79 years are expected to have a higher prevalence of MetS than Canadian women aged 60 to 79 years, 60% and 40%, respectively. However, there was no expected difference in prevalence between Korean and Canadian men (40% in both samples). Power estimates indicated that the study will be underpowered to detect between-country gender difference in prevalence of 8% or smaller (power=.69 or less).

Table 4 Results of power calculation

	Difference in prevalence of MetS between Korean and Canada			
	10%	8%	7%	5%
Power Sig. 0.05	0.99	0.93	0.85	0.60

4.5 Research Ethics

Ethics clearance for the present study was granted by the Office of Research Ethics at University of Waterloo (ORE #: 18820). Permission was granted from Statistics Canada and the Korea Centres for Disease Control and Prevention to access CHMS (cycle 1) and KNHANES (cycle 4) data, respectively.

CHAPTER 5 RESULTS

The results are divided into the following seven sections: 1) description of study sample; 2) prevalence of MetS and biomedical, biosocial, and psychosocial variables studied; 3) correlation and partial correlation analysis; 4) univariate associations between Mets and biomedical, biosocial, and psychosocial variables; 5) mediation analysis; 6) moderation analysis; and 7) multiple logistic regression analysis to identify a parsimonious model.

5.1 Study Sample

CHMS (cycle 1) sample

This sample included participants who completed both the household questionnaire and medical examination; were 60 to 79 years; and completed fasting laboratory tests (unweighted N=551). Based on the results of dietary pattern analysis (see section 5.4.2), one person was found to be an outlier, leading to unreliable results in terms of dietary pattern clusters. This participant was eliminated from the final CHMS sample. Therefore, the final unweighted sample size was 550 (weighted N=4,886,039).

KNHANES (cycle 4) sample

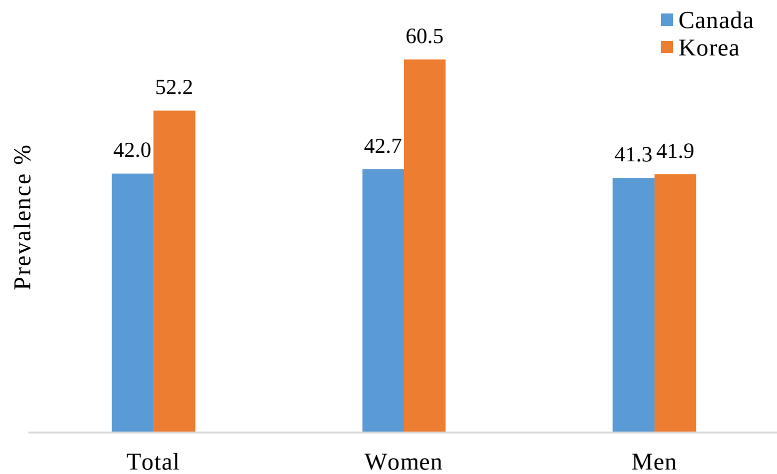
This sample included respondents who completed the household questionnaire, medical examination, and nutrition survey; were 60 to 79 years; and reported at least an 8-hour fast prior to providing a blood sample. The final unweighted sample size was 3,040 (weighted N=4,267,182).

The mean age of Canadian and Korean participants was 67.4 and 67.9 years, respectively. Approximately 52% and 54% of Canadian and Korean participants respectively were women. The mean BMI in Canadian women and men was 28.6 and 27.9, respectively, and in Korean women and men was 24.4 and 23.4, respectively. The prevalence of diagnosed diabetes was 11.6% and 13.9% in the Canadian and Korean older adults, respectively.

5.2 Prevalence of MetS

Figure 4 shows that MetS was common in both Korean and Canadians and Korean older adults (52.2% versus 42.0%, respectively, *p*<.0001). The prevalence of Mets in Korean women was very high (60.5%) and explained the overall increased prevalence in the Korean sample. The proportion of participants who had 4 or 5 abnormalities was also highest in Korean women (Appendix G-1).

Figure 4. Prevalence of MetS* in the CHMS (cycle 1) and KNHANES (cycle 4) participants aged 60 to 79 years

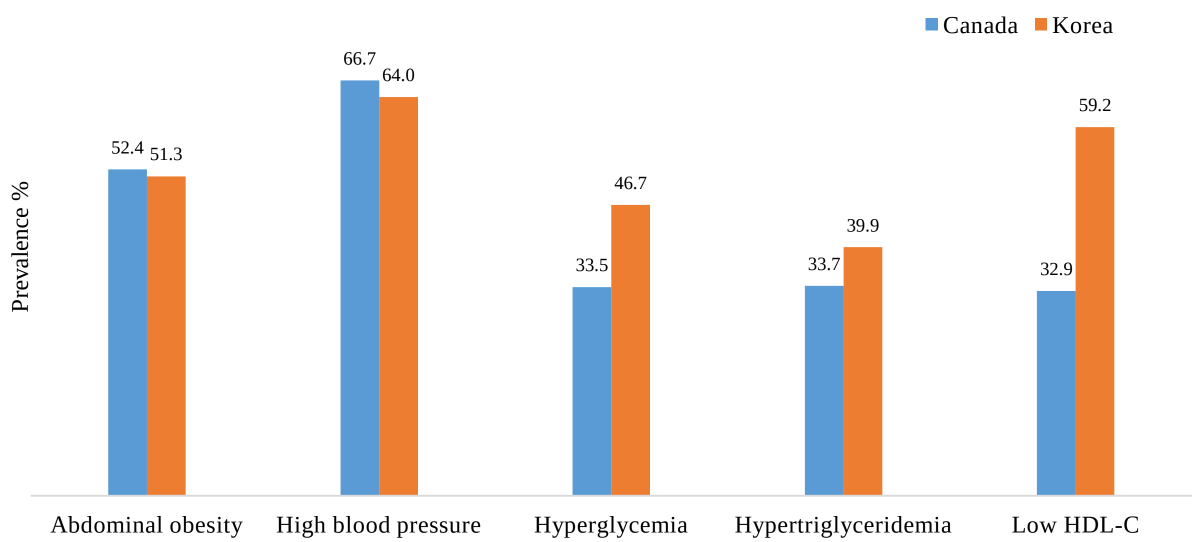


* Defined as three or more abnormalities of the following components: Abdominal obesity: ≥ 102 cm (Canadian men), 88 cm (Canadian women), 90 cm (Korean men), 80 cm (Korean women); High blood pressure: ≥ 130 (systolic blood pressure) or 85 (diastolic blood pressure) mmHg or treatment; Hyperglycemia: ≥ 5.6 mmol/L or treatment; Hypertriglyceridemia: ≥1.7 mmol/L or treatment; Low high density lipoprotein cholesterol (HDL-C): < 1.0 (men), 1.3 (women) mmol/L or treatment

5.2.1 Distribution of individual components of MetS

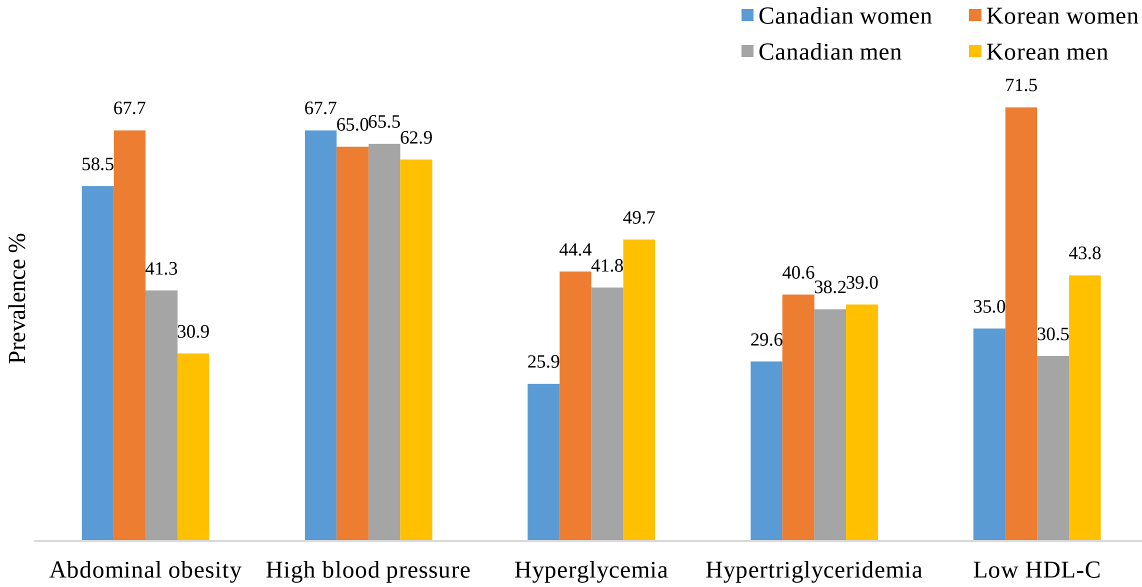
Results of estimated population mean values of the individual components of MetS are presented in Appendix G-2. In the Canadian sample, mean blood pressure and HDL-C fell within the desired acceptable range, while mean values of WC, FPG, and TG were somewhat elevated. In the Korean sample only blood pressure fell within the desired or acceptable range. Figure 5 shows the prevalence of each component of MetS. Overall Korean had a significantly higher prevalence of hyperglycemia, hypertriglyceridemia, and low HDL-C (p<.0001). There was no significant difference in prevalence of abdominal obesity or high BP between the two countries. With the exception of BP, Korean women had a significantly higher prevalence of each component compared with Canadian women (Figure 6). This was especially true for low HDL-C (Korean versus Canadian women = 71.5% and 35.0%, respectively, p<.001). Canadian men had higher prevalence of WC compared with Korean men (p<.01). There was no significant between-country difference in prevalence of high BP and hypertriglyceridemia among men (p>.05) (Appendix G-3).

Figure 5. Prevalence of individual components[*] of MetS by country



[*] Abdominal obesity: ≥ 102 cm (Canadian men), 88 cm (Canadian women), 90 cm (Korean men), 80 cm (Korean women); High blood pressure: ≥ 130 (systolic blood pressure) or 85 (diastolic blood pressure) mmHg or treatment; Hyperglycemia: ≥ 5.6 mmol/L or treatment; Hypertriglyceridemia: ≥1.7 mmol/L or treatment; Low high density lipoprotein cholesterol (HDL-C): < 1.0 (men), 1.3 (women) mmol/L or treatment

Figure 6. Prevalence of individual components of MetS* by gender and country



* Abdominal obesity: ≥ 102 cm (Canadian men), 88 cm (Canadian women), 90 cm (Korean men), 80 cm (Korean women); High blood pressure: ≥ 130 (systolic blood pressure) or 85 (diastolic blood pressure) mmHg or treatment; Hyperglycemia: ≥ 5.6 mmol/L or treatment; Hypertriglyceridemia: ≥1.7 mmol/L or treatment; Low high density lipoprotein cholesterol (HDL-C): < 1.0 (men), 1.3 (women) mmol/L or treatment

5.3 Prevalence of Biomedical and Biosocial Factors

Descriptive features are provided in Table 5 and Figure 7. The mean age of Canadian and Korean participants was 67.4 and 67.9 years, respectively. There were no significant between-country differences in gender-specific mean age.

Overall, Canadians were more likely to report two or more comorbid conditions compared with Koreans (Table 5). However, gender-specific analysis revealed that between-country difference in comorbidity was significant in men (p<.0001) but not women (p=.27). The proportion of participants with two or more comorbid conditions was significantly higher in Canadian men than Korean men (43.7% versus 12.4%, respectively) (p<.0001).

As shown in Table 5, in both samples there were more women than men. The distribution of adequacy of household income and education was significantly different between the two countries (p<.0001). In the Korean sample, a significant minority (43.2%) were in the lowest level of household income adequacy, with 13.6% falling into the highest level of income adequacy. By contrast, only 3.8% of Canadians were in the lowest category, and 30% were in the highest level of income adequacy. This pattern was observed in both men and women. Similarly, in the Korean sample, the majority (62.7%) had less than secondary school graduation. Approximately 8% had some post-secondary education. By contrast, 26.1% of Canadians was assigned the lowest category with majority having some post-secondary education (55%). Again this pattern was observed in both men and women; however, the between-country differences were especially marked in women, with 78.5% of Korean women having less than secondary school graduation compare with 26.6% of Canadian women. In terms of marital status, the majority of participants in both countries were married, with males being most likely to be married at time of interview. Single or never-married status was relatively infrequent, especially in the Korean sample (0.7%).

Figure 7. Distribution of biomedical and biosocial factors

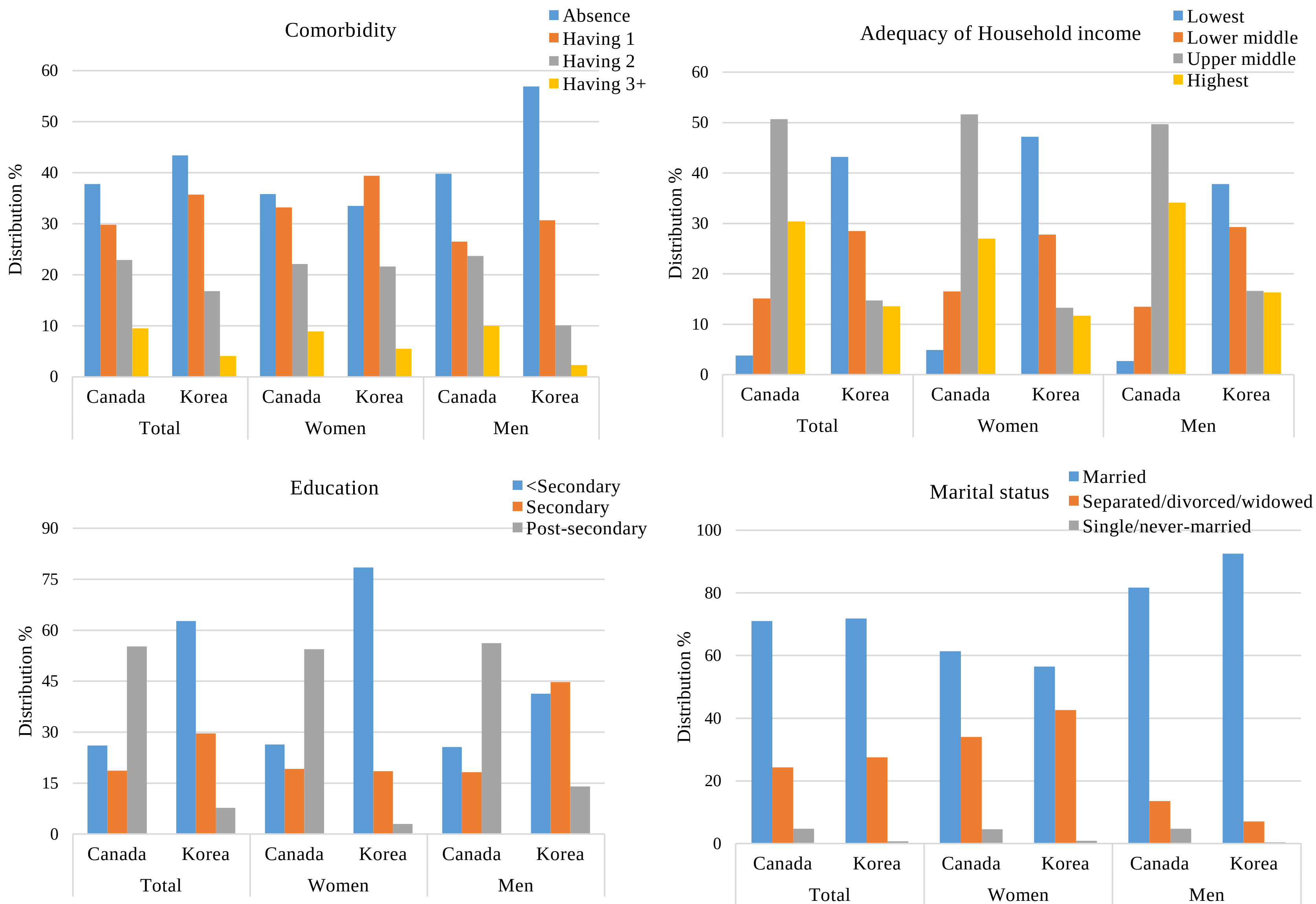


Table 5. Biomedical and biosocial characteristics of the CHMS (cycle 1) and KNHANES (cycle 4) participants aged 60 to 79 years

	Total				Women				Men			
	Canada		Korea		Canada		Korea		Canada		Korea	
Variables	Mean or weighted N	SE or %	Mean or weighted N	SE or %	Mean or weighted N	SE or %	Mean or weighted N	SE or %	Mean or weighted N	SE or %	Mean or weighted N	SE or %
Age	67.4	0.30	67.9	0.12	67.3	0.44	67.6	0.48	67.9	0.14	67.8	0.16
Between-country difference	*p*=.363				*p*=.150				*p*=.802			
Comorbidity												
None	1,835,624	37.8	1,776,965	43.4	941,981	35.8	752,248	33.5	893,642	39.8	1,024,717	56.9
Having 1	1,490,483	29.8	1,362,392	35.7	833,675	33.2	853,638	39.4	656,808	26.5	508,755	30.7
Having 2	1,148,899	22.9	608,474	16.8	607,045	22.1	439,529	21.6	541,853	23.7	168,945	10.1
Having 3+	411,034	9.5	151,757	4.1	181,694	8.9	118,920	5.5	229,340	10.0	32,838	2.3
Between-country difference	*p*<.0001				*p*=.270				*p*<.0001			
Gender												
Women	2,564,396	52.5	235,2130	55.5	-		-		-		-	
Men	2,321,644	47.5	1,915,052	45.5	-		-		-		-	
Between-country difference	*p*=.307											
Income Adequacy												
Lowest	186,704	3.8	2,118,044	43.2	125,211	4.90	1,330,037	47.2	61,493	2.7	788,007	37.8
Lower middle	737,205	15.1	1,395,432	28.5	423,996	16.5	784,496	27.8	313,210	13.5	610,936	29.3
Upper middle	2,477,519	50.7	719,565	14.7	1,323,019	51.6	374,777	13.3	1,154,500	49.7	344,788	16.6
Highest	1,484,611	30.4	668,440	13.6	692,169	27.0	329,046	11.7	792,442	34.1	339,394	16.3
Between-country difference	*p*<.0001				*p*<.0001				*p*<.0001			
Education												
< secondary	1,273,196	26.1	3,073,052	62.7	678,047	26.4	2,212,857	78.5	595,150	25.6	860,195	41.3
Secondary	913,674	18.7	1,452,256	29.6	492,184	19.2	520,130	18.5	421,491	18.2	932,126	44.7
≥post-secondary	2,699,169	55.2	376,174	7.7	1,394,165	54.4	85,370	3.0	1,305,003	56.2	290,804	14.0
Between-country difference	*p*<.0001				*p*<.0001				*p*<.0001			
Marital status												
Married or Common-law	3,469,644	71.0	3,519,067	71.8	1,573,742	61.4	1,592,053	56.5	1,895,902	81.7	1,927,014	92.5
Separated, divorced, or widowed	1,187,657	24.3	1,348,142	27.5	871,556	34.0	1,201,201	42.6	316,101	13.6	146,942	7.1
Single or never-married	228,738	4.7	34,273	0.7	119,097	4.6	25,103	0.9	109,641	4.7	9,170	0.4
Between-country difference	*p*<.0001				*p*=0.0010				*p*<.0001			

5.4 Prevalence of Psychosocial Factors

A range of lifestyle or behavioural factors was measured (Table 6 and Figure 8). In this study the relationships between MetS and physical activity and dietary pattern were of particular interest.

5.4.1 Level of physical activity

A significant minority of both Canadian (33.7%) and Korean participants (46.0%) were physically inactive, with the prevalence of physical inactivity being significantly higher in Korean women compared with Canadian women (50.3% versus 34.1%, respectively, p=.002). There was no significant difference in prevalence of physical inactivity between Korean and Canadian men (p=.11).

5.4.2 Dietary pattern

As can be seen in Table 6, three dietary patterns were derived using both principal component analysis and cluster analysis, previously described in section 4.4.2. The results of the dietary pattern analysis for each country are now described in detail.

CHMS

Principal component analysis

Ten factor solutions were tested using principal component analysis with varimax rotation method. To identify the best solution, a series of criteria were applied including eigenvalue-one criterion, scree test, cumulative percent of variance account for, and interpretability. Based on the assessment, the best solution matrix for each factor retained is presented in Appendix H-1. Of 38 food items, 35 loaded on more than one factor, while 3 food items (i.e., liver, sport drinks, and other organ meats) were not significantly loaded on any factor, presumably due to their low frequency of consumption. Factors 5 and 6 included only 2 food items. Together, the 7 factors explained 7.6% of the total variance.

Factor 1 was characterized by the most frequent intake of fries/hash brown potatoes, hot dogs, fat chips, sausage/bacon, instant/seasoned/wild rice, diet soft drinks, and sodium and the least frequent intake of yogurt, fruit, and other types of vegetables. Factor 2 represented the most frequent intake of spinach/mustard greens/collards, salt water fish, eggs, shellfish, water, vegetable juices, cheese, and fresh water fish. Factor 3 was characterized by the most frequent intake of brown bread and the least frequent intake of soft drinks, any kind pasta, and white bread. Factor 4 showed high positive loadings on lettuce/green leafy salad, fat salad dressing, and nuts and negative loadings on fruit flavoured drinks. Factor 5 was characterized as the most frequent intake of milk and hot/cold cereal. Factor 6 was represented by the most frequent intake of tomatoes/tomato sauce and cooked/dried beans. Factor 7 was represented by the most frequent intake of other potatoes, red meat, fruit juices, and ice cream and the least frequent intake of rice.

Cluster analysis

All individuals were given standardized factor scores from principal component analysis and the SAS PROC SCORE procedure, and the factor scores were then entered into a cluster analysis. A total of 10 cluster solutions were tested to identify the optimal number of clusters. Each cluster solution was examined according to interpretability and values of cubic clustering criterion (CCC). Based on CCC values, the best solution was the 3-cluster solution having a CCC value of 0.016. The mean values of each cluster are presented in Appendix H-2.

Cluster 1 was characterized by factor 2 (i.e., the most frequent intake of spinach/mustard greens/collards, salt water fish, eggs, shellfish, water, vegetable juices, cheese, and fresh water fish), factor 4 (i.e., the most frequent intake of lettuce/green leafy salad, fat salad dressings, and nuts and the least frequent intake of fruit flavoured drinks), and factor 6 (i.e., the most frequent intake of tomatoes/tomato sauce and cooked/dried beans). This cluster was also characterized by moderately frequent intake of brown bread (i.e., factor 3). Further, this cluster showed the lowest mean frequency of factor 1 (i.e., frequent intake of fries/hash brown potatoes, hot dogs, fat chips, sausage/bacon, instant/seasoned/wild rice, diet soft drinks, and sodium, and least frequent intake of yogurt, fruit, other types of vegetables) and factor 7 (i.e., frequent intake other potatoes, red meat, fruit juices, and ice cream, and least intake of any kind of rice). Cluster 1 was named 'prudent' dietary pattern. One hundred forty seven (26.7%) CHMS participants were classified in the 'prudent' dietary pattern group. Cluster 2 was characterized by factor 3 (i.e., the most frequent intake of brown bread and the least frequent intake of soft drinks, any kind of pasta, and white bread) and factor 5 (i.e., the most frequent intake of milk and hot/cold cereal) and moderately frequent intake of factor 7 (i.e., other potatoes, red meats, fruit juice, ice cream). Further cluster 2 showed the lowest mean frequency of factor 2 (i.e., frequent intake of spinach/mustard greens/collards, salt water fish, eggs, shellfish, water, vegetable juices, cottage cheese, and fresh water fish), factor 4 (i.e., frequent intake of lettuce/green leafy salad, fat salad dressing, and nuts, and least frequent intake of fruit flavoured drinks), and factor 6 (i.e., frequent intake tomatoes/tomato sauce and cooked/dried beans). Cluster 2 contained the largest number of individuals (n=264, 48%) and was named 'traditional' dietary pattern. Cluster 3 was characterized by factor 1 (i.e., the most frequent intake of fries/hash brown potatoes, hot dogs, fat chips, sausage/bacon, instant/seasoned/wild rice, diet soft drinks, and sodium and the least frequent intake of yogurt, fruit, and other vegetables) and factor 7 (i.e., the most frequent intake of other potatoes, red meat, fruit juices, and ice cream and the least frequent intake of rice). The cluster 3 showed the lowest mean frequency of factor 3 (i.e., frequent intake of brown bread and least intake of soft drinks, any kinds of pasta, and white bread) and factor 5 (i.e., frequent intake of milk and hot/cold cereal). The number of individuals observed in the cluster 3 was 139 (25.3%), and this cluster labeled as 'unhealthy' dietary pattern.

A cross-tabulation is presented in Appendix H-3 to compare the number of individuals assigned in each cluster derived from two different analyses (i.e., cluster analysis versus discriminant analysis). A total of 144 (98%) in the original 'prudent' group were observed in the same cluster derived from discriminant analysis. Of individuals in the original 'unhealthy' group, 135 (97.1%) were classified in the same group.

Ninety-eight percent of individuals in the original ‘traditional’ group were assigned in the same group derived from discriminant analysis.

The overall proportion classified correctly was 0.976 (97.6%) indicating an excellent level of agreement between the original and the new clustering classification. The sensitivity of the discriminant analysis ranged from 97.12% to 97.96 over the clusters as follows: 97.96% for the ‘prudent’ cluster; 97.12% for the ‘unhealthy’ cluster; and 97.73% for the ‘traditional’ cluster (Appendix H-4). The specificity of the discriminant analysis ranged from 98.6% to 99.03% across the clusters as follows: 98.76% for the ‘prudent’ cluster; 99.03% for the ‘unhealthy’ cluster; and 98.6% for the ‘traditional’ cluster.

KNHANES

Principal component analysis

The procedure was identical to those used in the CHMS dataset. The best solution was the 9-factor solution with eigenvalue of 1.1 and the absolute factor loading ≥ 0.20. The factor loading matrix for each extracted factor is presented in Appendix I-1. All food items with a factor loading of greater than 0.2 were retained in the solution. However, factors 7 and 9 included only two food items (beans and other grains for factor 7; instant noodle and noodle for factor 9). Together, the 9 factors explained 18.5% of the total variance.

Factor 1 was represented by the most frequent intake of fruits, tomato, sweet potato, and yogurt. Factor 2 was characterized as the most frequent intake of vegetables, mushroom, fishes, seaweeds, shellfish, fish paste, beef, banana, tofu, egg, and tea. Factor 3 was represented by the most frequent intake of pork, chicken, fried foods, coffee, sodium, and salted fish. Factor 4 showed high positive loadings on some vegetables including squash, cucumber, pepper, potato, radish leaves, and radish. Factor 5 was characterized by the most frequent intake of bread, crackers, rice cake, soft drinks, and soybean milk.

Factor 6 was represented by the most frequent of pizza, hamburger, and ham. Factor 7 was represented by the most frequent intake of bean and other grains. Factor 8 had high positive loadings on Korean cabbage including Kimchi and rice and the least intake of milk. Factor 9 was characterized as the most frequent intake of instant noodle and noodle.

Cluster analysis

All standardized factor scores derived from principal component analysis and the SAS PROC SCORE procedure entered in the cluster analysis. A total of 9 clusters solutions were examined to determine the optimal number of clusters, and the results were assessed according to interpretability and CCC values. Based on the results of CCC values, the best solution was 3-cluster solution (CCC=-4.21), and the mean values of each cluster are presented in Appendix I-2.

Cluster 1 was represented by the most frequent intake of vegetables (i.e., spinach, bean sprout, carrot, squash, cucumber, pepper, potato, radish, radish leaves), fishes (i.e., pollack, mackerel, tuna, yellow fish, squid, anchovy, fish cake, clam), seaweeds, mushroom, banana, tofu, beef, eggs, bean, other grains, and tea. Individuals (n=1,003, 33%) in this group frequently consumed fruits (i.e., water melon, grapes, oriental melon, strawberry, peach, tangerine, apple, pear, persimmon, orange), tomato, sweet potato, and yogurt in a moderate level. The cluster 1 showed the lowest mean frequency of factor 5 (i.e., frequent intake of bread, cracker, rice cake, soft drink, and soybean milk), factor 6 (i.e., frequent intake of pizza, hamburger, and ham), and factor 8 (i.e., frequent intake of Korean cabbage-Kimchi and rice, and least intake of milk). Cluster 1 was named ‘prudent’ dietary pattern. Cluster 2 containing the largest number of individuals (n=1,568, 51.6%) was characterized by the most frequent intake of Korean cabbage including Kimchi and rice and less frequent intake of milk, and individuals in this cluster less frequently consumed other food items (i.e., food items in factor 1, 2, 3, 4, 7, and 9) compared with those in the other two clusters. This cluster was labeled as ‘traditional’ dietary pattern, since a typical Korean meal consists of these two food items (i.e., Korean cabbage-Kimchi and rice). Cluster 3 was characterized by the most frequent intake of pizza, hamburger, ham, pork, chicken, fried foods, noodle, instant noodle, coffee, sodium, salted fish, fruits (i.e., water melon, grapes, oriental melon, strawberry, peach, tangerine, apple, pear, persimmon, orange), tomato, sweet potato, yogurt, bread, cracker, rice cake, soft drinks, and soybean milk and moderately frequent intake of spinach, bean sprout, cabbage, mushroom, carrot, Pollack, seaweed, clam, fish cake, beef, mackerel, tuna, tofu, eggs, laver, yellow fish, squid, anchovy, and tea. Cluster 3 comprised of 469 (15.4%) participants was labeled as 'unhealthy' dietary pattern.

The number of observations in each cluster (i.e., original clusters) derived from cluster analysis was compared with those in new clusters derived from discriminant analysis, and the cross-tabulation is presented in Appendix I-3. Of individuals in the original 'traditional' cluster, 96.9% was classified into the same cluster derived from discriminant analysis. Ninety-nine percent of individuals in the original 'prudent' cluster was observed in the same cluster derived from discriminant analysis. Of individuals in the original 'unhealthy' cluster, 90.4% was classified into the same cluster derived from discriminant analysis.

The overall proportion classified correctly was 0.9543 (95.4%) indicating a very high level of agreement between the original and the new clustering classification. The sensitivity of the discriminant analysis ranged from 96.3% to 99.7% over the clusters as follows: 96.9% for the 'traditional' cluster; 99.0% for the 'prudent' cluster; and 90.4% for the 'unhealthy' cluster (Appendix I-4). The specificity for the discriminant analysis ranged from 96.32% to 99.65% across the clusters as follows: 98.64% for the 'traditional' cluster; 96.32% for the 'prudent' cluster; and 99.65% for the 'unhealthy' cluster.
Table 6 shows that a similar proportion of the Canadian and Korean participants (approximately 48%) consumed a 'traditional' diet. However, the proportion of participants consuming a 'prudent' diet was higher in Korea than in Canada, with a higher proportion of Canadians, especially males, consuming an

‘unhealthy’ diet. In both countries, women were more likely to consume either a ‘traditional’ or ‘prudent’ dietary pattern than men.

5.4.3 Additional psychosocial factors

Smoking status was significantly different between countries (*p*<.0001), but this difference varied considerably by gender (Table 6). In Korea, 90% of women never smoked, while 6% were current smokers. The corresponding proportions in Canadian women were 50% and 15%, respectively. By contrast, in Korean men, only 16% never smoked and 30% were current smokers. The corresponding proportions in Canadian men were 37% and 11%. There was also a significant between-country difference in alcohol consumption (*p*<.0001). The proportion of lifetime abstainer was higher in Koreans than Canadians. This difference was especially marked in women. Forty percent of Korean women were lifetime abstainer compared with 14.7% of Canadian women.

The prevalence of depression or high levels of psychological distress was higher in Koreans than Canadians (26.8% versus 14.1%, *p*<.0001). Again, difference varied by gender. Korean women had a significantly higher prevalence compared with Canadian women (33.7% versus 16.3%, respectively, *p*<.0001), whereas there was no statistically significant difference in the prevalence between Korean and Canadian men (17.6% versus 11.6%, respectively, *p*=.07).

Finally, there was a significant difference in sleep duration between countries (*p*<.0001). Approximately 29% of Koreans reported less than 6 hours per day, compared with 6.8% of Canadian elderly. This pattern was observed in men and women; however, the between-country difference was greater in women, with 33.8% of Korean women reporting less than 6 hours of sleep per day compared with 6.8% of Canadian women.

Figure 8. Distribution of psychosocial factors

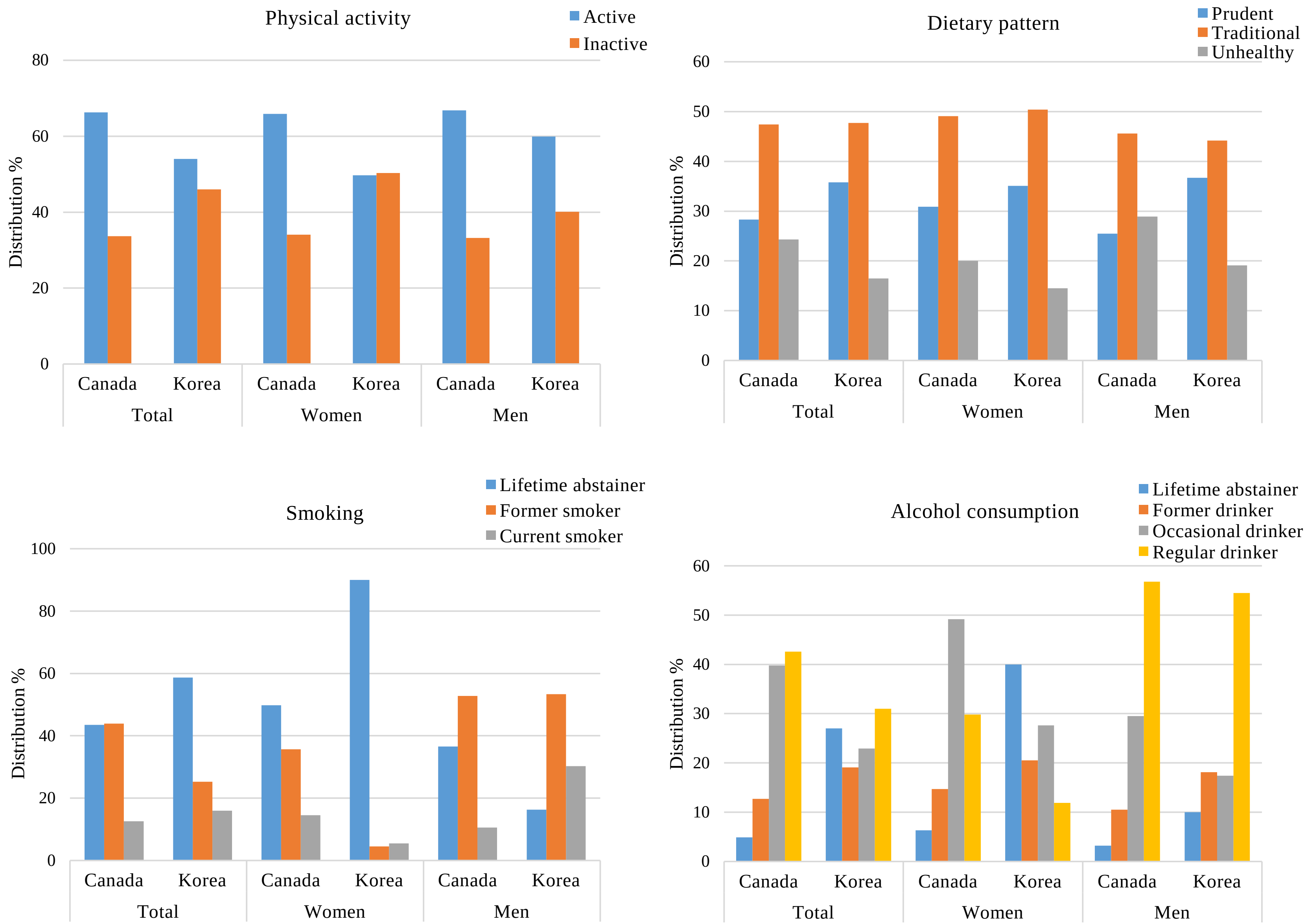
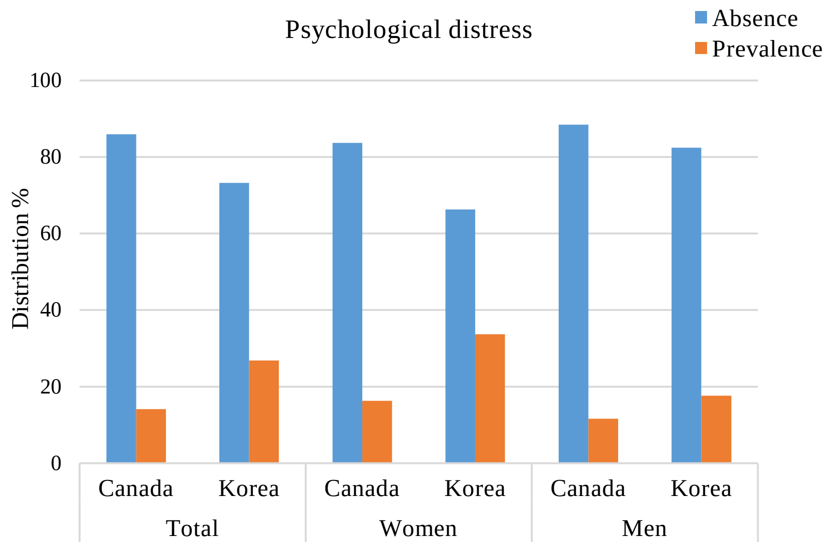


Figure 8. Distribution of psychosocial factors − continued



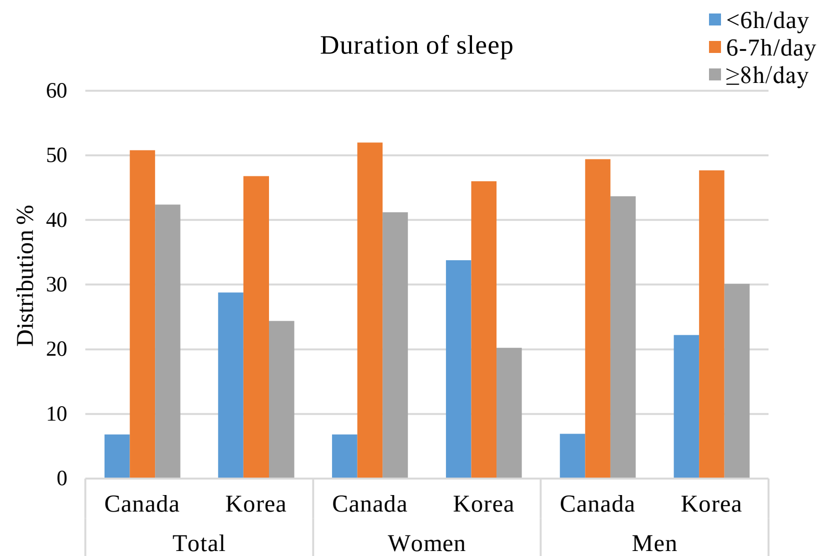


Table 6. Psychosocial characteristics of CHMS (cycle 1) and KNHANES (cycle 4) participants aged 60 to 79 years

Variables	Total				Women				Men			
	Canada		Korea		Canada		Korea		Canada		Korea	
	Weighted N	%	Weighted N	%	Weighted N	%	Weighted N	%	Weighted N	%	Weighted N	%
Physical activity												
Active	3,239,226	66.3	2,648,954	54.0	1,688,999	65.9	1,401,773	49.7	1,550,228	66.8	1,247,181	59.9
Inactive	1,646,813	33.7	2,252,528	46.0	875,397	34.1	1,416,584	50.3	771,416	33.2	835,944	40.1
Between-country difference		*p*=.0002				*p*=.0018				*p*=.110		
Dietary pattern												
Prudent	1,384,396	28.3	1,754,897	35.8	792,928	30.9	989,457	35.1	591,468	25.5	765,441	36.7
Traditional	2,316,749	47.4	2,340,147	47.7	1,259,194	49.1	1,420,065	50.4	1,057,555	45.6	920,082	44.2
Unhealthy	1,184,894	24.3	806,438	16.5	512,274	20.0	408,835	14.5	672,621	28.9	397,603	19.1
Between-country difference		*p*=.0156				*p*=.337				*p*=.0304		
Smoking												
Lifetime abstainer	2,125,980	43.5	2,877,671	58.7	1,276,098	49.8	2,538,283	90.0	849,882	36.6	339,387	16.3
Former smoker	2,142,526	43.9	1,238,217	25.3	915,695	35.7	125,455	4.5	1,226,831	52.8	1,112,762	53.4
Current smoker	617,533	12.6	785,594	16.0	372,603	14.5	154,619	5.5	244,930	10.6	630,975	30.3
Between-country difference		*p*<.0001				*p*<.0001				*p*<.0001		
Alcohol consumption												
Lifetime abstainer	236,973	4.9	1,335,256	27.0	162,489	6.30	1,127,983	40.0	74,484	3.2	207,273	10.0
Former drinker	620,738	12.7	954,666	19.1	376,901	14.7	577,826	20.5	243,837	10.5	376,840	18.1
Occasional drinker	1,944,786	39.8	1,140,460	22.9	1,261,079	49.2	777,675	27.6	683,707	29.5	362,785	17.4
Regular drinker	2,083,543	42.6	1,471,100	31.0	763,927	29.8	334,873	11.9	1,319,616	56.8	1,136,227	54.5
Between-country difference		*p*<.0001				*p*<.0001				*p*=<.0001		
Psychological distress												
Absence	4,197,577	85.9	3,585,985	73.2	2,145,327	83.7	1,869,751	66.3	2,052,250	88.4	1,716,234	82.4
Presence	688,462	14.1	1,315,496	26.8	419,069	16.3	948,606	33.7	269,394	11.6	366,891	17.6
Between-country difference		*p*<.0001				*p*<.0001				*p*=.070		
Duration of Sleep												
< 6 h/day	333,272	6.8	1,413,111	28.8	173,130	6.8	951,814	33.8	160,142	6.9	461,297	22.2
6-7 h/day	2,480,412	50.8	2,291,948	46.8	1,333,763	52.0	1,297,793	46.0	1,146,649	49.4	994,155	47.7
≥ 8h/day	2,072,355	42.4	1,196,423	24.4	1,057,502	41.2	568,750	20.2	1,014,853	43.7	627,673	30.1
Between-country difference		*p*<.0001				*p*<.0001				*p*<.0001		

5.5 Results of Correlation and Partial Correlation Analysis among MetS and Study Variables

Results of correlation (upper triangular matrix) and partial correlation (lower triangular matrix) analysis are presented in Appendix J-1. Since dietary pattern was a nominal variable, it might be hard to appreciate the association between the dietary patterns and other study variables. For a better understanding, therefore, frequencies of dietary patterns by biomedical, biosocial, and psychosocial factors are presented in Appendices J-2 and J-3 for each country. Note that for correlation analyses, as well as the subsequent univariate and multivariate logistic regression analyses, it was necessary to recode three study variables, specifically comorbidity, adequacy of household income, and marital status. Two categories of comorbidity (i.e., having 2 and 3+ comorbid conditions), two categories of household income adequacy (i.e., lowest and lower middle), and two categories of marital status (separated/divorced/widowed and single/never-married) were collapsed to avoid small numbers of subjects in certain cells.

5.5.1 CHMS

Results of correlation analysis indicated weak associations ($r<0.25$) among MetS and biomedical, biosocial, and psychosocial variables. The strongest correlations were between alcohol consumption and being male ($r=0.21$) and alcohol consumption and household income adequacy ($r=0.24$). The results of the partial correlation analysis also indicated weak associations, with one exception. After adjusting for every other covariates, adequacy of household income was negatively correlated with marital status ($r=-.31$).

Dietary patterns were not associated with age, comorbidity, gender, household income adequacy, marital status, psychological distress, and sleep duration (Appendix J-2). Education had a borderline significant association with dietary pattern ($p<.09$). People with less than secondary education were least likely to have the prudent dietary pattern and more likely to have an unhealthy dietary pattern compared with participants with higher levels of education. Physically active people were more likely to consume a prudent dietary pattern and less likely have an unhealthy dietary pattern compared with physically inactive participants. Lifetime non-smokers and former smokers were less likely to consume an unhealthy dietary pattern compared with current smokers.

5.5.2 KNHANES

Results of correlation analysis indicated that the majority of associations were weak (r<.25). However, being male was moderately associated with education (r=.38), marital status (r= -.39), smoking (r=.65), and alcohol consumption (r=.44). That is, Korean men were more likely to be educated, smokers, and drinkers but less likely to be non-married compared with Korean women. These results of associations remained after adjusting for other covariates.

Dietary patterns were not associated with age and alcohol consumption (Appendix J-3). Participants with comorbidities were less likely to consume a prudent diet and more likely to have a traditional dietary pattern than those without comorbidity. Men were more likely to have an unhealthy diet and less likely to have a traditional diet compared with women. In terms of household income adequacy, participants with higher income adequacy were more likely to consume a prudent diet, but more likely to have unhealthy dietary pattern compared with participants in lowest household income adequacy, whereas those with the two higher levels of household income adequacy were least likely to have traditional dietary pattern rather than unhealthy pattern. A similar pattern was observed with increasing education and dietary pattern. Lifetime non-smokers and former smokers were more likely to consume a prudent dietary pattern compared with current smokers. Participants with depression or high levels of psychological distress were less likely to consume a prudent diet and more likely to have a traditional diet compared with those without psychological distress, and participants who reported 6 to 7 hours of daily sleep were more likely to consume a prudent diet.

5.6 Univariate Measures of Associations between MetS and Biomedical, Biosocial, and Psychosocial Factors

Table 8 shows the results of univariate logistic regression analysis that examined the association between MetS and biomedical and biosocial factors. In both countries, increasing age was associated with prevalence of MetS, although this association was not statistically significant in the Canadian sample. Number of comorbidities was also positively associated with MetS in both samples. Men were less likely to have MetS compared with their women counterparts in both countries, although this association did not achieve statistical significance in the Canadian sample. In both countries, MetS was negatively associated with adequacy of household income; however, these associations were not statistically significant. Prevalence of MetS was significantly associated with education in both Canadian and Korean older adults. Individuals with higher levels of education were less likely to have MetS. There was, however, a difference in the association between marital status and MetS ($p<.0001$) between countries, as assessed by examining the interaction between marital status and country in in the model for MetS. In the Canadian sample, the non-married group were less likely to have MetS compared with those who were married. The reverse was seen in the Korean sample, with non-married participants having higher odds of MetS. Further analyses revealed that this could be explained by the association between gender, marital status, and MetS (Table 7).

Table 7. Association between gender, marital status, and MetS among Korean sample

				Prevalence of MetS	
Gender	Marital status	Weighted N	%	Weighted N	%
Female	Married	1,592,053	56.5	934,535	58.7
	Non-married	1,226,304	44.7	779,929	63.6
Male	Married	1,927,014	92.5	824,762	42.8
	Non-married	156,112	7.5	69,626	44.6

As shown in Table 7, men were more likely to be married and less likely to have MetS. Once adjusting for gender, non-married still had higher odds of MetS, although the relationship was no longer significantly associated with MetS (OR, 1.17, 95% CI, 0.95-1.45).

Table 8. Results of the univariate logistic regression analysis of MetS* on biomedical and biosocial factors by country

		Canada				Korea				
		95% CI				95% CI				
Parameters	Category	OR	Lower	Upper	Sig.[a]	OR	Lower	Upper	Sig.[a]	Sig.[b]
Age	-	1.02	0.97	1.07	0.559	1.02	1.01	1.03	0.039	0.945
Comorbidity	Absence [ref.]	-	-	-	-	-	-	-	-	
	Having 1	1.40	0.96	2.05	0.062	1.38	1.15	1.67	<.0001	0.995
	Having 2+	1.68	1.07	2.62		1.64	1.31	2.04		
Gender	Women [ref.]	-	-	-	-	-	-	-	-	
	Men	0.95	0.68	1.32	0.746	0.48	0.41	0.57	<.0001	0.0004
Income adequacy	Lowest [ref.]	-	-	-	-	-	-	-	-	
	Middle	0.71	0.42	1.21	0.451	0.86	0.67	1.11	0.480	0.721
	Highest	0.71	0.36	1.39		0.95	0.73	1.22		
Education	< Secondary [ref.]	-	-	-	-	-	-	-	-	
	Secondary	0.74	0.47	1.17	0.117	0.73	0.60	0.89	<.0001	0.978
	Post-secondary	0.53	0.28	1.01		0.49	0.33	0.72		
Marital status	Married [ref.]	-	-	-	-	-	-	-	-	
	Non-married[c]	0.55	0.33	0.90	0.017	1.61	1.34	1.94	<.0001	<.0001

[a] within-country difference; [b] between-country difference assessed by looking at the interaction between the factor and country; Age: continuous variable; [ref.]: reference group; * metabolic syndrome; [c] separated, divorced, widowed, single or non-married

As shown in Table 9, physical inactivity was positively associated with MetS in both Canadian and Korean older adults, although the association in each country did not achieve statistical significance at the *p*<.05 level.

In the Canadian sample, compared with the prudent diet, traditional and unhealthy dietary patterns were positively associated with MetS; however, the overall association was not statistically significant (*p*=.72). By contrast, traditional and unhealthy dietary patterns were negatively associated with MetS compared with prudent dietary pattern in the Korean sample. In particular, individuals who consumed the Korean traditional dietary pattern had a significantly lower odds of MetS compared with those with the prudent dietary pattern (OR, 0.82, 95% CI, 0.68-0.99). However, there was no statistically significant difference in the overall association between dietary patterns and MetS across the two countries (*p*=.29).

There was significant difference in the association between smoking and MetS between the two counties (*p*=.005). In the Canadian sample, former and current smokers were more likely to have MetS compared with lifetime abstainers (OR, 1.90, 95% CI, 1.01-3.55 and OR, 1.38, 95% CI, 0.53-3.54, respectively), although the overall association between current smoking status and MetS was not statistically significant (*p*=.12). By contrast, Korean former and current smokers had significantly lower odds of MetS compared with lifetime abstainers (OR, 0.63, 95% CI, 0.52-0.77 and OR, 0.55, 95% CI, 0.43-0.71, respectively). Again, this unexpected finding was due to the association between gender, smoking and MetS. Korean men were more likely to be former and current smokers and less likely to have MetS (Appendix K). Once adjusting for gender, former and current smoking was no longer significantly associated with MetS (OR, 1.15, 95% CI, 0.84-1.56; OR, 0.94, 95% CI, 0.70-1.27, respectively).

The pattern of association between alcohol consumption and MetS was similar between the two countries, suggesting that former, occasional, and regular drinkers were less likely to have MetS compared with lifetime abstainers. However, these associations were not statistically significant in both countries.

Presence of depression or high levels of psychological distress was positively associated with MetS. In the Canadian sample, there was a borderline significant association between psychological distress and MetS (p=.06), while the association was not significant in Korean sample (p=.12).

Finally, compared with participants who slept less than 6 hours per day, those who reported sleeping 6 or more hours a day were less likely to have MetS. However, the association between sleep duration and MetS was not statistically significant in both countries.

Table 9. Results of the univariate logistic regression analysis of MetS* on psychosocial factors by country

		Canada				Korea				
			95% CI				95% CI			
		OR	Lower	Upper	Sig.[a]	OR	Lower	Upper	Sig[a]	Sig.[b]
Physical activity	Active [ref.]	-	-	-	-	-	-	-	-	
	Inactive	1.32	0.81	2.14	0.267	1.18	0.99	1.42	0.067	0.684
Dietary pattern	Prudent [ref.]	-	-	-	-	-	-	-	-	
	Traditional	1.22	0.74	2.01	0.717	0.82	0.68	0.99	0.098	0.289
	Unhealthy	1.17	0.57	2.38		0.93	0.72	1.19		
Smoking	Lifetime abstainer [ref.]	-	-	-	-	-	-	-	-	
	Former	1.90	1.01	3.55	0.118	0.63	0.52	0.77	<.0001	0.005
	Current	1.38	0.53	3.54		0.55	0.43	0.71		
Alcohol consumption	Lifetime abstainer [ref.]	-	-	-	-	-	-	-	-	
	Former	0.58	0.14	2.43	0.023	0.90	0.71	1.16	<.0001	0.103
	Occasional	0.34	0.09	1.34		0.82	0.65	1.04		
	Regular	0.44	0.14	1.36		0.56	0.46	0.69		
Psychological distress	Absence [ref.]	-	-	-	-	-	-	-	-	
	Presence	1.87	0.98	3.57	0.057	1.17	0.96	1.42	0.115	0.170
Duration of sleep	< 6 hours/day [ref.]	-	-	-	-	-	-	-	-	
	6-7 hours/day	0.60	0.27	1.34	0.090	0.98	0.79	1.21	0.931	0.132
	≥ 8 hours	0.86	0.35	2.14		0.95	0.74	1.23		

* metabolic syndrome; [a] within-country difference; [b] between-country difference assessed by looking at the interaction between the factor and country; [ref.]: reference group

5.7 Mediating Effect of Physical Activity and Dietary Pattern on the Association between MetS and Biomedical and Biosocial Factors

The mediation analysis was previously described in detail in Chapter 4, section 4.4.6. Briefly, the mediation analysis involved testing three regression models, and was restricted to univariate associations between MetS and individual biomedical or biosocial factors that were found to be statistically significant. As shown in Table 6, MetS and marital status were significantly associated at the univariate level in the Canadian sample. The association between Mets and comorbidity was also of borderline significance (*p*=.062). In the Korean sample, MetS and age, comorbidity, gender, education and marital status were significantly associated at the univariate level.

The results of the mediation analysis are provided in Appendices L-1 to L-10 provide the results of the mediation analysis. None of the observed statistically significant associations between biomedical and biosocial factors and MetS was mediated by either physical activity or dietary pattern. The magnitude of the univariate association between the individual factor and MetS (indicated by B (τ) in Model 1) did not materially change (i.e., did not disappear) after adjusting for the mediator variable (as indicated by B (τ') in model 3), with one exception. In the Korean sample the magnitude of the inverse association between education and MetS was stronger after adjusting for dietary pattern. This was explained by the relationship between education and dietary pattern. Individuals with higher levels of education were more likely to consume a prudent diet (Figure 9). However, the prudent diet was associated with a higher prevalence of MetS compared with the traditional diet, even after adjusting for education (Figure 10). Hence, when left uncontrolled in the analysis, dietary pattern distorted or under-estimated the relationship between education and MetS.

Figure 9. Association between education and dietary pattern: Korean sample

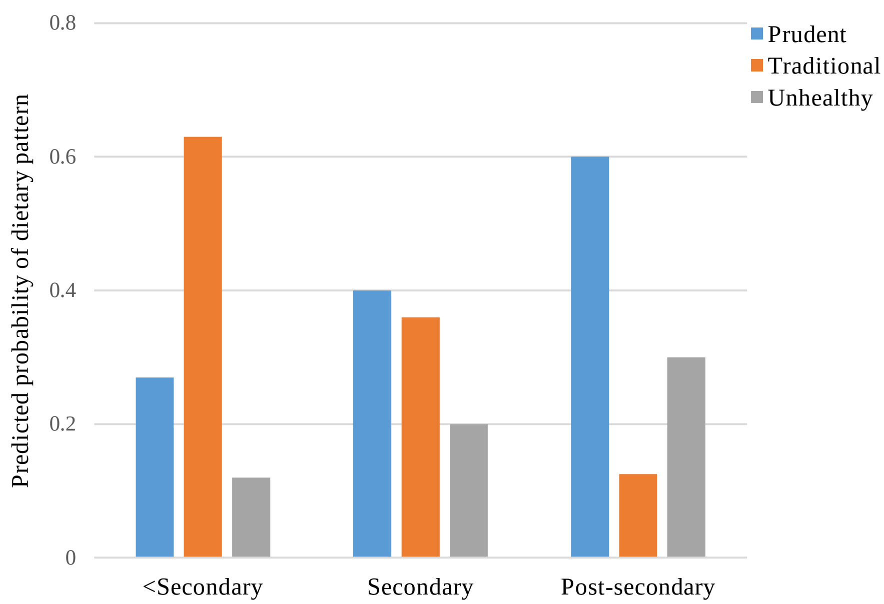
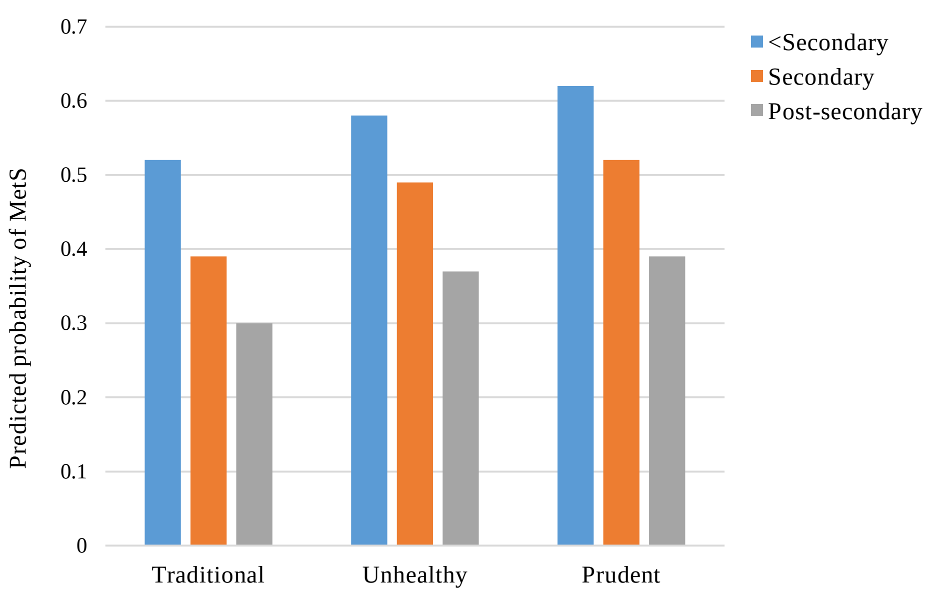


Figure 10. Association between dietary pattern, education, and MetS: Korean sample



5.8 Moderating Effect of Physical Activity and Dietary Pattern on the Association between Mets and Biomedical and Biosocial Factors

The moderation analytic technique was described in detail in Chapter 4, section 4.4.6. Briefly, a series of logistic regression models including an explanatory variable (a biomedical or biosocial factor), a moderator (physical activity or dietary pattern) and the country variable to predict MetS were built. In these models, two-way interactions and a three-way interaction consisting of the country variable were also included. It was examined whether a three-way interaction including the country variable was significant, domain analysis was conducted to investigate how the moderator worked differently depending on country. Appendices M-1 and M-2 provide the results of the moderation analysis.

5.8.1 Moderation effect of physical activity

There was evidence that level of physical activity moderated the association between gender and MetS, between household income adequacy and MetS, and between education and MetS (Appendix M-1).

Interaction of gender with physical activity

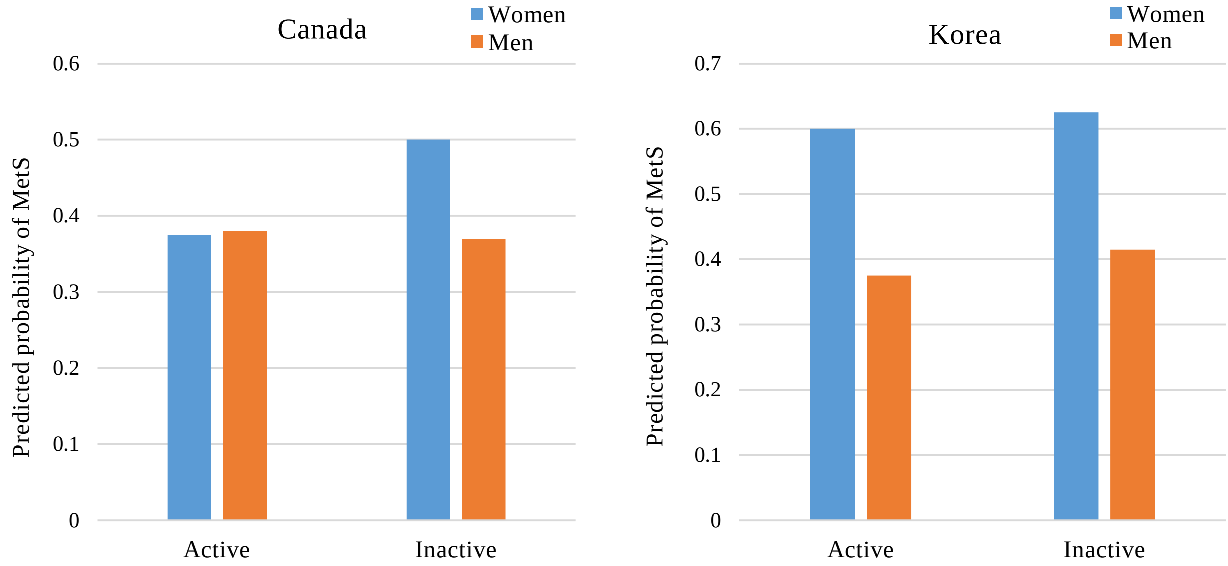
The association between gender and MetS by level of physical activity differed between countries (Table 10 and Figure 11). In the Canadian sample, being female increased the probability of MetS in the presence of physical inactivity (p<.0001). There was no evidence of interaction of gender with physical activity in the Korean participants (p=.21).

Table 10. Results of domain analysis for moderation effect of physical activity on the association between gender and MetS

Country	Parameters	B	SE	Sig.
Canada	Gender*PA	-1.1988	0.2709	<.0001
Korea	Gender*PA	0.2490	0.1983	0.2100

PA: physical activity
Reference groups – women; physically active

Figure 11. Gender-related differences in prevalence of MetS dependent on level of physical activity by country



Interaction of household income adequacy with physical activity

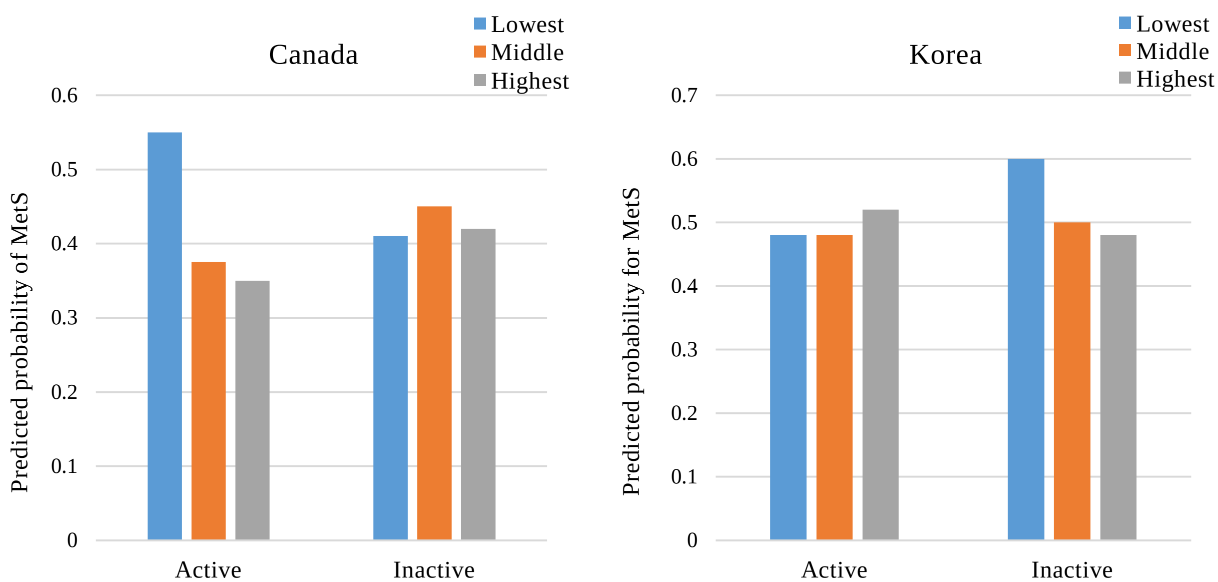
The association between adequacy of household income and MetS by level of physical activity also differed between countries (Table 11 and Figure 12). When physically inactive, Korean participants with higher income adequacy were less likely to have MetS compared with those with the lower levels (p=.012). In other words, among physical inactivity, Korean participants with the lowest adequacy of household income were more likely to have MetS. Among Canadian participants there was no evidence of interaction of household income with physical activity (p=.184). Note that the high probability of MetS observed in Canadian active sample with the lowest income was obtained in a very small sample size for the lowest income group (3.8% of the total sample).

Table 11. Results of domain analysis for moderation effect of physical activity on the association between adequacy of household income and MetS

Country	Parameters	B	SE	Sig.[a]	Sig.[b]
Canada	Income1*PA	0.9161	0.5115	0.0733	0.1840
	Income2*PA	1.2219	0.9061	0.1775	
Korea	Income1*PA	-0.4844	0.2771	0.0804	0.0118
	Income2*PA	-0.6438	0.2372	0.0066	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
Income1: middle level; Income2: highest; PA: physical activity
Reference group – lowest household income; physically active

Figure 12. Adequacy of household income-related differences in prevalence of MetS dependent on level of physical activity by country



Interaction of education with physical activity

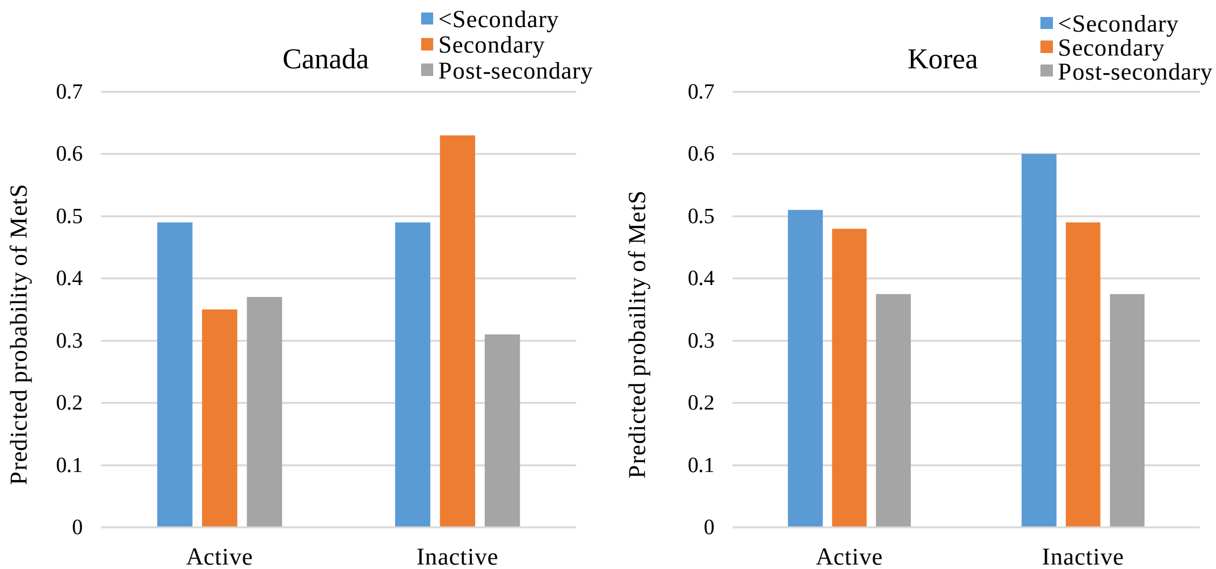
As shown in Table 12 and Figure 13, Canadian participants showed a different pattern of association between education and MetS by level of physical activity (p<.0001). When physically inactive, Canadian older adults with secondary school graduation were more likely to have MetS than those with less than secondary school graduation, whereas Canadians with post-secondary school graduation were less likely to have MetS compared with the lowest level of education. In Korean participants, there was no evidence of an interaction of education with level of physical activity (*p*=.408).

Table 12. Results of domain analysis for moderation effect of physical activity on the association between education and MetS

	Parameters	B	SE	Sig.[a]	Sig.[b]
Canada	Education1*PA	1.1317	0.7695	0.1414	<.0001
	Education2*PA	-0.6304	0.5474	0.2495	
Korea	Education1*PA	-0.2083	0.1982	0.2932	0.4077
	Education2*PA	-0.3676	0.3552	0.3008	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
Education1: secondary school graduation; Education2: post-secondary school graduation; PA: physical activity
Reference group – < secondary school graduation; physically active

Figure 13. Education-related differences in prevalence of MetS dependent on physical activity by country



5.8.2 Moderation effect of dietary pattern

Of 6 moderation models tested, only one model showed a significant between-country difference in moderation effect of dietary pattern (Appendix M-2).

Interaction of gender with dietary pattern

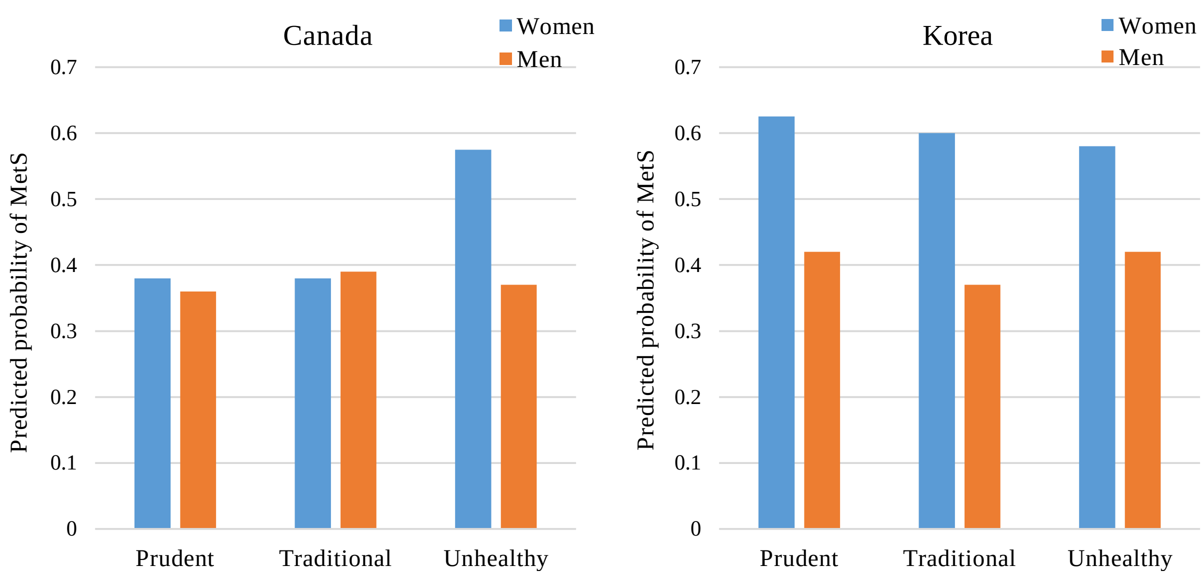
Among Canadians with the unhealthy dietary pattern, women were more likely to have MetS compared with men (*p*=.02) (Table 13 and Figure 14). By contrast, there was no statistical difference in the association between gender and MetS depending on dietary patterns in Korean sample.

Table 13. Results of domain analysis for moderation effect of dietary pattern on the association between gender and MetS

	Parameters	B	SE	Sig.[a]	Sig.[b]
Canada	Gender*Diet1	0.4319	0.3680	0.2405	<.0001
	Gender*Diet2	-0.8850	0.3818	0.0205	
Korea	Gender*Diet1	-0.2735	0.1977	0.1665	0.1456
	Gender*Diet2	0.1791	0.2651	0.4994	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern
Reference group – women; prudent dietary pattern

Figure 14. Gender-related difference in prevalence of MetS dependent on dietary patterns by country



5.9 Multivariate Associations between MetS and Biomedical, Biosocial, and Psychosocial Factors

The research aim 4 was to build multivariate models for the joint associations of biomedical, biosocial, and psychosocial factors on MetS. In the first step of these analyses, a full model including all study biomedical, biosocial, and psychosocial factors was tested separately for each country (Appendices N-1 and O-1 for Canadian and Korean sample, respectively). The least significant variable was removed from the analysis in a backward elimination manner. This iterative process continued until a multivariate model did not significantly decrease the variability explained (as indicated by likelihood chi-square) was identified (Appendices N-2 and O-2 for Canadian and Korean sample, respectively). Next, interactions consisting of variables that remained in the multivariate model were entered in the model (Appendices N-3 and O-3 for Canadian and Korean sample, respectively). After removing non-significant interactions (i.e., $p>.05$), the final (parsimonious) model was then achieved.

5.9.1 Results of multivariate logistic regression analysis in Canadian sample

Table 14 shows the results for the final multivariate model. In the first analytic step, adequacy of household income, marital status, alcohol consumption, and psychological distress remained in the model. These four variables and interaction terms among these variables were simultaneously entered into a logistic regression model (Appendix N-3). As shown in Appendix N-3, only one interaction term of household income with marital status was significantly associated with MetS at $p=.02$. This interaction was therefore included in the final model, even though the significance level in the final model was 0.12.

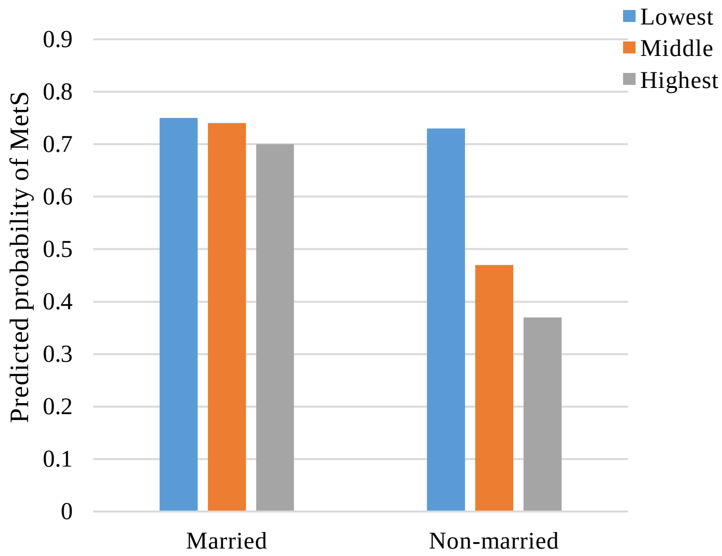
Both adequacy of household income and marital status were significantly inversely associated with MetS in the multivariate model prior to the introduction of the interaction term of income adequacy with marital status (OR, 0.57, 95% CI, 0.35-0.93; OR, 0.46, 95% CI, 0.25-0.84; OR, 0.40, 95% CI, 0.27-0.61, for middle level of income adequacy, highest level of income adequacy, and non-married, respectively). In the final model, however, the interaction of the two variables were significantly associated with MetS at *p*<.12 (OR, 0.35, 95% CI, 0.11-1.12; OR, 0.29, 95% CI, 0.07-1.12, for marital status*middle household income adequacy and marital status*highest household income adequcay), whereas the two main effects were no longer significant. As shown in Figure 15, the association between marital status and MetS differed depending on adequacy of household income (OR, 0.35, 95% CI, 0.11-1.12; OR, 0.29, 95% CI, 0.07-1.12 for middle and highest household income adequacy, respectively). The prevalence of MetS did not differ significantly between non-married and married people in the lowest adequacy income group, whereas in the middle and highest income groups, non-married people were less likely to have MetS than married people. Alcohol consumption was significantly inversely associated with prevalence of MetS (*p*=.006). Compared with lifetime non-drinkers, occasional and regular drinkers were significantly less likely to have MetS (adjusted OR, 0.23, 95% CI, 0.08-0.66; adjusted OR, 0.31, 95% CI, 0.14-0.69). Presence of depression or high levels of psychological distress had a positive association with prevalence of MetS (OR, 2.07, 95% CI, 1.04-4.12, *p*=.04).

Table 14 Results for final multivariate logistic regression model of MetS on biomedical, biosocial, and psychosocial factors in Canadian adults aged 60 to 79 years

			95% CI		
Variable		OR	Lower	Upper	Sig.
Household income adequacy	Lowest [ref.]	-	-	-	-
	Middle	0.95	0.41	2.20	0.6949
	Highest	0.76	0.30	1.94	
Marital status	Married [ref.]	-	-	-	-
	Non-married	0.87	0.39	1.95	0.7406
Alcohol consumption	Lifetime abstainer [ref.]	-	-	-	-
	Former	0.38	0.12	1.19	0.0062
	Occasional	0.23	0.08	0.66	
	Regular	0.31	0.14	0.69	
Psychological distress	Absence [ref.]	-	-	-	-
	Presence	2.07	1.04	4.12	0.0379
Marital status* Household income adequacy	Marital status*Lowest [ref.]	-	-	-	-
	Marital status*Middle	0.35	0.11	1.12	0.1180
	Marital status*Highest	0.29	0.07	1.12	

[ref.]: reference group

Figure 15. Marital status-related differences in prevalence of MetS dependent on adequacy of household income in Canadian adults aged 60 to 79 years



5.9.2 Results of multivariate logistic regression analysis in Korean sample

Table 15 shows the results for the final multivariate model for the Korean sample. In the first analytic step, comorbidity, gender, education, marital status, physical activity, and dietary pattern remained in the model (Appendix O-1). Next, these six variables and interaction terms among these variables were simultaneously entered into a logistic regression model (Appendix O-3). Two interactions, comorbidity*marital status and gender*education were significantly associated with MetS (*p*=.049; *p*=.003, respectively) (Appendix O-3) and therefore entered into the final model.

Table 15. Results for final multivariate logistic regression model of MetS on biomedical, biosocial, and psychosocial factors in Korean adults aged 60 to 79 years

Variable		OR	95% CI Lower	95% CI Upper	Sig.
Comorbidity	Absence [ref.]	-	-	-	
	Having 1	1.03	0.81	1.30	0.2417
	Having 2+	1.26	0.95	1.66	
Gender	Women [ref.]	-	-	-	
	Men	0.41	0.31	0.54	<.0001
Education	< Secondary [ref.]	-	-	-	
	Secondary	0.59	0.44	0.79	<.0001
	≥ Post-secondary	0.23	0.10	0.50	
Marital status	Married [ref.]	-	-	-	
	Non-married	0.85	0.62	1.17	0.3298
Physical activity	Active [ref.]	-	-	-	
	Inactive	1.15	0.96	1.38	0.1349
Dietary pattern	Prudent [ref.]	-	-	-	
	Traditional	0.69	0.56	0.84	0.0005
	Unhealthy	0.94	0.72	1.22	
Marital status*Comorbidity	Marital status*Absence [ref.]	-	-	-	
	Marital status*Having 1	1.93	1.23	3.01	0.0152
	Marital status*Having 2+	1.33	0.77	2.28	
Gender*Education	Gender*<Secondary [ref.]	-	-	-	
	Gender*Secondary	2.10	1.42	3.09	0.0001
	Gender*Post-secondary	4.03	1.68	9.67	

[ref.]: reference group

There was a trend towards physical inactivity being positively associated with MetS (OR, 1.15, 95% CI, 0.96-1.38). Korean older adults with the traditional dietary pattern were significantly less likely to have MetS compared with those with prudent dietary pattern (adjusted OR, 0.69, 95% CI, 0.56-0.84). By contrast, there was no significant difference in prevalence of MetS between unhealthy and prudent dietary patterns.

In the final model, there was an evidence of a significant interaction of marital status with comorbidity (p=.015). As shown in Figure 16, the probability of Mets between married and non-married people did not significantly differ among participants without comorbid conditions. In contrast, a significant difference in the probability of MetS between married and non-married people was observed in those with one or more comorbid conditions. Non-married people with comorbidity had a higher probability of MetS than those in other categories.

There was also evidence of a significant interaction of gender with education. As shown in Figure 17, women with less than secondary education were more likely to have MetS compared with men. Similarly, women with secondary education were more likely to have MetS compared with men, although the difference between men and women was smaller. By contrast, in the highest education group, women were significantly less likely to have MetS.

Figure 16. Marital status-related differences in prevalence of MetS dependent on comorbidity in Korean older adults aged 60 to 79 years

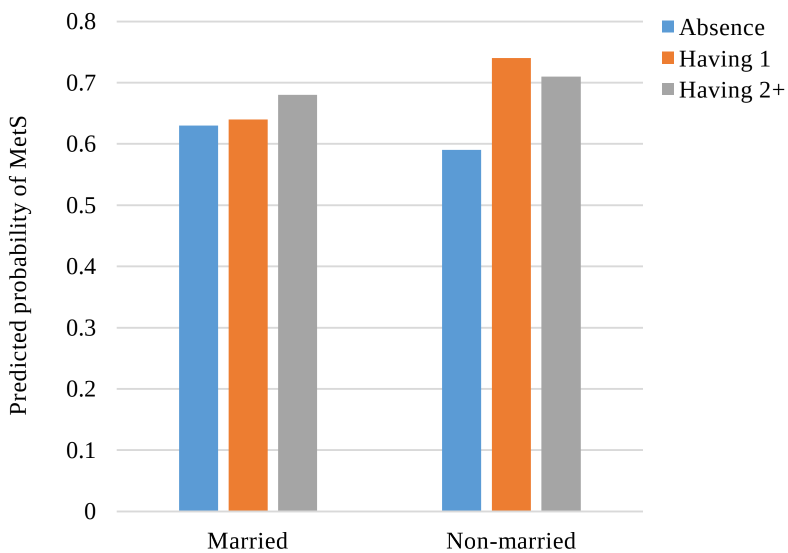
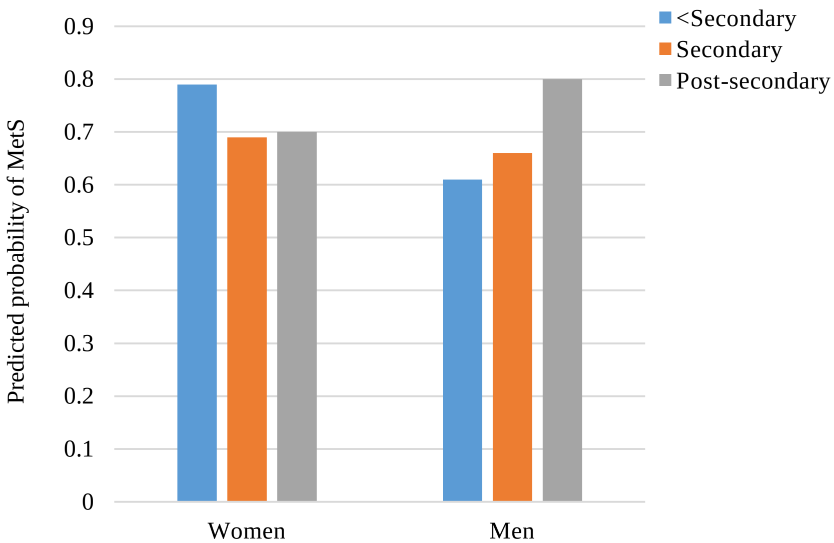


Figure 17. Gender-related differences in prevalence of MetS dependent on education in Korean older adults aged 60 to 79 years



5.9.3 Results of alternate multivariate logistic regression analysis

When testing the multivariate logistic regression models using a merged dataset with country as an indicator variable, the final results (Table 16) showed a similar pattern of multivariate associations between study variables and MetS that was observed in the Korean sample (Table 15). This was due to the larger sample in the Korean dataset compared with the Canadian dataset. This was the primary reason for conducting the multivariate logistic regression analysis separately for each country.

Table 16. Results of multivariate logistic regression analysis of MetS on biomedical, biosocial and psychosocial factors in both countries

Study variable		OR	95% CI lower	95% CI Upper	Sig.
Country	Canada [ref.]	-	-	-	-
	Korea	1.10	0.80	1.53	0.554
Comorbidity	Absence [ref.]	-	-	-	-
	Having 1	1.25	1.05	1.49	0.014
	Having 2	1.44	1.15	1.79	0.0012
	Having 3+	1.30	0.88	1.94	0.188
Gender	Women [ref.]	-	-	-	-
	Men	0.41	0.32	0.53	<.0001
Education	<Secondary [ref.]	-	-	-	-
	Secondary	0.60	0.46	0.79	0.0002
	Post-secondary	0.31	0.19	0.50	<.0001
Dietary pattern	Prudent [ref.]	-	-	-	-
	Traditional	0.76	0.63	0.92	0.004
	Unhealthy	0.95	0.74	1.21	0.662
Gender*Education	Gender*<Secondary [ref.]	-	-	-	-
	Gender*Secondary	2.05	1.41	2.98	0.0002
	Gender*Post-secondary	3.11	1.95	4.96	<.0001

[ref.]: reference group

CHAPTER 6 DISCUSSION

6.1 Major Study Findings

The main purpose of this study was to compare prevalence and correlates of MetS between Canadian and Korean older adults aged 60 to 79 years, using two population-based, cross-sectional datasets from the CHMS (cycle 1) and KNHANES (cycle 4). The conceptual model was the Biopsychosocial Model developed by Hoffman & Driscoll, 2000 and was used to examine the associations between physical activity, dietary pattern, other possible correlates, and MetS across the two populations.

In the fasted sample of the CHMS and KNHANES, the estimated prevalence of MetS in Canadian and Korean aged 60 to 79 years was 42.0% and 52.2%, respectively. Both estimates suggest that MetS is relatively common in older adults even among a socially advantaged Canadian sample, and were consistent with those reported in the literature for adults aged 60 to 79 years. Canadian population-based studies using the Harmonizing definition of MetS have reported prevalence estimates ranging from 39 % to 41% (Riediger & Clara, 2011; Setayeshgar et al., 2012). Korean population-based studies have reported prevalence estimates ranging from 46.8 to 52.7% (Korean Ministry of Health Welfare, 2006; Choi et al., 2013). However, a recent Korean study (Choi et al., 2013) reported a lower prevalence of 46.8%. This might be due to difference in the threshold used for waist circumference in women. Choi et al. (2013) applied 85 cm (33.5 inches) based on the recommendation of the Korean Society for the Study of Obesity (KSSO) (Lee et al., 2006), whereas the present study used 80 cm (31.5 inches) consistent with the ethnic-specific threshold used in previous Korean studies (Kim et al., 2008; Kim & Jo, 2011; Ahn et al., 2013) and recommended by the Harmonizing definition of MetS. When the waist circumstance threshold of the KSSO was applied to the Korean women of the present study, the overall prevalence of MetS remained higher in the Korean sample than in the Canadian sample (48.5% versus 42.0%, respectively), although prevalence of abdominal obesity of Korean women was now significantly lower than that of Canadian women (45.3% versus 58.5%, respectively).

This is the first study to compare the prevalence of MetS between Korean and Canadian older adults. However, several studies have shown that Asians had a greater risk for MetS or abnormal metabolic profiles than Caucasians. Tillin et al. (2005) showed that South Asians had the highest prevalence of MetS than Europeans among residents aged 40 to 69 years living in west London, the UK. Palaniappan et al. (2011) also reported that Asian Americans have higher rates of MetS compared with non-Hispanic whites at lower BMI levels and lower prevalence of obesity. A longitudinal study (Chiu et al., 2011) examining a multiethnic cohort living in Ontario, Canada reported that South Asian and Chinese subjects had higher incidence rates and earlier onset of T2DM compared with white subjects at lower ranges of BMI.

Racial/ethnic difference in body composition, particularly body fat, might be one of the contributors to the difference in prevalence of MetS. Deurenberg et al. (1998) reported that Asians including Chinese, Ethiopians, Indonesians, and Thais had a higher amount of body fat compared with Caucasians for the same level of BMI. Further, when comparing abdominal adiposity between Asians and Caucasians with computed tomography (CT) or magnetic resonance imaging (MRI), Asians were observed to have a greater amount of visceral adipose tissue (VAT) or deep subcutaneous abdominal adipose tissue (DSAT) compared with Caucasians at the same BMI or waist circumference (Deurenberg et al., 1998; Lear et al., 2007). As Sniderman et al. (2007) proposed, the difference in amount of VAT or DSAT between Asians and Caucasian might be explained by difference in capacity to store fatty acids (namely excess energy) in superficial subcutaneous abdominal adipose tissue (SSAT). Since Caucasians have a higher capacity to store fatty acids in SSAT (i.e., the primary or initial adipose tissue to store excess energy) than Asians, their fat accumulation in VAT and/or DSAT (i.e., the secondary adipose tissue stores) would be less rapidly developed. Further, previous studies (Kelley et al., 2000; Smith et al., 2001) showed that development of VAT and/or DSAT rather than SSAT had stronger correlation with increased risk of metabolic profiles such as insulin resistance, high blood pressure, and abnormalities of triglycerides and

HDL-C. Therefore, these findings from the earlier studies did not differ significantly from the results observed in the present study, indicating that the Korean sample had a significantly higher prevalence of hyperglycemia, low-HDL, and hypertriglyceridemia compared with the Canadian sample (Appendix G-3), in spite of no significant between-country difference in prevalence of abdominal obesity (as defined by ≥ 102, 88, 90, and 80 cm for Canadian men and women and Korean men and women, respectively), as shown in Figure 6. Further, a synergetic effect of this genetic predisposition and physiological changes after menopause might explain the highest prevalence of MetS, hyperglycemia, hypertriglyceridemia, and HDL-C abnormality in Korean women (Regitz-Zagrosek et al., 2006; Yang & Kozloski, 2011).

A clear underlying mechanism for the racial/ethnic difference in amount or distribution of body fat, metabolic susceptibility, or MetS has not yet been established. However, from an evolutionary perspective, Neel (1962, 1999) proposed a role of 'thrifty gene' (also called 'the thrifty genotype') among ancestral populations who experienced a regular cycle of feast and famine. The notion of the thrifty genotype was proposed to explain a high prevalence of obesity and T2DM in modern society, indicating that people with the thrifty gene store their energy as body fat during the times of feast for the possible starvation in the future; however, in modernized societies where food supply is abundant and sedentary lifestyle is prevalent, the thrifty gene leads to an excess body fat which causes obesity and T2DM. Researchers have hypothesized that this adverse effect of the thrifty genotype may be more prominent to certain populations such as Asians whose ancestors had lived in agricultural society and had been exposed to regular starvation due to crop failure caused by seasonal or climatic variation compared with European descents whose ancestors had consumed foods steadily (Kagawa et al., 2002; Chiu et al., 2011).

More recently, other researchers suggested that 'the thrifty phenotype' rather than 'the thrifty genotype' might be more suitable to explain the racial/ethnic or geographic variance in prevalence of obesity and T2DM (Barker, 1997; Lindsay & Bennett, 2001). Based on the thrifty phenotype theory, a disease such as obesity or T2DM may be caused by early environmental exposures such as malnutrition or disease. For instance, Painter et al. (2005) reported in their review that prenatal exposure (especially in late or mid gestation) to the Dutch famine (1944 to 1945) influenced low birth weight and had great effects on health in later life such as coronary heart disease, increased lipids, obesity, and decreased glucose tolerance. Although there were no tangible data or statistics to investigate the association between prenatal exposures and MetS among the Canadian and Korean sample born between 1928 and 1949, citizens of both countries experienced considerable hardship due to the Great Depression of the late 1920s and World War II (1940 to 1945). However, the Korean cohort likely experienced increased environmental deprievation, since the vast majority of the sample was born in the colonial period (1910 to 1945), leading to food insecurity and economic and social deprivation (Kwak, 2007).

This difference in historical backgrounds between the two countries might also explain the marked differences between the Canadian and Korean participants in social economic distribution, as measured by education and adequacy of household income. As shown in Table 5, 62.7 % of Korean older adults had less than secondary education compared with 26.1% in Canadian older adults. The lower level of education in the Korean cohort can be explained by the fact that a series of Korean historical events such as the colonial period (1910 to 1945), World War II (1940 to 1945), and Korean War (1950 to 1953) had deprived most Koreans of educational opportunities. This difference was especially marked in women where 78.5% of Korean women had less than secondary education compared with 26.4% in Canadian women. A similar pattern was observed in adequacy of household income at time of interview. In addition, a lower level of government sponsored social security programs for older adults in Korea compared with Canada might not mitigate poverty or socioeconomic inequity (Yeo et al., 2012).

It is also speculated that differences in traditional social norms regarding gender roles between the two countries might further influence prevalence of MetS, especially in Korean older women. Figures 8 and 9 show that Korean women were not only disadvantaged relative to their Canadian counterparts, but werealso less educated, had lower adequacy of household incomes, were less physically active, had higher perceived stress and less sleep than Korean men. Such differences were not seen between Canadian men and women, perhaps with the exception of smoking and alcohol consumption. For example, the difference in prevalence of lifetime non-drinking between genders was greater in Korean older adults (40% in women and 10 % in men) compared with Canadian older adults (6.3% and 3.2% in women and men, respectively). This suggests that the Korean sample was still strongly bound by traditional social norms on drinking, indicating "drinking women are not feminine" or "non-drinking men are too feminine" (Mäkelä et al., 2006; Bernards et al., 2009). The inverse association between alcohol intake and HDL-C abnormality was reported by previous studies (Wilsgaard & Jacobsen, 2007; Baik & Shin, 2008; Stoutenberg et al., 2013). Thus, the high prevalence of low HDL-C concentration among Korean older women in the present study might, in part, be explained by their high prevalence of non-drinking. In addition, the difference between Korean women and men in frequency of being divorced, separated, or widowed was greater (42.6% and 7.1% in women and men, respectively) than in Canadian older adults (34.0% and 13.6% in women and men, respectively). This finding may in part be related with the Korean traditional social norm discouraging remarriage in divorced and widowed women (Burch, 1990; Leem, 1994; Woo, 2012). However, failure to remarry is likely linked with harsh financial challenges due to lower level of education among Korean older women (Leem, 1994; Woo, 2012). Given this Korean specific context, low socioeconomic status, exacerbated by the traditional norm on remarriage for Korean women may be a potential risk factor for MetS. Taken together, the higher prevalence of MetS in the Korean older adults, specifically in women than in Canadian older adults may, in part, be explained by a genetic predisposition, historical events, and societal norms.

Nevertheless, the majority of the univariate measures of associations between MetS and biomedical, biosocial and psychosocial factors studied were similar between the Canadian and Korean sample. In both samples increasing age was associated with MetS, although the association was not statistically significant in the Canadian sample possibly due to the relatively small sample size. These findings suggest that age is associated with MetS even within an older age cohort. Number of comorbid conditions was also positively associated with MetS in both Canadian and Korean older adults. This was not an unexpected finding since previous studies also reported that MetS often co-occurs with asthma (Grundy et al., 2004; Brumpton et al., 2013), arthritis (Ferraz-Amaro et al., 2013), back pain (Ha, 2011), heart disease (Gorter et al., 2004), stroke (Arenillas et al., 2007), hearing problem (Brennan et al., 2009; Carriere et al., 2013), and cancers (Esposito et al., 2012), and the authors pointed out that these comorbidities and MetS share underlying pathophysiological mechanisms such as inflammatory processes. Both Canadian and Korean data showed a non-significant trend towards participants with higher levels of household income adequacy being less likely to have MetS compared with those with low level of household income adequacy. This finding was consistent with several previous reports. Using data from the CHMS (cycle1) participants aged 18 to 79 years; Riediger & Clara (2011) also reported an inverse association between adequacy of household income and prevalence of MetS (i.e., 21.3% for the lowest versus 20.5% and 15.2% for the middle and highest, respectively). A Korean study (Park et al. 2007) also reported that women with middle and high level of income had lower prevalence of MetS compared with those with the lowest income. A possible explanation for this finding is that participants with higher incomes have more resources to engage in healthy food choices and lifestyles (Monsivais & Drewnowski, 2009; Mathews et al., 2010).

As predicted, there was a statistically significant association between MetS and education in both Canadian and Korean older adults. Participants with higher levels of education were less likely to have MetS. This was consistent with findings of previous studies (Dallongeville et al., 2005; Brunner et al., 1997). A possible explanation for the inverse relationship between education and MetS might be the effect of education on health behaviours such as diet or physical activity (Dallongeville et al., 2005;

Monsivais & Drewnowski, 2009). In both countries, former, occasional, and current drinkers were significantly less likely to have MetS compared with lifetime abstainers. This finding was consistent with a previous longitudinal study (Wilsgaard & Jacobson, 2007), indicating that alcohol drinkers (2, 3-5, and over 6 times per month) had a lower incidence of MetS compared with non-drinkers. Due to the unavailability of data, the amount of alcohol consumption was not considered in the analysis of the present study; however, the finding was similar with the finding from a meta-analysis study (Alkerwi et al., 2009) reporting that responsible drinkers (i.e., 0.1-19.99g/day for women and 0.1-39.99g/day for men) had lower prevalence of MetS compared with non-drinkers. The inverse association between alcohol consumption and MetS may be explained by earlier reports showing that ethanol increases HDL-C level (De Oliveira e Silva et al., 2000; Brinton, 2012; Shimomura & Wakabayashi, 2013). Researchers proposed several mechanisms for the effect of alcohol on HDL-C, including increase in the activity of lipoprotein lipase (Shimomura & Wakabayashi, 2013) and transport rate of HDL apolipoproteins such as A-I and A-II (De Oliveira e Silva et al., 2000) and decrease in the activity of cholesteryl ester transfer protein (Brinton, 2012). Observational studies also have consistently reported that the level of HDL-C in drinkers was significantly higher than that in non-drinkers (Wilsgaard & Jacobsen., 2007; Baik & Shin, 2008; Stoutenberg et al., 2013). It is noteworthy that HDL-C abnormality greatly contributed to the high prevalence of MetS in Korean participants (Figures 6 and 7), especially Korean women. Additional data analyses were conducted to examine whether Korean women who were non-drinkers (lifetime abstainer and former drinker) were more likely to have HDL-C abnormality compared with other groups (non-drinkers and drinkers in Korean men and Canadian men and women) (Appendix P). The findings showed that compared with Korean women who were non-drinkers; the other subgroups had significantly lower odds of HDL-C abnormalities. Further, even non-drinkers in Canadian women had a lower odds of HDL-C abnormality (OR, 0.54, 95% CI, 0.29-1.02, $p<.06$) than non-drinkers in Korean women. Similarly, non-drinkers in Korean and Canadian men also showed significantly lower odds for HDL-C abnormality (OR, 0.32, 95% CI, 0.22-0.45; OR, 0.31, 95% CI, 0.08-0.21, for Korean and Canadian men, respectively).

In Canadian and Korean older adults prevalence of physical inactivity was 33.7% and 46.0%, and positively associated with MetS. However, in both samples the magnitude of associations was weak (OR=1.32 in Canadians and 1.18 in Koreans, respectively) and did not achieve statistical significance (p=.27 and .07, respectively). Three previous studies (Brien & Katzmarzyk, 2006; Setayeshgar et al., 2012; Clarke & Janssen, 2013) using Canadian population-based data have reported a significant inverse association between physical activity and MetS, but samples consisted of either younger adults (18-64 years) or a wide range of ages (12-79 years). Using the KNHANES (cycle 4) dataset and three categories of physical activity (low, moderate, and high), Choi et al. (2013) reported a significant inverse association between high level of physical activity and MetS in Korean women aged 65 years and older, but not in men.

Misclassification error of physical activity may have underestimated the association between MetS and physical activity. In this study, the CHMS physical activity measure defined physical activity as regular participation in a wide range of physical activities lasting more than 15 minutes per day. This threshold was lower than that of current physical activity guidelines developed by the World Health Organization (2010) (i.e., at least 150 minutes of moderate-to-vigorous physical activity per week in bouts of at least 10 minutes). The rationale for using this question with a lower physical activity threshold was not only to facilitate comparison with KNHANES physical activity measure, but also to identify subjects who were highly likely to be inactive, and then to examine whether they had higher odds of MetS. However, when using another CHMS physical activity measure based on the total energy expenditure values (variable name: PACDPAI), there remained a weak association between physical activity and MetS (OR, 1.33, 95% CI, 0.93-1.92), perhaps due to inadequate statistical power. There might also be a possibility of misclassification error due to the use of the self-reported measure of physical activity. Using accelerometer data collected by CHMS cycle 1 and 2, Clarke & Janssen (2013) showed that participants who were inactive and moderately inactive had significantly higher odds of MetS compared with those with a high level of physical activity. The finding reported by Clarke & Janssen (2013) suggests that self-reported measures may be less accurate than other objective measures such as accelerometer. Another issue regarding self-reported physical activity questionnaires was discussed by Colly et al. (2011). Using accelerometer data, the authors found that only 13.1% of the CHMS participants aged 60 to 79 years performed moderate-to-vigorous physical activities, whereas Statistics Canada (2010) reported that 50% and 38% of male and female adults aged 65 years and older reported that they participated in at least moderate level of physical activity. Colly et al. (2011) pointed out that there was a substantial difference between self-reported and objective measures in the percentage of Canadian older adults who were classified as active. It was suggested that this discrepancy might be due to social desirability bias. The physical activity measures of KNHANES might, also, have the same measurement problems. There were no previous studies that assessed reliability or validity of KNHANES self-reported physical activity measure. Another issue regarding the weak association between physical activity and MetS may be the possibility that people who were diagnosed with diabetes, lipid abnormalities, or MetS may have already changed or increased their level of physical activity. Since both CHMS and KNHANES data were cross-sectional, it was difficult to capture a clear temporal sequence between physical activity and MetS.

Although the majority of the univariate measure of associations between MetS and biomedical, biosocial and psychosocial factors studied were similar between the Canadian and Korean sample, there were some meaningful differences. In both Canadian and Korean older adults, women were more likely to have MetS with the prevalence of individual components varying by gender (Appendix G-2). However, the magnitude of association between gender and MetS was stronger in Korean older adults. This led to a statistically significant between-country difference in the association between gender and MetS. The weak association between gender and MetS in CHMS (cycle 1) was also observed in a previous study by Riediger and Clara (2011), and the authors suggested that this may be due to low statistical power, arising from the relatively small sample size of the fasted sample of the CHMS (cycle 1). Compared with

Canadian men, Canadian women had a higher prevalence of abdominal obesity and low HDL-C, but a lower prevalence of hyperglycemia and hypertriglyceridemia. Previous Korean studies have consistently reported that Korean women aged 65 years and older had significantly higher prevalence of MetS than their male counterparts (Korean Ministry of Health and Welfare, 2006; Ahn et al., 2013). Compared with Korean men, Korean women had a higher prevalence of all components of MetS excluding hyperglycemia. This higher prevalence of individual components of MetS in Korean women compared with Korean men may be explained by a synergistic effect of their postmenopausal physiological changes and a genetic predisposition among Korean women. It has been proposed that decline in endogenous estrogen concentration after menopause is associated with increased abdominal fat and dysregulation of metabolic markers such as increased level of inflammatory coagulation markers (Regitz-Zagrosek et al., 2006; Yang & Kozloski, 2011). Further these physiological changes of postmenopausal women might be more prominent in Korean women than Canadian women due to the fact that Asians might have a greater amount of VAT or DSAT than Caucasians (Deurenberg et al., 1998; Lear et al., 2007; Sniderman et al., 2007). The lower SES of Korean women compared with that of Korean men may further increase their risk of MetS.

There was also a significant between-country difference in the association between marital status and MetS. In the Canadian sample, non-married participants were less likely to have MetS compared with married participants. By contrast, in the Korean sample, non-married participants were more likely to have MetS compared with married participants. However, once adjusting for gender, there was no relationship between marital status and MetS. That is, in the Korean sample being non-married did not protect against MetS. There is a lack of studies that have examined mechanisms underlying higher prevalence of MetS in married people versus non-married people, or vice versa. The between-country differences in the association between marital status and MetS may relate to differences such as levels of education and household income, cultural norms surrounding divorce and remarriage and gender inequalities (Burch, 1990; Leem, 1994; Wu, 2012).

Further, the direction and strength of the association between dietary pattern and Mets differed between the two countries. In the Canadian sample, as expected traditional and unhealthy patterns were positively associated with MetS when compared with the prudent diet (Williams et al., 2000; Lutsey et al., 2008; Heidemann et al., 2011), although these associations were not statistically significant. In the Korean sample, traditional and unhealthy patterns were inversely associated with MetS compared with the prudent diet, with the traditional diet showing a statistically significant inverse association with MetS. The weak association between dietary pattern and MetS in the Canadian participants may be due to several factors. One factor was that each derived dietary cluster contained both healthy and unhealthy food items. For example, the majority of food items in the prudent pattern were healthy; however, several food items with potentially adverse effects on diabetes or CVD such as shellfish, eggs, and fat salad dressings were also included (Connor & Lin, 1982; Li et al., 2013). Similarly, the traditional dietary pattern included frequent consumption of healthy food items such as brown bread, milk, and hot/cold cereal (McKeown et al., 2004; Elwood et al., 2006), but also moderately frequent consumption of unhealthy foods such as red meat and ice cream (Manzel et al., 2014). Further, given the dietary patterns were derived using the semiquantitative FFQs, there was no information on relative portions of healthy and unhealthy foods consumed and therefore energy consumed. Lutsey et al. (2008) also reported no statistically significant association between prudent pattern and incidence of MetS, and their prudent dietary pattern also showed a mixture of healthy (e.g., vegetables, fruits, and fishes) and an unhealthy food item such as high intake of red meat (i.e., poultry). Another issue that may explain the lack of statistically significant association between MetS and the derived dietary patterns might be inadequate statistical power due to the relatively small sample size. Further, given the cross-sectional nature of the CHMS data, participants who were diagnosed with diabetes, lipid abnormalities, and MetS may have already made healthy dietary changes, particularly given the overall sample was highly educated and economically advantaged. In their study of prevalence of MetS in Canadian aged 12 to 79 years, Setayeshgar et al. (2012) provided evidence of diet modification among those with chronic disease, in particular reduces consumption of dairy products, dietary fat, and sugar sweetened beverages.

Some of these factors might also have explained the findings in the Korean sample. A mixture of healthy and unhealthy food items was also observed in the prudent and unhealthy dietary patterns. This might have resulted in no statistically significant difference in prevalence of MetS between the prudent and unhealthy dietary pattern. Specifically, Korean participants with a prudent pattern frequently consumed not only healthy foods (vegetables, sea foods, bean, barley, and tea) but also unhealthy foods (beef and clam). Similarly, Korean participants with an unhealthy dietary pattern also frequently consumed fruits, some vegetables, yogurt, and soybean milk and consumed with moderate frequency vegetables, fishes, seaweeds, tofu, and tea. The frequent consumption of these unhealthy foods in the prudent pattern and healthy foods in the unhealthy pattern might mask their protective or adverse effect of the prudent and unhealthy dietary pattern on MetS. Again given the cross-sectional nature of the KNHANES data, participants who were diagnosed with diabetes, lipid abnormalities, and MetS may have already made healthy dietary changes. Further recent efforts of the Korean government and academics, for instance the national campaign to encourage reduction in salt and fat consumption and increase in vegetable consumption (Korean Society of Hypertension, 2013), might play a role in their healthy dietary changes.

By contrast, Korean older adults with a traditional dietary pattern were significantly less likely to have MetS compared with those with a prudent dietary pattern. Compared with the seven food items of the Canadian traditional dietary pattern, the Korean traditional dietary pattern included only two items, rice and Kimchi. Presumably, Korean participants who consumed a traditional pattern were likely to consume rice and Kimchi at every meal, and were less likely to consume other food items during their meals and snacks. This implied that Korean older adults with the traditional dietary pattern might be light (or low-caloric) eaters. Although their energy consumption could not be assessed in the present study, one previous Korean study (Song & Joung, 2012) showed that energy intake was relatively low in Koreans with a traditional dietary pattern. Specifically, using 24-hour recall data from the 2005 KNHANES, Song and Joung (2012) reported that Korean adults aged 20 years and older who consumed a traditional diet including only rice, Kimchi, and vegetables had the lowest daily energy intake (1,805 kcal) compared with two other dietary patterns, 'meat and alcohol' and Korean 'healthy' (2,450 kcal and 2,091 kcal, respectively), with the meat & alcohol group being more likely to have MetS compared with the traditional dietary pattern group (OR, 1.33, 95% CI, 1.01-1.75). However, there were concerns about the traditional diet due to the high consumption of carbohydrate. Song and Jeoung (2012) also reported that Koreans with a traditional dietary pattern including rice, Kimchi, and vegetables were more likely to consume carbohydrate than those with the other two dietary patterns. However, the authors did not find a significant association between rice intake and prevalence of MetS. One Chinese study (Shi et al., 2012) also reported non-significant association between high intake of rice and MetS. However, in both studies (Song & Joung, 2012; Shi et al., 2012), rice intake had significant positive association with low HDL-C concentration. As Frost et al. (1999) proposed, this might be due to the fact that consumption of rice with high GI would decrease HDL-C concentration by decreasing insulin sensitivity. However, in the present study there was no evidence to suggest a positive association between rice intake and HDL-C abnormality (Appendix Q). In fact, there was a trend towards participants with a traditional pattern being less likely to have HDL-C abnormalities, as well as being less likely to have abdominal obesity, high blood pressure, and hypertriglyceridemia. In both the present study and Song and Jeoung's (2012) study, the traditional pattern was significantly and inversely associated with hyperglycemia. The discrepancy in the association between rice intake and individual components of MetS between Korean studies (Song & Jeoung, 2012; the present study) and the Chinese study (Shi et al., 2012) might be due to difference in type of rice consumed. Since there was no question that asked about type of rice in the KNHANES food frequency questionnaire, it was hard to determine; however, there was a possibility that brown rice or rice with other grains or beans rather than white rice were more likely to be consumed in the Korean sample (Song et al., 2012; Ahn et al., 2013), whereas 99% of the Chinese sample in the Shi et al. (2012) study consumed white rice only.

Another concern about the Korean traditional dietary pattern may be the effect of high salt consumption through Kimchi intake on high blood pressure. In the present study, however, the high consumption of sodium was one of the features of the unhealthy dietary pattern. Further, additional data analysis (Appendix Q) showed that the traditional dietary pattern had an inverse association with high blood pressure although the association was not statistically significant. Previous studies (Park, 1995; Park et al., 2014) provided evidence of non-significant association between salt and Kimchi consumption, suggesting adverse effects of salt in Kimchi can be reduced in the fermentation process (Park, 1995; Park et al., 2014). In addition, it has been known that Kimchi has beneficial effects on obesity, diabetes, and metabolic abnormalities, since Kimchi is a good source of lactic acid bacteria, dietary fibers, and a diverse of vitamins such as vitamin A, C, and K (Park et al., 2014). In their cross-over intervention study, Kim et al. (2011) showed that the participants showed significantly decreased body fat, blood pressure, fasting glucose levels, and total cholesterol when consuming fermented Kimchi versus fresh Kimchi. Taken together, the Korean traditional dietary pattern seemed to be a low-caloric diet. Further, rice intake due to high intake of carbohydrate may cause hyperglycemia and low HDL-C, but when rice (especially brown rice) was consumed in combination with Kimchi, the adverse effects might be reduced.

A final between-country difference related to the univariate measure of association between smoking status and MetS. Among Canadian older adults, former and current smokers were more likely to have MetS compared with non-smokers. This finding was consistent with previous reports, indicating that current and former smokers had positive association with MetS (Matsuchita et al., 2011; Bradshaw et al., 2013). By contrast, among Korean older adults, former and current smokers were significantly less likely to have MetS. Further, additional analysis showed that the association between smoking and MetS was confounded by gender, indicating that most of the former and current smokers were men, and men were less likely to have MetS compared with women (Appendix K). Further analysis also revealed that current smoking was associated with hyperglycemia, hypertriglyceridemia, and reduced HDL-C, after adjusting for other factors (Appendix R).

Given the guiding conceptual framework of this thesis, that is, the Biopsychosocial Model of MetS (see Figure 1, Biopsychosocial model of MetS), the mediating effects of physical activity and dietatry pattern were tested. There was no evidence to suggest that physical activity or dietary pattern mediated the association between MetS and biomedical or biosocial factors in either Canada or Korea. Possible reasons for the negative findings may relate to the previously discussed concerns about both the measurement of physical activity and dietary intake. Measurement error may have led to an underestimate of the associations between physical activity, dietary pattern, biomedical or biosocial factors and MetS. The cross-sectional nature of the CHMS and KNHANES also made it difficult to establish a clear temporal sequence between biomedical, biosocial, physical activity, dietary pattern, and MetS. Further, the biopsychosocial model may oversimplify the complex interrelationships among the study variables across different populations. For instance, the moderation analysis indicated that physical activity and dietary pattern significantly moderated the association between gender and MetS in Canadian sample, but not in the Korean sample (Figures 12 and 15). Specifically, among Canadians who were physically inactive or consumed the unhealthy dietary pattern, women were more likely to have MetS than men. This gender difference was not observed among physically active participants or those with a prudent or traditional dietary pattern. It has been suggested that older women are more likely to be vulnerable to metabolic abnormalities than men due to changes in body fat distribution caused by menopause, leading to a higher prevalence of MetS (Regitz-Zagrosek et al., 2006; Yang & Kozloski, 2011). In the Korean sample, women had a higher prevalence of MetS than men regardless of level of physical activity and dietary pattern. However, physical activity significantly moderated the association between adequacy of household income and MetS in the Korean sample, but not in the Canadian sample (Figure 13). Specifically, among Koreans who were physically inactive, participants with low adequacy of household income were more likely to have MetS than those with the higher income adequacy. This finding was consistent with a previous finding reported by Paek et al. (2006) and may implicate that social advantage provides some protection against the impact of physical activity on MetS. In Canadian sample, there was no statistically significant evidence of physical activity moderating the relationship between household income adequacy and MetS, with small sample sizes leading to some instability in prevalence estimates across the various subgroups.

In the multivariate analyses, physical activity and dietary pattern, along with the other psychosocial, biomedical and biosocial factors were considered in the final model building process. These analyses were done separately for each country. In the Canadian sample, the final multivariate model included four variables. Adequacy of household income moderated the association between marital status and MetS, with the lower prevalence of MetS among non-married compared to married being confined to those with higher adequacy of household income. That is, the prevalence of MetS was similar in non-married and married participants with low income adequacy. Since there were a lack of studies that have examined interaction between marital status and household income on MetS, the results of the present study could not be compared with previous research. However, several studies have reported that married people were more likely to have MetS compared with non-married people, (Park et al. 2007; Bhaunshali et al., 2013), plus more likely to have cardiovascular risk factors such as obesity and hypertension (Fukuda, & Hiyoshi, 2013) and lower physical fitness (Ortega et al., 2010), although the results differed by genders. A possible explanation for these results was provided by Lindström (2009), who suggested that financial security may be an important factor that affects the association between marital status and self-reported health.

This is consistent with the results of the present study, where non-married older adults with higher levels of financial security may have more resources (e.g., leisure time, reduced family or work responsibilities), enabling them to be engaged in healthy lifestyles or to have social supports (informational or emotional) from social network ties and medical community (Goldman et al., 1995; Cornwell & Waite, 2012) that help to reduce prevalence of MetS.

In addition, the inverse association between alcohol consumption and MetS remained significant in the multivariate model. Evidence from physiological studies showed that ethanol increases HDL-C concentrations (Shimomura & Wakabayashi, 2013; Oliveira e Silva et al., 2000; Brinton, 2012), and previous observational studies (Wilsgaard & Jacobsen, 2007; Baik & Shin, 2008; Stoutenberg et al., 2013) also support these findings. Despite this evidence of a protective effect of alcohol consumption on MetS and/or HDL-C, researchers have warned of the adverse effect of heavy drinking, suggesting that heavy drinking could increase abnormalities in other components of MetS such as high blood pressure, hyperglycemia, and hypertriglyceridemia (Baik & Shin, 2008; Stoutenberg et al., 2013) and could increase risk of MetS and CVD, especially in obese individuals (Baik & Shin, 2008). For this reason, even light level of alcohol consumption should not be recommended for diabetic patients (Shimomura & Wakabayashi, 2013).

Finally, diagnosed depression or high levels of psychological distress was another factor that was significantly associated with MetS in the final multivariate model. The positive association between psychological distress and MetS has been observed in past studies (Pan et al., 2001; Räikkönen et al., 2007; Bove et al., 2010). Possible explanations for the high prevalence of MetS among people with high level of psychological distress include dysregulation of endocrine systems in response to psychological distress (Cowen, 2002; Holmes et al., 2010; Pompili et al., 2010; Lambert & Lambert, 2011) and increase in unhealthy lifestyle choices that might be related to psychological distress or medication-related changes in metabolic profile (Bonnet et al., 2005; Chokka et al., 2006). Physical activity and dietary pattern were not retained in the final model, possibly due to previously mentioned measurement issues, inadequate sample size, and unclear temporal sequence between diagnosis of MetS and physical activity or dietary pattern.

In the Korean sample six variables were retained in the final multivariate model. Consistent with other studies, prevalence of MetS was higher in Korean women than in men, but there was evidence of a significant interaction of gender with education. Gender difference in prevalence of MetS decreased as level of education increased. In fact, when comparing men and women with highest level of education, women had a lower prevalence of MetS than men. In contrast to women, a positive association between education and MetS was observed in men. This was not an unexpected finding when considering the Korean culture. In some Asian countries, especially Korea and Japan, workers (mainly men) often have social meetings, the so-called ‘Hoi Sik’ in Korea and ‘Enkai’ in Japan, after work with their colleagues to get rid of work stress or strengthen their sense of belonging. From a public health perspective, however, the benefits of this culture may not outweigh the detriments including heavy drinking and high fat foods. Yoon et al. (2006) found that Korean men with higher levels of education who were more likely to participate in ‘Hoi Sik’ often consumed a greater amount of energy and fat intake, compared with those with the lowest education. This led to a positive association between education and abdominal obesity among men, whereas Korean women with higher education showed the inverse association. Ikeda et al. (2009) also reported that Japanese men with higher social support that presumably arose from colleagues through participation in ‘Enkai’ had a higher prevalence of MetS than men with lower levels of social support, whereas a non-significant association between social support and MetS was observed in Japanese women. In this study the positive association between education and MetS observed in Korean men could potentially be explained by the Korean-specific cultural context.

Marital status also significantly moderated the association between comorbidity and MetS in the Korean sample. Non-married participants with comorbidity were more vulnerable to MetS compared with their married counterparts with comorbidity. This result suggests that in the presence of comorbidity, spousal support may reduce prevalence of MetS. There were no studies examining interrelationships among marital status, comorbidity, and MetS. However, earlier studies reported beneficial effects of spousal supports on chronic illness and caner survival or stage (Gallant et al., 2007; Wang et al., 2011). A spouse may encourage lifestyle changes such as smoking cessation, increase in physical activity or healthy diets and provide help with disease management such as monitoring the use of prescribed medications. For people with a chronic illness, having a spouse or partner may be a motivator to manage illness and prevent further complication.

In the multivariate model, the Korean traditional dietary pattern still had a significant inverse association with MetS. As discussed earlier, Korean older adults with a traditional dietary pattern might consume a lower level of energy intake than those with a prudent dietary pattern since the traditional pattern included only 2 food items that were frequently consumed, rice and Kimchi, and were characterized as a low-fat diet (Song & Joung, 2012). High intake of carbohydrate through high rice intake was expected to have increased risk of hyperglycemia and low HDL-C (Frost et al., 1999; Song & Joung, 2012; Shi et al., 2012; Song et al., 2012); however, the traditional dietary pattern of the present study showed an inverse association with all individual components of MetS, and the inverse association between traditional dietary pattern and hyperglycemia was statistically significant after adjusting for other covariates. This may be due to the fact that a majority of Korean adults consume rice with other grains or less refined rice. As reported by Ahn et al. (2013), only 23.6 % of Korean adults consumed white rice only, and the rest of the sample consumed rice with beans or other grains. High consumption of salt due to high intake of Kimchi in the traditional dietary pattern was expected to be problematic on increased risk of high BP or MetS. However, the traditional dietary pattern group did not have higher abnormalities of MetS compared with the prudent group, and the most frequent salt consumption was observed in the unhealthy dietary pattern group.

Finally, inactive Korean participants were more likely to have MetS compared with their active counterparts, although the association was not strong (adjusted OR, 1.15, 95% CI, 0.96-1.38). One possible reason for the weak association might be due to the use of a relatively low minimum cut-off for active group (approximately 495 MET-min/week). However, using a higher cut-off for active group than that of the present study (i.e., 600 to 2999 MET-min), Choi et al. (2013) also did not show a significant association with MetS and, only vigorous activity (i.e., at least 3,000 MET-min/week) was significantly associated with MetS in Korean older adults with mean age of 72.4 years. Sénéchal et al. (2012) also observed a significant association in vigorous active group (aged 50 years and older) only. It therefore seemed that only vigorous activities not moderate or light activities reduced prevalence of MetS, at least on the basis of findings from cross-sectional studies. However, a longitudinal study with 10-year follow-up (Laursen et al., 2012) reported that people (approximate mean age of 51 years) who had walking exercise with even average speed (i.e., a moderate level of activity) were significantly less likely to develop MetS than people in slow-speed walking group. This finding remained significant after controlling for other covariates and the duration of physical activity. Another longitudinal study (Stensvold et al., 2011) examined the effect of physical activity on all-cause and CVD mortality among Norwegian older adults aged 65 years and older with MetS at baseline. The results showed that older adults with even low level of physical activity (approximately 594 MET-min/week) had significantly lower all-cause and CVD mortalities compared with their inactive counterparts (HR, 0.75, 95% CI, 0.65-0.86; HR, 0.76, 95% CI, 0.62-0.93, respectively). Therefore findings from cross-sectional studies, especially using a self-reported physical activity questionnaire should be interpreted cautiously. As discussed earlier, there might be a possibility of misclassification error or social desirability bias due to the use of a self-administered questionnaire which is less valid than objective measures such as accelerometer (Colly et al., 2011; Clarke & Janssen, 2013). Another limitation of the use of a self-reported physical activity questionnaire for older adults may relate to inaccuracy of recall due to memory problems. This may underestimate the association between physical activity and MetS (Kowalski et al., 2012). Further, there was a possibility that some portion of the Korean sample had already increased their level of physical activity after diagnosis of MetS. Again this was hard to capture with a cross-sectional study design.

6.2 Strengths and Limitations

A major strength of this study was the use of fasted data from both the CHMS and KNHANES survey. This permitted the use of the same diagnostic criteria of MetS to estimate and compare prevalence of MetS (and its components) in Canadian and Korean adults aged 60 to 79 years. The diagnostic criteria were based on the Harmonizing definition, widely used by other recent population-based studies in MetS. This facilitated comparison across other studies. Using a theoretical model derived from the Biopsychosocial Model of Health (Hoffman & Driscoll, 2000), a wide range of factors potentially associated with MetS in older adults was examined in an attempt to better understand the structure of the pathways linking these factors and MetS. Where possible, the CHMS and KNHANES used comparable methods and measures to collect information on possible risk factors or correlates of MetS. For instance, dietary intake was assessed using FFQ in both surveys. The strength of the FFQ was that it asked about the respondent's usual intake of foods over the past year, minimizing the potential impact of recent dietary changes (Thompson & Subar, 2013). In addition, the use of dietary pattern analysis versus a single or a group of nutrients or foods analysis helped to appreciate how dietary patterns in each country were associated with MetS.

However, there were several limitations associated with the present study. The generalizability of the study findings at the national level is limited for several reasons. The response rate in the CHMS fasted sample was only 46.6%. A comparison of the fasted sample with the full sample on prevalence of hypertension, abdominal obesity, and obesity (measured BMI < $30kg/m^2$), as well as on mean and distribution of serum total cholesterol and serum high density lipoproteins, indicated no differences (Statistics Canada, 2010). In addition, a portion of Canadian individuals with diabetes were excluded in the fasted sample, potentially underestimating the prevalence of MetS (and individual components, especially hyperglycemia). It is also unclear whether there was a differential response rate in the fasted sample by age or socio-economic status. As a group, Canadian adults aged 60 to 79 years in the fasted sample were highly educated and economically advantaged. Further, participants were survivors of those Canadians born between 1928 and 1949 and therefore the findings may reflect unique cohort or period effects such as the Great Depression, World War II, and post-war growth. The average life expectancy for birth chorts of 1930, 1940, and 1950 was 61 years, 64.5 years, and 68.5 years, respectively (Statistics Canada, 2012). Similar sampling issues arose in the fasted subsample of the KNHANES; although the response rate appeared higher (overall response rate for the household questionnaire and MEC and for the nutrition survey was 74.5% and 81.8%, respectively). However, the average life expectancy for birth cohorts of 1940 and 1950 was only 48.7 years and 47.5 years (presumably influenced by the Korean War) (Acemoglu & Johnson, 2007).

A second limitation was the use of survey or cross-sectional data to test the Biopsychosocial Model of Health (Hoffman & Driscoll, 2000). Temporal interrelationships among the various explanatory variables could not be determined. Further, testing of mediating or moderating effects was suboptimal in a cross-sectional study due to the fact that a temporal sequence cannot be captured; however, findings of this study regarding the mediation and moderation analyses might be helpful to build a knowledge for future longitudinal or experimental studies and to identify subgroups of the population with elevated prevalence of MetS.

There are several issues regarding possible heterogeneity in data collection methods or study variables between CHMS and KNHANES data and in use of secondary data to measure study variables. First, there might be heterogeneity in clinical measures, especially blood pressure and blood specimens, between CHMS and KNHANES data due to the use of different measurement methods (i.e., automated versus manual device) and analytic methods including analyzing methods, facilities, and reagents. Second, the physical activity questions (PAQs) of the two surveys differed in terms of reference period (i.e., past 3 months in CHMS versus past week in KNHANES), the duration and frequency (i.e., over 15 minutes daily in CHMS versus over 30 minutes at least 5 days in KNHANES). Intensity of physical activities also might be different. For instance, the PAQ of CHMS included a wide range of intensity activities, whereas the PAQ of KNHANES focused on moderate intensity activities. This may have overestimated level of physically activity in Canadian participants and contributed to the observed weak association between physical activity and MetS in Canadian sample. However, when using another PAQ that measured intensity level, the association between physical activity and MetS was still weak. Third, due to differences in data collection methods (ATC codes versus disease codes) between CHMS and KHANES, several comorbidities known to be related with MetS (e.g., chronic kidney disease, non-alcohol fatty disease, PCOS, erectile dysfunction, male hypogonadism, and psoriasis) were not included in the analysis. The elimination of these conditions might have weakened the association between comorbidity and MetS in both samples.

Due to a lack of existing information, it was hard to assess whether the PAQs and food frequency questionnaires (FFQs) of both surveys had an acceptable validity or reliability. As previous studies pointed out (Colly et al., 2011; Clarke & Janssen, 2013), when using a self-reported PAQ, there was a possibility of overestimation of physically active people due to social desirability. This might result in the weak association between physical activity and MetS in the both Canadian and Korean older adults. Similar with the PAQs, data from the FFQs of the both surveys also might be biased by social desirability. In general, due to social desirability a self-administered FFQ may have under-reported or over-reported consumption of certain foods considered as unhealthy or healthy (Thompson & Subar, 2013). In addition, the present study assessed dietary patterns using the FFQs without information on portions of foods. This was done to facilitate comparability between surveys. Consequently, it was impossible to estimate the calories that respondents consumed, and the dietary patterns of both Canadian and Korean sample could not be adjusted by energy intake. Thus, the use of FFQs without information on portions of foods might limit the validity of the study results in terms of the association between dietary pattern and MetS. Further, it has been known that the a FFQ may be less validate than a 24-hour recall or dietary recall since the latter methods have more detailed information (Subar et al., 2003; Thompson & Subar, 2013). Nevertheless several researchers suggested when assessing diets of older adults, a 24-hour recall may be less valid than a FFQ, since short-term memory required for a 24-hour recall among older adults is often less accurate than their long-term memory required for completion of a FFQ (de Vries, et al., 2009; Thompson & Subar, 2013). An FFQ is also thought to be easy and cost-effective to administer in a large population (Thompson & Subar, 2013). Compared to a 24-hour recall, a FFQ was found to have a morederate level of reliability (r=0.6) (Liu et al., 2011). A potential limitation of dietary pattern analysis was that findings may not be generalizable to other populations or the same population over time since the dietary patterns are dependent on the studied population.

A final limitation was the relative small sample size of the Canadian fasted sample, as indicated by the wide confidence intervals around estimated univariate measures of associations, indicating low statistical power.

6.3 Potential Implications

This study has the potential to improve our understanding of the relationship between factors studied and MetS among both Canadian and Korean adults aged 60 to 79 years. Specifically, it was possible to examine the association between physical activity and dietary patterns and MetS across Canadian and Korean older adults and to explore why the association between MetS and a single factor like physical activity or diet may differ between countries. As shown in the moderating and multivariate analyses, the factors associated with MetS differed within the two countries, presumably, in part, due to differences in prevalence and patterns of background characteristics that arose from their unique genetic, historical, cultural, and societal context. For the same reason, there may be inconsistent findings regarding MetS and a single factor like physical activity or diet in the same population across time due to cohort or period influences

From a public health perspective, there is evidence to suggest that potentially modifiable factors such as physical activity and dietary intake influence the prevalence of MetS. In the Canadian sample, a high risk group for prevalence of MetS was women who were inactive and consumed the unhealthy dietary pattern. In the Korean sample, physical activity and the traditional diet were both associated with reduced prevalence of MetS. This evidence seems to support current public health strategies in both countries that promote physical activity and healthy eating. In the Canadian sample the results suggest that increased role responsibilities (i.e., being married versus non-married) were associated with MetS, although only among those with higher adequacy of household income. There was no difference in MetS among married and non-married in participants with low income adequacy. High levels of psychological distress was also associated with MetS. Together, these findings suggest that role demands and psychosocial stressors may influence engagement in physical activity or healthy eating. In the Korean sample, the findings related to gender, education, and MetS indicate that education is an important healthy public policy. Also, efforts by Korean companies to change their organizational culture related to after-work social meetings may help to reduce prevalence of MetS among Korean men with higher levels of education. Finally, 43% of the Korean sample fell in the lowest categories of household income adequacy, suggesting that income insecurity among older Korean adults is an important public health issue.

6.4 Future Research

Results of the present study identified several directions for future research, using data from the CHMS and KHANES. First, findings of the weak association between physical activity and MetS in both samples might be, in part, due to over-reporting of physical activity. Social desirability might be one reason for the over-reporting; however, construct validity of the self-reported PAQ would be another possible reason. To the author's knowledge, there was no study that tested measurement properties of the PAQ of CHMS (cycle 1) and KNHANES (cycle 4), such as reliability or validity. Thus, detailed information on the measurement properties of the PAQs especially for older adults may help to clarify the association between physical activity and MetS.

Second, the physical activity measure used in this study is not recommended for future research. The binary physical measure of the CHMS and the KNHANES was primarily used for the sake of comparability; however, these measures failed to take into account the intensity of each type of physical activity. This might have led to the weak association between physical activity and MetS in both countries. Additionally, binary measures of physical activity (i.e., did not participate versus participated or inactive versus active) are limited in terms of establishing public health guidelines or interventions, since they do not provide information on how much and type of physical activity that would be beneficial.

Third, future research should also try to examine gender-specific dietary patterns. Due to complexity of data analysis, the present study did not derive gender-specific patterns. As suggested by previous studies (Wirfält & Jeffery, 1997; Newby & Tucker, 2004), dietary patterns may differ by gender, since there may be difference in eating behaviours between women and men. In terms of dietary pattern analysis, due to unavailability of data (i.e., portions of foods consumed or a 24-hour recall), the dietary patterns retrieved through the FFQs of the both surveys could not be adjusted by energy intake. Since dietary factor solutions may be affected by energy adjustment (Newby & Tucker, 2004), future research should examine how energy adjustment affects the Korean dietary patterns derived in this study. This could be done using KNHANES 24-hour recall data. The derived Canadian dietary patterns could also be compared with those from other population-based datasets such as the 24-hour recall data of the CCHS (cycle 2.2), although this would not be a direct comparison.

Fourth, weak associations between some study variables and MetS or point estimates with wide confidence intervals were observed in CHMS (cycle 1) data. This might be due to the relatively small size arising from the low participation rate of the fasted sample (46.3%). Thus, future research should examine the association between study variables and MetS using a large Canadian sample. This could be done by using the combined dataset of the CHMS cycles 1 and 2.

Further, the results raised questions about the appropriateness of the underlying conceptual framework of the proposed biopsychosocial model of MetS (Figure 1). This framework assumed a unidirectional relationship between biomedical and biosocial factors and MetS. For instance, comorbidity increased likelihood of MetS. However, especially in a sample of older adults, MetS might have led to observed comorbidities, specifically CVD and diabetes. In this thesis, the possibility of a bidirectional relationship between MetS and biomedical and bisosocial factors was not considered in either the design or analyses. Further, there was no evidence that either physical activity or dietary pattern mediated the relationship, although the mediating influences of smoking, alcohol consumption, psychological distress, and sleep duration were not tested.

Lastly, future research should include population-based longitudinal studies to establish a causal relationship between physical activity (and dietary pattern) and MetS among older adults. Changes in physical activity and/or dietary pattern may have occurred among people who were already diagnosed with MetS, T2DM, or lipid abnormalities. However, it was impossible to capture these lifestyle modifications in a cross-sectional study, and this may mask a true association or weaken the association between these factors and MetS.

7.0 CONCLUSION

The present study found that MetS was a significant public health problem in both Canadian and Korean adults aged 60 to 79 years, with Korean older adults having a significantly higher prevalence of MetS including hyperglycemia, hypertriglyceridemia, and HDL-C abnormality, despite lower abdominal obesity, compared with Canadian older adults. Findings of the present study also suggested that the prevalence and interrelationships among factors significantly associated with MetS differed between countries. This difference likely reflects the distinct racial/ethnic, historical, cultural, or societal background of each country. This cross-national comparison study therefore enabled us to gain a deeper understanding of possible underlying mechanisms regarding MetS. Further, the present study was able to identify subgroups within each population that had an increased vulnerability to MetS. This may, in turn, contribute to the development of effective interventions and health policies to prevent or manage MetS.

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Appendix A. Content of household questionnaire, physical measures (CHMS and KNHANES), and nutrition survey (KNHANES)

	Household Questionnaire Modules		Physical Measures		Nutrition Survey Modules
Theme area	CHMS	KNHANES	CHMS	KNHANES	KNHANES
1. Socio-economic information	Socio-demographic characteristics, education, labour force activity, income	Socio-demographic characteristics, education and income	Anthropometry - standing height - sitting height - weight - waist circumference - hip circumference - skinfolds	Anthropometry - height - weight - waist circumference	Food intake - information on meals - name, code, total amounts of foods and intake - information on food-ingredients
2. Health status	General health, sleep, height and weight, weight change, Health Utility Index, chronic conditions, hepatitis, family medical history, oral health, phlegm, pregnancy, birth information, breast-feeding information	Chronic conditions, activity limitations and quality of life, injuries, weight and obesity control, oral health, mental health, women's health	Medical check-up - blood pressure - resting heart rate - spirometry - oral health exam	Medical check-up - blood pressure - resting heart rate - spirometry - chest X-ray - ophthalmic exam - otolaryngologic exam - bone mineral densitometry - body fat screening - osteoarthritis - family medical history - oral health exam	Food intake pattern - meal skipping - eating out - family meals Nutrition knowledge - nutritional facts label - nutrition education and counselling
3. Medical use	Medications, other health products and herbal remedies	Medications, vaccination, and medical check-up			Nutrition supplements - use of nutrition supplements - information on nutrition supplements used
4. Health behaviours	Physical activities, sedentary activities, smoking, alcohol use, illicit drug use, sexual behaviour, maternal breast-feeding, strengths and difficulties	Physical activity, smoking, alcohol use, accident prevention	Blood & Urine sample - storage of blood & urine - storage of DNA	Blood & Urine sample	Food security - food assistant programs - food security Breast-feeding - birth weight - breast-feeding - information on infant formula - supplemental foods for infants
5. Environmental factors	Exposure to second-hand smoke, sun exposure, housing characteristics, grooming product use	Working environment, exposure to second-hand smoke	Physical fitness - cardiovascular fitness - hand group strength - partial curl-ups - sit and reach		
6. Nutrition and food	FFQ[a]: 5 food groups & 37 items including salt use - meats, fish,nuts/grains,fruits, vegetables/milk,dairy products/soft drinks,water/ dietary fat	FFQ: 11 food groups & 63 items - grains, beans & root vegetables, meat & eggs, fish, vegetable, seaweed, fruit, milk and dairy products, soft drink, alcohol, tea & coffee	Physical activity - accelerometry		

[a] Food frequency questionnaire

Appendix B. Components of the harmonizing definition of metabolic syndrome (MetS) and their operational definition

Components of MetS	CMHS content code	Presence of metabolic Abnormality	KNHANES content code	Presence of metabolic Abnormality
Waist circumference	HWMD14IN	≥ 102 cm (M) ≥ 88 cm (W)	HE_wc	≥ 90 cm (M) ≥ 80 cm (W)
Blood pressure	BPMDPBPS BPMDPBPD	SBP ≥ 130 mmHg DBP ≥ 85 mmHg	HE_sbp (07) HE_dbp (07) HE_sbp_tr (08, 09) HE_dbp_tr (08,09)	SBP ≥ 130 mmHg DBP ≥ 85 mmHg
or medication use	ATC_101A ~ ATC_115A	ATC codes[a]: All C02, All C03, C04AA02, C04AB01, All C07, All C08, All C09	DI1_2	everyday, ≥ 20 days/month, 15 days/month, or < 15 days/month
or diagnosed	CCC_31	Yes	DI1-dg	Yes
Fasting plasma glucose	LAB_GLUP	≥ 5.6 mmol/L	HE_glu	≥ 5.6 mmol/L
or medication use	ATC_101A ~ ATC_115A	All A10	DE1_32	Yes
or diagnosed	CCC_51	Yes	DE1_dg	Yes
or insulin injection	N/A	N/A	DE1_31	Yes
Triglycerides	LAB_TRIG	≥ 1.7 mmol/L (150 mg/dL)	HE_TG	≥ 1.7 mmol/L
or medication use	ATC_101A ~ ATC_115A	ATC codes: C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02, C10AX06	DI2_2	everyday, ≥ 20 days/month, 15 days/month, or < 15 days/month
HDL cholesterol	LAB_HDL	< 1.0 mmol/L (40 mg/dL) (M) < 1.3 mmol/L (50 mg/dL) (W)	HE_HDL_tr	< 1.0 mmol/L (M) < 1.3 mmol/L (W)
or medication use	ATC_101A ~ ATC_115A	ATC codes: C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02	DI2_2	everyday, ≥ 20 days/m, 15 days/month, or < 15 days/month

[a] Codes of the Anatomical Therapeutic Chemical (ATC) classification system (2012); M (Men); W (Women); N/A: not available

Appendix C. Interview questions and response options for biomedical, biosocial, and psychosocial variables

		CHMS (cycle 1)			KNHANES (cycle 4)		
Domain	Variable	Code	Question	Response	Code	Question	Response
Biomedical	Age	DHH_AGE	Respondent's age at household interview	Continuous	age	Respondent's age at health interview	Continuous
	Comorbidity		We are interest in "long-term conditions" which are expected to last or have already lasted 6 months or more and that have been diagnosed by a health professional. Do you have_?	1: yes 2: no		Have you been diagnosed with the following health conditions by a health professional?	1: yes 2: no (have not been diagnosed yet) 8: no (do not have the condition)
		CCC_Q11	Asthma		DJ4_dg	Asthma	
		CCC_Q22	Arthritis or rheumatism (excluding fibromyalgia)		DM3_dg	Rheumatoid arthritis	
		CCC_Q24	Back problem (excluding fibromyalgia and arthritis)		DM6_dg	Back problem	
		CCC_Q43	Emphysema		DJ7_dg	Bronchiectasis	
		CCC_Q45	COPD		DJ5_dg	COPD	
		CCC_Q61	Heart disease		DI5_dg	Myocardial infarction	
		CCC_Q81	The effects of a stroke		DI3_dg	The effects of a stroke	
		HUI_07	Hearing problem		LQ4_13	Hearing problem	
		Coded based on the ATC codes[a]	Cataract		DH2_dg	Cataract	
			Glaucoma		DH3_dg	Glaucoma	
			Upper gastrointestinal disease		DK2_dg	Ulcer	
			Peripheral vascular disease		E11.50[a]	Peripheral vascular disease	
			Neurological disease (multiple sclerosis or Parkinson's)		G35[a]	Multiple sclerosis	
					G20[a]	Parkinson's disease	
	-	CCC_Q71	Cancer		DC1_dg	Gastric cancer	
		CCC_Q74A	Breast cancer		DC2_dg	Liver cancer	
		CCC_Q74B	Colorectal cancer		DC3_dg	Colorectal cancer	
		CCC_Q74D	Skin cancer		DC4_dg	Breast cancer	
		CCC_Q74E	Other types of cancer		DC5_dg	Cervical cancer	
					DC6_dg	Lung cancer	
					DC11_dg	Other types of cancer	
		Coded based on the ATC codes[a]	Non-alcohol fatty liver disease		K76.0[a]	Non-alcohol fatty liver disease	
			Chronic kidney disease		DN1_dg	Chronic kidney disease	
			Polycystic ovarian syndrome		E28.2[a]	Polycystic ovarian syndrome	
			Erectile dysfunction		E11.42[a]	Erectile dysfunction	
			Male hypogonadism		E23.0[a]	Male dysfunction	
			Psoriasis		L40	Psoriasis	

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Appendix C. Interview questions and response options for biomedical, biosocial, and psychosocial variables – continued

		CHMS			KNHANES		
Domain	Variable	Code	Question	Response	Code	Question	Response
Biosocial	Gender	DHH_SEX	Participant's gender	1: male, 2: female	sex	Participant's gender	1: male, 2: female
	Education	EDUDR04	The highest level of education acquired by the respondent	1: less than secondary school graduation 2: secondary school graduation 3: some post-secondary school graduation 4: post-secondary school graduation	edu	The highest level of education acquired by the respondent	1: less than elementary school and elementary school graduation 2: middle school graduation 3: high school graduation 4: college or university graduation or higher
	Income	INCDDIA4	Income adequacy on the basis of total household income and the number of individuals in the household	1: lowest 2: lower middle 3: upper middle 4: highest	ho-incm	Income adequacy on the basis of total household income and the number of individuals in the household	1: lowest 2: lower middle 3: upper middle 4: highest
	Marital status	DHH_MS	Marital status at household interview	1: married 2: common-law 3: widowed 4: separated 5: divorced 6: single, never-married	marri_2	Marital status at health interview	1: married or common-law 2: separated 3: widowed 4: divorced 8: single, never-married
Psychosocial	Physical activity	PACFD	Participant in daily physical activity lasting over 15 minutes	1: participate 2: do not participate	pa_mid pa_walk	Participant in moderate physical activities or walking for ≥ 30 minutes/day, at least 5 days/week	1: do not participate 2: participate
	Dietary pattern		The number of times per year the respondent ate	Continuous		The number of times the respondent ate	0: not at all 1: 6-11 times/year 2: once a month
		MFCD11Y	Red meat		F_BEEF	Beef	3: 2-3 times/month
		MFCD12Y	Liver		F_CHICK	Poultry	4: once a week
		MFCD13Y	Other organ meats		F_PORK	Pork	5: 2-3 times/week
		MFCD14Y	Beef or pork hot dogs		F_HAM	Ham (bacon, sausage)	6: 4-6 times/week
		MFCD15Y	Sausage or bacon		F_EGG	Eggs and eggs dishes	7: one time/day
		MFCD19Y	Eggs and egg dishes		F_MACK	Mackerel	8: twice/day
		MFCD16Y	Salt water fish		F_TUNA	Tuna	9: three times/day
		MFCD17Y	Fresh water fish		F_YFISH	Croaker	
		MFCD18Y	Shellfish		F_POLL	Pollack	

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Appendix C. Interview questions and response options for biomedical, biosocial, and psychosocial variables– continued

		CHMS			KNHANES		
Domain	Variable	Code	Question	Response	Code	Question	Response
Psychosocial	Dietary pattern			Continuous	F_ANCH	Anchovy	0: not at all
					F_FPASTE	Fish cake	1: 6-11 times/year
					F_SQUID	Squid	2: once a month
					F_CLAM	Shellfish	3: 2-3 times/month
					F_SFISH	Salted fish	4: once a week
		GFVD11Y	Hot or cold cereal		F_RICE	Rice	5: 2-3 times/week
		GFVD12Y	Brown bread		F_BARLEY	Multigrains	6: 4-6 times/week
		GFVD13Y	White bread		F_INSTND	Instant noodle	7: one time/day
		GFVD14Y	Any kind of pasta		F_NOODLE	Noodle	8: twice/day
		GFVD15Y	Any kind of rice		F_BREAD	Bread	9: three times/day
		GFVD16Y	Instant, seasoned or wild rice		F_RCAKE	Rice cake	
		GFVD17Y	Any kinds of fruits (fresh, frozen, canned)		F_CRACK	Crackers	
					F_TANG	Tangerine	
					F_PERS	Persimmon	
					F_PEAR	Pear	
					F_WMELON	Water melon	
					F_MMELON	Oriental melon	
					F_STRAW	Strawberry	
					F_GRAPE	Grapes	
					F_PEACH	Peach	
					F_APPLE	Apple	
					F_BANANA	Banana	
					F_CITRUS	Orange	
		GFVD18Y	Tomato or tomato sauce		F_KCABB	Korean cabbage	
		GFVD19Y	Lettuce or green leafy salad		F_RADISH	Radish	
		GFVD20Y	Spinach, mustard greens or collards		F_RD_LV	Radish leaves	
		GFVD22Y	Other potatoes		F_SPROUT	Bean sprout	
		GFVD21Y	French/home fries/hash brown potatoes		F_SPIN	Spinach	
		GFVD23Y	All other types of vegetables		F_CUCUM	Cucumber	
					F_PEPPER	Hot pepper	
					F_CARROT	Carrot	
					F_PUMP	Squash	
					F_CABB	Cabbage	

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Appendix C. Interview questions and response options for biomedical, biosocial, and psychosocial variables – continued

			CHMS			KNHANES	
Domain	Variable	Code	Question	Response	Code	Question	Response
Psychosocial	Dietary Pattern	MFCD20Y	Beans	Continuous	F_TOMATO	Tomato	0: not at all
		MFCD21Y	Nuts		F_POTATO	Potato	1: 6-11 times/year
		MDCD11Y	Milk		F_SWPOT	Sweet potato	2: once a month
		MDCD12Y	Cheese		F_MUSH	Mushroom	3: 2-3 times/month
		MDCD14	Yogurt		F_SEAWD	Seaweeds	4: once a week
		MDCD15Y	Ice cream		F_LAVER	Laver	5: 2-3 times/week
		WSDD11/12/13/14/15/16/21Y	Regular soft /diet soft/sport drinks/ fruit/vegetable juices/fruit flavoured drinks/water		F_BN_CD	Tofu	6: 4-6 times/week
					F_BEAN	Legumes	7: one time/day
					F_BN_MLK	Soybean milk	8: twice/day
					F_MILK	Milk	9: three times/day
					F_YOGURT	Yogurt	
					F_ICECM	Ice cream	
					F_SODA	Soft drink	
					F_COFFEE	Coffee	
					F_TEA	Tea	
		DFCD11/12Y	Fat salad dressing/ Fat potato, tortilla, corn chips		F_FRIED	Fried foods	
					F_PIZZA	Pizza	
					F_HAMBER	Hamburger	
	Smoking	SMKDSTY	Type of smoker	1: daily 2:occasional(former daily) 3: always an occasional 4: former daily 5: former occasional 6: never smoked	BS3_1	Type of smoker	1: current 2: former 3: never smoked
	Alcohol consumption	ALC_11 ALC_12 ALC_17	Drank alcohol - past 12 months Frequency of drinking alcohol Ever had a drink	1: regular 2: occasional 3: former 4: never drank	BD1_11	Frequency of drinking in the past year	1: never drank in the past one year 2: < one time/ month 3: once/month 4: 2-4 times/month 5: 2-3 times/week 6: ≥ 4 times/week 8: never drank

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Appendix C. Interview questions and response options for biomedical, biosocial, and psychosocial variables – continued

		CHMS			KNHANES		
Domain	Variable	Code	Question	Response	Code	Question	Response
	Psychological distress - Depression	CCC_83	"long-term conditions" which are expected to last or have already lasted 6 months or more and that have been diagnosed by a health professional	1: yes 2: no	DF2_dg	Diagnosed with depression by a health professional	1: yes 2: no (have not been diagnosed yet) 8: no (do not have depression)
	-Perceived stress	GEN_15	Thinking about the amount of stress in your life. Would you say that most days are:	1: not at all stressful 2: not very stressful 3: a bit stressful 4:quite a bit stressful 5: extremely stressful	BP1	Degree of perceived stress in daily life	1: extremely stressful 2: quite a bit stressful 3: not very stressful 4: not at all stressful
	Sleep	SLP_11	How many hours do you usually spend sleeping in a 24 hour period, excluding time spent resting?	Continuous	BP8	The average hours of sleep in a 24 hour period	Continuous

[a] The codes of the Anatomical Therapeutic Chemical (ATC) classification system (WHO, 2012)
[b] The Korean Standard Classification of Disease and Causes of Death (5th) codes (Statistics Korea, 2008)

Appendix D. Prevalence of comorbidity

Comorbidity	Source of data		Prevalence %	
	CHMS	KNHANES	CHMS	KNHANES
Asthma/Emphysema (CHMS)/Bronchitis (KNHANES)	Health questionnaire,	Health questionnaire	8.6	6.1
Arthritis/rheumatism		condition list	40.3	30.6
Back problem			27.4	26.2
Chronic obstructive pulmonary disease (COPD)			3.9	1.4
Heart disease (angina, myocardial infarction)			13.5	2.0
Stroke			3.7	4.9
Hearing problem			4.8	2.5
Cataract or Glaucoma	ATC codes[a]	Health condition list	3.4	26.2
Upper gastrointestinal disease (ulcer, hernia, reflux)	ATC codes		15.8	8.26
Peripheral vascular disease	ATC codes	KCD codes[b]	8.2	3.7
Neurological disease (multiple sclerosis or Parkinson's disease)	ATC codes	KCD codes	0	0.03
Cancer	Health condition list	Health condition list	10.3	5.2
Chronic kidney disease	ATC codes	Health condition list	0	0.47
Non-alcohol fatty liver disease	ATC codes	KCD codes	0	0.13
PCOS[c], erectile dysfunction, male hypogonadism	ATC codes	KCD codes	11.7	0.4
Psoriasis	ATC codes	KCD codes	0.1	1.3

[a] the Anatomical Therapeutic Chemical classification system to recode the Drug Identification Numbers (DIN) reported by the CHMS participants

[b] the Korean Standard Classification of Disease and Causes of Death (5th) codes used to recode the health conditions reported by the KNHANES participants

[c] Polycystic ovary syndrome

Bold: health conditions used in the final analysis

Appendix E. Comparison of biomedical and biosocial factors between participants with and without missing data on adequacy of household income

Biomedical/ Biosocial factors	Category	Canada					Korea				
		Non-missing group		Missing group			Non-missing group		Missing group		
		Mean or weighted n	SE or %	Mean or weighted n	SE or %	Between group-diff.	Mean or weighted n	SE or %	Mean or weighted n	SE or %	Between-group diff.
Age	-	67.2	0.27	69.3	1.41	*NS*	67.9	0.12	68.4	0.78	*NS*
Comorbidity	Absence	1,612,365	37.0	159,160	35.7	*NS*	2,024,141	40.3	51,347	47.8	*NS*
	Having 1	1,303,117	28.7	161,006	31.0		1,669,131	35.2	36,404	30.5	
	Having 2	984,790	22.8	145,647	23.8		810,151	18.1	19,735	15.9	
	Having 3+	487,782	11.5	32,172	9.5		282,954	6.4	7,618	5.8	
Gender	Female	2,286,668	48.6	277,728	57.1	*NS*	2,735,667	57.4	82,690	69.6	*NS*
	Male	2,101,386	51.4	220,257	42.9		2,050,710	42.6	32,415	30.4	
Education	< secondary	1,112,355	21.5	160,842	31.0	*NS*	2,999,443	66.2	73,609	66.7	
	Secondary	706,516	17.7	117,185	16.7		1,419,080	27.1	33,176	27.5	
	Post-secondary	2,569,184	60.8	219,959	52.3		367,854	6.7	8,320	5.8	
Marital status	Married	3,087,068	60.8	382,576	71.4	*NS*	3,448,825	71.9	70,242	66.7	-
	Separated, widowed, divorced	1,079,397	32.3	108,261	23.8		1,303,280	27.5	44,862	33.3	
	Never-married	221,589	6.9	7,149	4.8		34,273	0.6	0	0	

NS: Not significant, *p*>.05

− : No test can be done due to frequency of zero

Appendix F-1. Imputation method for missing value in Canadian older adults aged 60 to 79 years

Variable	Don't know or Not stated (%)	Imputation method
Waist circumference	0.54	Imputed based on relationship with BMI or individual components of MetS
Diagnosed hypertension	0.54	Imputed with the value of 2 (i.e., not having) after checking their lab measures
Glucose	0.54	Imputed with the average value after checking their reported diagnosed diabetes and medication use
Triglyceride	0.18	Imputed with the average value after checking their reported diagnosed lipid abnormality and medication use
Diagnosed lipid abnormality	1.10	Imputed with the value of 2 2 (i.e., not having) after checking their lab measures
Asthma	0.18	Imputed with the value of 2 (i.e., not having)
Arthritis or rheumatism	0.36	Imputed with the value of 2 (i.e., not having)
Emphysema	0.36	Imputed with the value of 2 (i.e., not having)
COPD	0.91	Imputed with the value of 2 (i.e., not having)
Heart disease	0.36	Imputed with the value of 2 (i.e., not having)
The effects of stroke	0.18	Imputed with the value of 2 (i.e., not having)
Hearing problem	2.36	Imputed with the value of 2 (i.e., not having)
Education	1.09	Imputed based on relationship with household income and gender
Household income	7.62	Multiple imputation
Liver intake	0.18	Imputed based on relationship with consumption of other foods – meats, other organ meats, hot dogs, eggs
Other organ meats intake	0.18	Imputed based on relationship with consumption of other foods – meats, liver, hot dogs, eggs
Fresh water fish intake	0.36	Imputed based on relationship with consumption of other foods – salt water fish, shell fish
Shellfish intake	0.18	Imputed based on relationship with consumption of other foods – salt water fish, fresh water fish
Instant, seasoned or wild rice intake	8.17	Imputed the value of 0 (do not eat) since these missing cases were from the respondents who answered "don't eat rice".
Other vegetables intake	0.18	Imputed based on relationship with consumption of other foods – tomatoes, lettuce/green leafy, potatoes
Urine sodium	1.09	Imputed based on relationship with other surrogates such as salt added to food, table salt added cooking or preparing foods
Smoking	0.73	Imputed based on relationship with other smoking-related questions such as current smoking type.
Diagnosed depression	0.18	Imputed with the value of 2 (i.e., not having)

Appendix F-2. Imputation method for missing value in Korean older adults aged 60 to 79 years

Variable	Missing %	Don't know or Not stated %	Imputation method
Medication use-lipid abnormality	-	0.21	Imputed with the value of 2 (i.e., not having) after checking their lab measures
Education	0.4	-	Imputed based on relationship with responses on other questions such as household income and gender
Household income	2.48	-	Multiple imputation
Marital status	-	0.25	Imputed based on relationship with responses on other questions such as gender and household income
Physical activity-moderate intensity	0.34	-	Imputed based on relationship with responses on other physical activity-related questions
Physical activity-walking	0.06	0.15	Imputed based on relationship with responses on other physical activity-related questions
Hamburger intake	-	0.06	Imputed based on relationship with other foods intake such as pizza
Croaker intake	-	0.09	Imputed based on relationship with other types of fish intake
Pollack intake	-	0.03	Imputed based on relationship with other types of fish intake
Squid intake	-	0.03	Imputed based on relationship with other types of fish intake
Multigrains intake	-	0.06	Imputed based on relationship with rice intake
Instant noodle intake	-	0.03	
Tangerine intake	-	0.03	
Persimmon intake	-	0.03	
Pear intake	-	0.03	
Water melon intake	-	0.03	
Oriental melon intake	-	0.03	
Strawberry intake	-	0.03	* Deleted the case (the same person) who did not answer on multiple questions
Grapes intake	-	0.03	
Peach intake	-	0.03	
Apple intake	-	0.03	
Banana intake	-	0.03	
Orange intake	-	0.03	
Korean cabbage intake	-	0.03	
Radish leaves intake	-	0.03	
Bean sprout intake	-	0.03	
Radish intake	-	0.03	

Continued on next page

Appendix F-2. Imputation method for missing value in Korean older adults aged 60 to 79 years - continued

Variable	Missing %	Don't know or Not stated %	Imputation method
Spinach intake	-	0.03	* Deleted the case (the same person) who did not answer on multiple questions
Cucumber intake	-	0.03	
Hot pepper intake	-	0.03	
Carrot intake	-	0.03	
Squash intake	-	0.15	Imputed based on relationship with other types of fish intake
Cabbage intake	-	0.03	Deleted the case (the same person) who did not answer on multiple questions.
Tomato intake	-	0.03	
Legumes intake	-	0.06	Imputed based on relationship with other foods intake such as multigrains, soybean milk, and tofu.
Milk intake	-	0.03	* Deleted the case (the same person) who did not answer on multiple questions
Yogurt intake	-	0.03	
Fried foods intake	-	0.06	Imputed based on relationship with other foods intake such as pizza or soda
Soda intake	-	0.06	Imputed based on relationship with other foods such as hamburger and pizza
Smoking	0.06	0.03	Imputed based on relationship with responses on other smoking-related question
Alcohol consumption	0.06	0.09	Imputed based on relationship with responses on other alcohol consumption-related question
Perceived stress	0.06	0.15	Imputed based on relationship with responses on other stress-related questions
Sleep	0.06	0.15	Imputed based on relationship with responses on other sleep-related questions

Appendix G-1. Prevalence of MetS and the number of metabolic abnormalities

			Total		Women		Men	
			Canada	Korea	Canada	Korea	Canada	Korea
Prevalence of metabolic syndrome		Weighted N	2,054,101	2,036,582	1,094,310	1,308,653	959,791	727,929
		%	42.0	52.2*	42.7	60.5***	41.3	41.9
Number of abnormalities	0	Weighted N	529,826	243,099	318,504	84,087	211,322	159,012
		%	10.8	6.2	12.4	3.9	9.1	9.2
	1	Weighted N	1,153,021	688,572	607,868	295,621	545,153	392,951
		%	23.6	17.7	23.7	13.7	23.5	22.6
	2	Weighted N	1,149,091	931,336	543,713	475,974	605,378	455,361
		%	23.5	23.9	21.2	22.0	26.1	26.2
	3	Weighted N	1,153,834	878,315	619,595	507,614	534,239	370,702
		%	23.6	22.5	24.2	23.5	23.0	21.4
	4	Weighted N	696,810	794,107	363,548	517,344	333,263	276,763
		%	14.3	20.4	14.2	23.9	14.4	16.0
	5	Weighted N	203,457	364,160	111,167	283,695	92,290	80,465
		%	4.2	9.3	4.3	13.1	4.0	4.6

*p<.05 **p<.01 *** p<.001: significant difference between the two countries

Appendix G-2. Mean values of individual components of MetS

			Mean (SE)					
		Weighted N	Waist circumference	Systolic blood pressure	Diastolic blood pressure	Fasting plasma glucose	Triglyceride	High density lipoprotein cholesterol
Total								
	Canada	4,886,039	38.1 (0.25)	124.6 (0.67)	72.4 (0.54)	5.5 (0.07)	1.6 (0.05)	1.4 (0.03)
	Korea	3,899,589	33.3 (0.09)***	127.3 (0.45)**	77.0 (0.26)***	5.8 (0.03)***	1.7 (0.03)	1.2 (0.01)***
Women								
	Canada	2,564,396	36.4 (0.47)	126.6 (1.16)	71.7 (0.74)	5.3 (0.07)	1.5 (0.09)	1.5 (0.04)
	Korea	2,164,334	33.1 (0.12)***	127.7 (0.52)	76.7 (0.29)***	5.8 (0.04)***	1.6 (0.03)	1.2 (0.01)***
Men								
	Canada	2,321,644	40.0 (0.36)	122.4 (0.93)	73.2 (0.65)	5.7 (0.09)	1.6 (0.07)	1.2 (0.03)
	Korea	1,735,254	33.6 (0.12)***	126.8 (0.61)**	77.3(0.36)***	5.9 (0.05)	1.7 (0.04)	1.2 (0.01)

*p<.05 **p<.01 *** p<.001: significant difference between the two countries

Appendix G-3. Prevalence of individual components of MetS according to 'Harmonizing Definition'

	Abdominal obesity		High blood pressure		Hyperglycemia		Hypertriglyceridemia		Low HDL-C	
	Weighted N	%	Weighted N	%	Weighted N	%	Weighted N	%	Weighted N	%
Total										
Canada	2,560,116	52.4	3,256,430	66.7	1,634,732	33.5	1,646,281	33.7	1,605,524	32.9
Korea	2,002,035	51.3	2,497,184	64.0	1,823,117	46.7***	1,553,996	39.9**	2,307,084	59.2***
Women										
Canada	1,500,470	58.5	1,736,391	67.7	663,285	25.9	759,336	29.6	897,769	35.0
Korea	1,466,214	67.7*	1,406,585	65.0	960,162	44.4***	877,787	40.6*	1,547,513	71.5***
Men										
Canada	1,059,645	41.3	1,520,039	65.5	971,446	41.8	886,945	38.2	707,756	30.5
Korea	535,820	30.9**	1,090,599	62.9	862,955*	49.7*	676,208	39.0	759,572	43.8**

* p<.05 ** p<.01 *** p<.001: significant difference between the two countries

Appendix H-1. Factor loading matrix for the seven dietary patterns of Canadian older adults aged 60 to 79 years

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Fries/hash brown potatoes	**0.48**	.	.	.	.	.	.
Hot dogs	**0.38**	.	.	.	.	.	.
Fat chips	**0.34**	.	.	.	.	.	.
Sausage/bacon	**0.29**	.	-0.16	.	.	.	0.15
Instant/seasoned/wild rice	**0.27**	.	.	.	.	.	.
Diet soft drinks	**0.23**	.	.	.	.	.	.
Sodium	**0.18**	.	.	.	.	.	.
Spinach/mustard greens/collards	-0.23	**0.31**	.	0.20	.	0.21	-0.20
Yogurt	**-0.28**	0.19	.	.	.	.	.
Fruit	**-0.29**	0.27	.	.	0.22	.	.
Other types vegetables	**-0.34**	0.32	0.19	.	.	.	.
Salt water fish	.	**0.50**	.	.	.	.	-0.18
Eggs	.	**0.40**	.	.	.	.	.
Shellfish	.	**0.38**	.	.	.	.	-0.18
Water	.	**0.30**	.	.	.	.	.
Vegetable juices	.	**0.26**	.	.	.	.	.
Cottage cheese	.	**0.23**	.	.	.	.	.
Fresh water fish	.	**0.20**	.	.	.	.	.
Brown bread	.	.	**0.64**	.	0.19	0.16	0.18
Soft drinks	0.16	.	**-0.22**	.	0.18	.	.
Any kind pasta	.	.	**-0.23**	.	.	0.20	.
White bread	0.18	.	**-0.61**	.	.	.	.
Lettuce/green leafy salad	.	.	.	**0.76**	.	0.21	.
Fat salad dressing	.	.	.	**0.40**	.	.	.
Nuts	-0.16	0.18	0.25	**0.28**	.	.	.
Fruit flavoured drinks	.	.	.	**-0.15**	.	.	.
Milk	.	.	.	.	**0.73**	.	.
Hot/cold cereal	-0.17	.	.	.	**0.53**	.	.
Tomatoes/tomato sauce	.	.	.	0.17	.	**0.68**	.
Cooked dried beans	.	.	.	.	.	**0.32**	-0.21
Other potatoes	.	.	.	.	.	.	**0.53**
Red meat	0.16	.	.	.	.	.	**0.32**
Fruit juices	.	.	.	.	.	.	**0.20**
Ice cream	.	.	.	.	.	.	**0.17**
Any kind of rice	.	.	.	.	.	0.21	**-0.29**

Bold: the highest factor loadings
Absolute factor loading values <.15 are not shown for simplicity

Appendix H-2. Mean frequency of dietary patterns (clusters) for Canadian older adults aged 60 to 79 years

	Cluster1: Prudent (n=147)	Cluster2: Traditional (n=264)	Cluster3: Unhealthy (n=139)
Factor1	-0.30	-0.14	**0.58**
Factor2	**0.43**	-0.17	-0.14
Factor3	<u>0.17</u>	**0.34**	-0.83
Factor4	**0.84**	-0.37	-0.19
Factor5	-0.20	**0.28**	-0.32
Factor6	**0.48**	-0.19	-0.14
Factor7	-0.26	<u>0.02</u>	**0.24**

Bold: most frequent intake; <u>Underline</u>: moderately frequent intake

Appendix H-3. Number of observations and percent classified into clusters for Canadian older adults aged 60 to 79 years

			New clusters derived from discriminant analysis			
			Prudent	Unhealthy	Traditional	Total
Original clusters derived from cluster analysis	Prudent	N	144	2	1	147
		%	97.96	1.36	0.68	100
	Unhealthy	N	1	135	3	139
		%	0.72	97.12	2.16	100
	Traditional	N	4	2	258	264
		%	1.51	0.76	97.73	100
	Total	N	149	139	262	550
		%	27.09	25.27	47.64	100

Appendix H-4. Results of discriminant analysis for Canadian older adults aged 60 to 79 years

Cluster	Sensitivity (95% CI)	Specificity (95% CI)
Prudent	0.9796 (0.9417-0.993)	0.9876 (0.9713-0.9947)
Unhealthy	0.9712 (0.9283-0.9888)	0.9903 (0.9752-0.9962)
Traditional	0.9773 (0.9513-0.9895)	0.9860 (0.9646-0.9945)

95% CI: 95% confidence interval

Appendix I-1. Factor loading matrix for the nine dietary patterns of Korean older adults aged 60 to 79 years

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
Water melon	**0.67**	.	.	.	.	.	.	.	.
Grapes	**0.66**	.	.	.	.	.	.	.	.
Oriental melon	**0.64**	.	.	.	.	.	.	.	.
Strawberry	**0.64**	0.29	.	.	.	.	.	.	.
Peach	**0.58**	.	.	.	.	.	.	.	.
Tangerine	**0.56**	.	.	.	.	.	.	.	.
Apple	**0.56**	0.23	.	.	.	.	0.22	.	.
Pear	**0.55**	.	.	.	.	.	.	.	.
Persimmon	**0.51**	.	.	.	.	.	.	.	.
Tomato	**0.39**	0.25	.	0.23	.	.	.	.	.
Orange	**0.32**	0.25	.	.	0.22	0.21	.	.	.
Sweet potato	**0.27**	.	.	0.24	.	.	.	.	.
Yogurt	**0.21**	.	.	.	.	.	.	.	.
Spinach	0.22	**0.54**	.	.	.	.	.	.	.
Bean sprout	.	**0.52**	.	0.26	.	.	.	.	.
Cabbage	.	**0.51**	.	.	.	.	.	.	.
Mushroom	0.29	**0.49**	0.23	0.21	.	.	.	.	.
Carrot	0.21	**0.42**	.	0.29	.	.	.	.	.
Pollack	.	**0.41**	0.21	0.23	.	.	.	.	.
Seaweeds	0.21	**0.41**	.	.	.	.	.	.	.
Shellfishes	.	**0.40**	.	.	.	.	.	.	.
Fish paste	.	**0.40**	.	.	0.26	0.20	.	.	.
Beef	0.25	**0.38**	0.36	.	.	.	.	.	.
Banana	0.35	**0.38**	.	.	.	0.21	.	.	.
Mackerel	.	**0.37**	0.32	.	.	.	.	.	.
Tuna	.	**0.37**	.	.	.	0.24	.	.	.
Tofu	.	**0.36**	.	.	.	.	.	.	.
Egg	.	**0.33**	0.25	.	.	.	.	.	.
Laver	0.28	**0.33**	.	0.20	.	.	.	.	.
Yellow fish	0.26	**0.32**	0.26	.	.	.	.	.	-0.28
Squid	.	**0.31**	0.29	.	0.22	.	.	.	.
Tea	.	**0.28**	.	.	.	.	.	.	.
Anchovy	0.22	**0.28**	0.20	0.22	.	.	0.20	.	.
Pork	.	0.20	**0.53**	.	.	.	.	.	.
Chicken	.	0.30	**0.45**	.	.	.	.	.	.
Fried foods	.	.	**0.30**	.	0.26	0.27	.	.	.
Coffee	.	.	**0.29**	.	.	.	.	.	.
Sodium	.	.	**0.27**	.	.	.	.	.	.
Salted fish	.	.	**0.23**	.	.	.	.	.	.
Squash	.	0.26	.	**0.50**	.	.	.	.	.
Cucumber	0.25	0.24	.	**0.45**	.	.	.	.	.
Pepper	.	.	0.25	**0.41**	.	.	.	.	.
Potato	.	0.21	.	**0.36**	0.21	.	.	.	.
Radish leaves	.	.	.	**0.35**	.	.	.	.	.
Radish	.	.	.	**0.25**	.	.	.	0.24	.
Bread	.	.	.	.	**0.47**	.	.	-0.20	.
Cracker	.	.	.	.	**0.47**	.	.	.	.
Rice cake	0.22	0.20	.	.	**0.40**	.	.	.	.
Soft drink	.	.	.	.	**0.31**	.	.	.	.
Soybean milk	.	.	.	.	**0.21**	.	.	.	.

Continued

Appendix I-1. Factor loading matrix for the nine dietary patterns of Korean older adults aged 60 to 79 years - continued

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
Soybean milk	.	.	.	.	**0.21**	.	.	.	.
Pizza	.	.	.	.	.	**0.67**	.	.	.
Hamburger	.	.	.	.	.	**0.61**	.	.	.
Ham	.	0.22	.	.	0.28	**0.30**	.	.	.
Bean	.	.	.	.	.	.	**0.53**	.	.
Other grains	.	.	.	.	.	.	**0.47**	.	.
Korean cabbage	.	.	.	.	.	.	.	**0.40**	.
Rice	.	.	.	.	.	.	.	**0.40**	.
Milk	0.20	.	.	.	.	.	.	**-0.30**	.
Instant noodle	.	.	0.26	.	0.23	.	.	.	**0.40**
Noodle	.	.	.	.	0.24	.	.	.	**0.30**

Bold: the highest factor loadings
Absolute factor loading values <.20 are not shown for simplicity

Appendix I-2. Mean frequency of dietary patterns (clusters) for Korean older adults aged 60 to 79 years

	Cluster1: Prudent (n=1,003)	Cluster2: Traditional (n=1,568)	Cluster3: Unhealthy (n=469)
Factor1	<u>0.45</u>	-0.44	**0.50**
Factor2	**0.60**	-0.48	<u>0.32</u>
Factor3	<u>0.04</u>	-0.17	**0.50**
Factor4	**0.36**	-0.21	-0.08
Factor5	-0.15	-0.13	**0.77**
Factor6	-0.27	-0.16	**1.10**
Factor7	**0.28**	-0.16	-0.08
Factor8	-0.13	**0.09**	-0.03
Factor9	<u>0.01</u>	-0.04	**0.10**

Bold: most frequent intake; <u>Underline</u>: moderately frequent intake

Appendix I-3. Number of observations and percent classified into clusters for Korean older adults aged 60 to 79 years

			New clusters derived from discriminant analysis			
			Traditional	Prudent	Unhealthy	Total
Original clusters derived from cluster analysis	Traditional	N	1,519	44	5	1,568
		%	96.88	2.81	0.32	100
	Prudent	N	6	993	4	1,003
		%	0.60	99.0	0.40	100
	Unhealthy	N	14	31	424	469
		%	2.99	6.61	90.41	100
	Total	N	1,539	1,068	433	3,040
		%	50.63	35.13	14.24	100

Appendix I-4. Results of discriminant analysis for Korean older adults aged 60 to 79 years

Cluster	Sensitivity (95% CI)	Specificity (95% CI)
Traditional	0.9688	0.9864
	(0.9589 - 0.9763)	(0.9791 - 0.9912)
Prudent	0.9900	0.9632
	(0.9817 - 0.9946)	(0.9541 – 0.9705)
Unhealthy	0.9041	0.9965
	(0.874 - 0.9275)	(0.9934 – 0.9982)

95% CI: 95% confidence interval

Appendix J-1. Results of correlation and partial correlation analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13
Canada													
1 MetS		0.07	0.06	-0.03	-0.08	-0.11	-0.10	0.03	0.05	0.06	-0.11	0.07	0.01
2 Age	0.05		0.19	-0.004	-0.17	-0.15	0.06	0.001	0.004	-0.05	-0.12	-0.07	0.02
3 Comorbidity	0.02	0.18		-0.0006	-0.19	-0.07	0.003	0.07	0.02	0.13	-0.05	0.13	-0.009
4 Gender	-0.04	0.04	0.004		0.12	0.04	-0.19	-0.03	0.14	0.10	0.21	-0.06	0.01
5 Household income adequacy	-0.06	-0.10	-0.15	0.04		0.21	-0.33	-0.10	-0.06	-0.11	0.24	-0.04	0.02
6 Education	-0.04	-0.12	0.02	0.04	0.17		0.03	-0.17	-0.09	-0.12	0.18	-0.05	-0.04
7 Marital status	-0.14	0.03	-0.06	-0.14	-0.31	0.13		0.04	-0.01	0.01	-0.19	0.04	-0.04
8 Physical activity	-0.01	-0.03	0.04	-0.03	-0.02	-0.11	0.01		0.19	0.11	-0.14	0.14	0.03
9 Dietary pattern	0.03	-0.01	-0.02	0.16	-0.05	-0.04	-0.001	0.17		0.08	-0.03	0.06	0.04
10 Smoking	0.06	-0.10	0.11	0.11	-0.10	-0.10	0.02	0.07	0.03		0.04	0.12	0.06
11 Alcohol consumption	-0.09	-0.06	0.01	0.15	0.13	0.12	-0.12	-0.09	-0.02	0.07		-0.10	0.01
12 Psychological distress	0.05	-0.10	0.13	-0.04	0.03	-0.02	0.04	0.10	0.03	0.09	-0.07		-0.01
13 Duration of sleep	-0.001	0.03	-0.02	-0.01	0.02	-0.04	-0.03	0.02	0.03	0.06	0.01	-0.01	
Korea													
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 MetS		0.03	0.08	-0.20	-0.03	-0.09	0.11	0.06	-0.03	-0.13	-0.10	0.05	-0.01
2 Age	0.01		0.18	-0.03	-0.24	-0.20	0.20	0.05	0.06	-0.001	-0.13	0.02	-0.07
3 Comorbidity	0.05	0.10		-0.14	-0.08	-0.12	0.09	0.03	0.002	-0.13	-0.13	0.11	-0.06
4 Gender	-0.10	0.14	-0.10		0.11	0.38	-0.39	-0.10	0.02	0.65	0.44	-0.18	0.15
5 Household income adequacy	0.001	-0.17	-0.01	0.004		0.36	-0.11	-0.03	-0.06	0.02	0.08	-0.10	0.04
6 Education	-0.004	-0.11	-0.08	0.25	0.30		-0.23	-0.02	-0.07	0.20	0.20	-0.13	0.05
7 Marital status	0.04	0.18	-0.04	-0.33	-0.003	-0.05		0.06	0.05	-0.17	-0.15	0.06	-0.11
8 Physical activity	0.04	0.04	0.01	-0.06	-0.01	0.04	0.01		0.08	-0.06	-0.08	0.07	-0.002
9 Dietary pattern	-0.04	0.03	0.01	-0.02	-0.02	-0.05	0.05	0.08		0.05	-0.01	0.01	0.02
10 Smoking	-0.01	-0.003	-0.04	0.56	-0.05	-0.04	0.10	0.01	0.03		0.37	-0.10	0.11
11 Alcohol consumption	-0.01	-0.12	-0.02	0.25	0.01	0.02	0.04	-0.03	-0.01	0.12		-0.10	0.06
12 Psychological distress	0.006	-0.03	0.10	-0.09	-0.06	-0.03	-0.02	0.05	0.01	0.03	-0.02		-0.12
13 Duration of sleep	0.03	-0.06	-0.03	0.07	0.01	-0.03	-0.06	0.02	0.02	0.03	-0.01	-0.10	

Upper triangular matrix: correlation coefficients; Lower triangular matrix: partial correlation coefficients; MetS: metabolic syndrome

Reference group – absence of MetS; absence of comorbidity; female; lowest household income; less than secondary school graduation; married or common-law; physically active; more healthy dietary pattern; lifetime abstainer (for smoking and alcohol consumption); absence of psychological condition; less than 6 hours per day

Appendix J-2. Cross-tabulation for dietary patterns against biomedical, biosocial and psychosocial factors in Canadian older adults aged 60 to 79 years

		Prudent		Traditional		Unhealthy		
		Weighted N or mean	SE or %	Weighted N or mean	SE or %	Weighted N or mean	SE or %	Sig.
Age	-continuous	67.5	0.59	67.6	0.40	66.9	0.41	0.505
Comorbidity	Absence	573302	30.3	748252	43.3	514070	26.4	0.307
	Having 1	417464	23.8	727538	51.2	345481	25.0	
	Having 2+	393630	25.3	840960	50.6	325343	24.1	
Gender	Women	792928	31.8	1259194	48.3	512274	19.9	0.248
	Men	591468	21.9	1057555	47.6	672621	30.5	
Income adequacy	Lowest	194687	18.8	477868	53.4	251354	27.8	0.225
	Middle	710608	28.7	1250059	48.8	516852	22.5	
	Highest	479101	30.1	588821	42.3	416688	27.6	
Education	<Secondary	284676	18.9	575329	45.9	413191	35.2	0.094
	Secondary	316697	34.0	376856	48.5	130147	17.5	
	Post-secondary	783023	27.5	1364564	48.6	641556	23.9	
Marital status	Married	993168	27.4	1660176	46.6	816299	26.0	0.782
	Non-married	391228	25.6	656573	50.2	368595	24.2	
Physical activity	Active	973178	29.5	1739384	51.6	526663	18.9	0.0004
	Inactive	411218	20.6	577364	40.0	658231	39.4	
Smoking	Lifetime abstainer	692493	26.9	994752	50.4	433922	22.7	0.058
	Former	551946	27.2	1121285	49.6	469295	23.2	
	Current	139957	24.2	200712	32.3	281677	43.5	
Alcohol consumption*	Lifetime abstainer	-	-	-	-	-	-	
	Former	-	-	-	-	-	-	
	Occasional	-	-	-	-	-	-	
	Regular	-	-	-	-	-	-	
Psychological distress	Absence	1207888	27.7	1998019	47.8	991670	24.5	0.784
	Presence	176508	21.7	318730	48.9	193224	29.4	
Duration of sleep	< 6 h/day	113377	30.8	129845	38.4	90050	30.8	0.359
	6-7 h/day	785764	29.7	1128255	45.7	566392	24.6	
	≥ 8h/day	485255	22.7	1058648	52.1	528452	25.2	

* The frequencies of alcohol consumption types (especially lifetime abstainers) were suppressed due to insufficient cell sizes according to the rule of Statistics Canada

Appendix J-3. Cross-tabulation for dietary patterns against biomedical, biosocial, and psychosocial factors in Korean older adults aged 60 to 79 years

		Prudent		Traditional		Unhealthy		
		Weighted N or mean	SE or %	Weighted N or mean	SE or %	Weighted N or mean	SE or %	Sig.
Age	-continuous	66.7	0.20	69.0	0.19	66.5	0.33	0.106
Comorbidity	Absence	807109	36.2	817342	47.4	361314	16.4	<.0001
	Having 1	499103	31.3	701656	51.9	284320	16.8	
	Having 2+	249524	29.2	440721	59.6	106092	11.2	
Gender	Women	839680	32.0	1133972	54.6	378478	13.4	0.039
	Men	716056	34.3	825748	47.4	373248	18.3	
Income adequacy	Lowest	922072	27.5	1648695	60.3	404696	12.2	<.0001
	Middle	322164	47.9	188144	30.7	153086	21.3	
	Highest	311500	48.6	122880	23.3	193943	28.1	
Education	<Secondary	751369	25.6	1519337	63.4	314205	11.0	<.0001
	Secondary	601998	44.9	413069	32.6	327060	22.5	
	Post-secondary	202370	57.9	27314	11.9	110461	30.2	
Marital status	Married	1209743	36.1	1292678	47.6	569660	16.3	<.0001
	Non-married	345993	25.1	667041	61.7	182065	13.2	
Physical activity	Active	929917	36.7	970835	48.8	381533	14.5	0.0005
	Inactive	625819	28.5	988884	54.9	370193	16.6	
Smoking	Lifetime abstainer	926626	33.9	1075159	51.6	413809	14.5	0.001
	Former	431161	36.0	474317	46.6	208538	17.4	
	Current	197949	24.8	410244	59.5	129379	15.7	
Alcohol consumption	Lifetime abstainer	397653	32.5	522922	53.3	198109	14.2	0.123
	Former	257005	28.1	419744	57.7	130163	14.2	
	Occasional	365838	35.3	446086	48.2	180610	16.5	
	Regular	535240	34.9	570968	48.5	242843	16.6	
Psychological distress	Absence	1198886	34.8	1344030	48.4	592387	16.8	<.0001
	Presence	356850	28.1	615689	60.1	159339	11.8	
Duration of sleep	< 6 h/day	370302	29.3	652278	57.3	185837	13.4	<.0001
	6-7 h/day	835605	37.3	810988	46.8	348899	15.9	
	≥ 8h/day	349830	29.2	496453	54.0	216990	16.8	

Appendix K. Prevalence of MetS by smoking status among Korean older adults aged 60 to 79 years

			Prevalence of MetS	
Gender	Smoking	Weighted N (%)	Weighted N	Prevalence
Female	Lifetime abstainer	2103642 (90.6)	1276007	59.6
	Former	106428 (4.3)	63652	65.3
	Current	142060 (5.1)	92678	2.2
Male	Lifetime abstainer	311951 (17.2)	133318	37.8
	Former	1007588 (53.1)	460019	43.3
	Current	595513 (29.7)	228997	35.6

Appendix L-1. Physical activity as mediator on the association between age and MetS in Korean older adults aged 60 to 79 years

	Parameter		B	SE	Sig.
Model 1	MetS regressed on Age	τ	0.0170	0.00820	0.0385
Model 2	PA regressed on Age	α	0.0182	0.00832	0.0283
Model 3	MetS regressed on Age via PA	τ'	0.0163	0.00827	0.0493
	MetS regressed on PA when controlling for Age	β	0.1596	0.0925	0.0844

MetS: metabolic syndrome; Age: continuous variable; PA: physical activity

Appendix L-2. Physical activity as mediator on the association between comorbidity and MetS

	Parameter		B	SE	Sig.[a]	Sig.[b]
Canada						
Model 1	MetS regressed on Comorbidity1	τ	0.3388	0.1923	0.0780	0.0616
	MetS regressed on Comorbidity2		0.5173	0.2281	0.0233	
Model 2	PA regressed on Comorbidity1	α	0.3757	0.2788	0.1778	0.2961
	PA regressed on Comorbidity2		0.00523	0.2592	0.9839	
Model 3	MetS regressed on Comorbidity1 via PA	τ'	0.3167	0.1771	0.0738	0.0490
	MetS regressed on Comorbidity2 via PA		0.5190	0.2176	0.0171	
	MetS regressed on PA when controlling for Comorbidity	β	0.2721	0.2526	0.2813	
Korea						
Model 1	MetS regressed on Comorbidity1	τ	0.3246	0.0959	0.0007	<.0001
	MetS regressed on Comorbidity2		0.4915	0.1138	<.0001	
Model 2	PA regressed on Comorbidity1	α	0.0064	0.1015	0.9498	0.3825
	PA regressed on Comorbidity2		0.1581	0.1236	0.2009	
Model 3	MetS regressed on Comorbidity1 via PA	τ'	0.3249	0.0964	0.0007	<.0001
	MetS regressed on Comorbidity2 via PA		0.4859	0.1141	<.0001	
	MetS regressed on PA when controlling for Comorbidity	β	0.1609	0.0917	0.0793	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; PA: physical activity ; Comorbidity1: having 1 condition; Comorbidity2: having 2+ conditions
Reference group - absence of comorbidity; physically active

Appendix L-3. Physical activity as mediator on the association between gender and MetS in Korean adults aged 60 to 79 years

	Parameter		B	SE	Sig.
Model 1	MetS regressed on Gender	τ	-0.7272	0.0881	<.0001
Model 2	PA regressed on Gender	α	-0.4398	0.0875	<.0001
Model 3	MetS regressed on Gender via PA	τ'	-0.7174	0.0882	<.0001
	MetS regressed on PA when controlling for Gender	β	0.0938	0.0934	0.3153

MetS: metabolic syndrome; PA: physical activity
Reference group - women; physically active

Appendix L-4. Physical activity as mediator on the association between education and MetS in Korean adults aged 60 to 79 years

	Parameter		B	SE	Sig.[a]	Sig.[b]
Model 1	MetS regressed on Education1	τ	-0.3096	0.1003	0.0020	<.0001
	MetS regressed on Education2		-0.7237	0.1996	0.0003	
Model 2	PA regressed on Education1	α	-0.1176	0.1022	0.2498	0.5149
	PA regressed on Education2		-0.0828	0.1969	0.6739	
Model 3	MetS regressed on Education1 via PA	τ'	-0.3054	0.1006	0.0024	<.0001
	MetS regressed on Education2 via PA		-0.7215	0.2006	0.0003	
	MetS regressed on PA when controlling for Education	β	0.1604	0.0915	0.0797	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; PA: physical activity; Education1: secondary school graduation; Education2: post-secondary school graduation
Reference group – less than secondary school graduation; physically active

Appendix L-5. Physical activity as mediator on the association between marital status and MetS

	Parameter		B	SE	Sig.
Canada					
Model 1	MetS regressed on Marital1	τ	-0.6078	0.2553	0.0173
Model 2	PA regressed on Marital1	α	0.3061	0.2495	0.2199
Model 3	MetS regressed on Marital1 via PA	τ'	-0.6338	0.2481	0.0106
	MetS regressed on PA when controlling for Marital	β	0.3211	0.2316	0.1655
Korea					
Model 1	MetS regressed on Marital1	τ	0.4787	0.0945	<.0001
Model 2	PA regressed on Marital1	α	0.2904	0.0992	0.0034
Model 3	MetS regressed on Marital1 via PA	τ'	0.4690	0.0952	<.0001
	MetS regressed on PA when controlling for Marital	β	0.1422	0.0916	0.1205

MetS: metabolic syndrome; PA: physical activity; Marital1: non-married
Reference group – married; physically active

Appendix L-6. Dietary pattern as mediator on the association between age and MetS in Korean older adults aged 60 to 79 years

	Parameter		B	SE	Sig.[a]	Sig.[b]
Model 1	MetS regressed on Age	τ	0.0170	0.0082	0.0385	
Model 2	Diet1 regressed on Age	α_1	0.0804	0.0103	<.0001	<.0001
	Diet2 regressed on Age	α_2	-0.00755	0.0149	0.6134	
Model 3	MetS regressed on Age via Diet1, 2	τ'	0.0215	0.0084	0.0107	
	MetS regressed on Diet1 when controlled for Age	β_1	-0.2486	0.0972	0.0105	0.0309
	MetS regressed on Diet2 when controlled for Age	β_2	-0.0712	0.1274	0.5764	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern
Reference group – prudent dietary pattern

Appendix L-7. Dietary pattern as mediator on the association between comorbidity and MetS

	Parameter		B	SE	Sig.[a]	Sig.[b]
Canada						
Model 1	MetS regressed on Comorbidity1	τ	0.3388	0.1923	0.0780	0.0616
	MetS regressed on Comorbidity2	τ_1	0.5173	0.2281	0.0233	
Model 2	Diet1 regressed on Comorbidity1	α_1	0.2891	0.2679	0.2804	0.0384
	Diet2 regressed on Comorbidity1		-0.0802	0.2979	0.7878	
	Diet1 regressed on Comorbidity2	α_2	0.4928	0.4039	0.2224	
	Diet2 regressed on Comorbidity2		-0.0815	0.4013	0.8391	
Model 3	MetS regressed on Comorbidity1 via Diet	τ'	0.3344	0.2013	0.0967	0.0728
	MetS regressed on Comorbidity2 via Diet	τ_1'	0.5088	0.2294	0.0266	
	MetS regressed on Diet1 when controlled for Comorbidity	β_1	0.1597	0.2795	0.5677	0.8484
	MetS regressed on Diet2 when controlled for Comorbidity	β_2	0.1650	0.3812	0.6652	
Korea						
Model 1	MetS regressed on Comorbidity1	τ	0.3246	0.0959	0.0007	<.0001
	MetS regressed on Comorbidity2	τ_1	0.4915	0.1138	<.0001	
Model 2	Diet1 regressed on Comorbidity1	α_1	0.3280	0.1096	0.0028	<.0001
	Diet2 regressed on Comorbidity1		0.2410	0.1435	0.0931	
	Diet1 regressed on Comorbidity2	α_2	0.5562	0.1416	<.0001	
	Diet2 regressed on Comorbidity2		-0.0514	0.1945	0.7915	
Model 3	MetS regressed on Comorbidity1 via Diet	τ'	0.3416	0.0948	0.0003	<.0001
	MetS regressed on Comorbidity2 via Diet	τ_1'	0.5241	0.1168	<.0001	
	MetS regressed on Diet1 when controlled for Comorbidity	β_1	-0.2479	0.0956	0.0095	0.0303
	MetS regressed on Diet2 when controlled for Comorbidity	β_2	-0.0858	0.1291	0.5062	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern; Comorbidity1: having 1 condition; Comorbidity2: having 2+ conditions
Reference group – absence of comorbidity; prudent dietary pattern

Appendix L-8. Dietary pattern as mediator on the association between gender and MetS in Korean older adults aged 60 to 79 years

	Parameter		B	SE	Sig.[a]	Sig.[b]
Model 1	MetS regressed on Gender	τ	-0.7272	0.0881	<.0001	
Model 2	Diet1 regressed on Gender	α_1	-0.1579	0.0970	0.1034	0.0362
	Diet2 regressed on Gender	α_2	0.1453	0.1327	0.2735	
Model 3	MetS regressed on Gender via Diet1, 2	τ'	-0.7397	0.0880	<.0001	
	MetS regressed on Diet1 when controlled for Gender	β_1	-0.2352	0.0966	0.0149	0.0361
	MetS regressed on Diet2 when controlled for Gender	β_2	-0.0504	0.1333	0.7056	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern
Reference group – women; prudent dietary pattern

Appendix L-9. Dietary pattern as mediator on the association between education and MetS in Korean older adults aged 60 to 79 years

	Parameter		B	SE	Sig.[a]	Sig.[b]
Model 1	MetS regressed on Education1	τ	-0.3096	0.1003	0.0020	<.0001
	MetS regressed on Education2	τ_1	-0.7237	0.1996	0.0003	
Model 2	Diet1 regressed on Education1	α_1	-1.0808	0.1284	<.0001	<.0001
	Diet2 regressed on Education1		0.2617	0.1578	0.0972	
	Diet1 regressed on Education2	α_2	-2.7068	0.2773	<.0001	
	Diet2 regressed on Education2		0.2664	0.2407	0.2683	
Model 3	MetS regressed on Education1 via Diet	τ'	-0.4146	0.1027	<.0001	<.0001
	MetS regressed on Education2 via Diet	τ_1'	-0.9131	0.2057	<.0001	
	MetS regressed on Diet1 when controlled for Education	β_1	-0.3823	0.0966	<.0001	0.0001
	MetS regressed on Diet2 when controlled for Education	β_2	-0.0413	0.1294	0.7497	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
MetS: metabolic syndrome; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern; Education1: secondary school graduation; Education2: post-secondary school graduation
Reference group – less than secondary school graduation; prudent dietary pattern

Appendix L-10. Dietary pattern as mediator on the association between marital status and MetS

	Parameter		B	SE	Sig.[a]	Sig.[b]
Canada						
Model 1	MetS regressed on Marital1	τ	-0.6078	0.2553	0.0173	
Model 2	Diet1 regressed on Marital1	α_1	0.00396	0.1561	0.9797	0.8312
	Diet2 regressed on Marital1	α_2	0.1365	0.2458	0.5786	
Model 3	MetS regressed on Marital1 via Diet1, 2	τ'	-0.6101	0.2514	0.0152	
	MetS regressed on Diet1 when controlled for Marital1	β_1	0.2057	0.2497	0.4100	0.7038
	MetS regressed on Diet2 when controlled for Marital1	β_2	0.1747	0.3720	0.6386	
Korea						
Model 1	MetS regressed on Marital1	τ	0.4787	0.0945	<.0001	
Model 2	Diet1 regressed on Marital1	α_1	0.5901	0.1165	<.0001	<.0001
	Diet2 regressed on Marital1	α_2	0.1111	0.1583	0.4827	
Model 3	MetS regressed on Marital1 via Diet1, 2	τ'	0.5136	0.0958	<.0001	
	MetS regressed on Diet1 when controlled for Marital1	β_1	-0.2619	0.0952	0.0059	0.0187
	MetS regressed on Diet2 when controlled for Marital1	β_2	-0.0862	0.1283	0.5020	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories

MetS: metabolic syndrome; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern; Marital1: non-married

Reference group – married; prudent dietary pattern

Appendix M-1. Summary of results to show between-country difference in moderation effect of physical activity

Parameters	B	SE	Sig.[a]	Sig.[b]
Age				
Age*PA*Country	-0.0130	0.0541	0.8108	
Comorbidity				
Comorbidity1*PA*Country	0.9146	0.6244	0.1430	0.3402
Comorbidity2*PA*Country	0.2642	M0.5149	0.6079	
Gender				
Gender*PA*Country	1.4477	0.3361	<.0001	
Household income adequacy				
Income1*PA*Country	-1.4004	0.5822	0.0162	0.0365
Income2*PA*Country	-1.8656	0.9375	0.0466	
Education				
Education1*PA*Country	-1.3398	0.7953	0.0920	0.0228
Education2*PA*Country	0.2627	0.6531	0.6876	
Marital status				
Marital status1*PA*Country	0.0454	0.4573	0.9209	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
Age: continuous variable
Comorbidity1: having 1 condition; Comorbidity2: having 2+ conditions; Income1: middle level; Income2: highest level; Education1: secondary school graduation; Education2: post-secondary school graduation; Marital status1: non-married; PA: physical activity.
Reference group – Canada; absence of comorbidity; women; lowest income level; less than secondary school graduation; married or common-law; physically active.

Appendix M-2. Summary of results to show between-country difference in moderation effect of dietary pattern

Parameters	B	SE	Sig.[a]	Sig.[b]
Age				
Age*Diet1*Country	0.0828	0.0570	0.1461	0.3457
Age*Diet2*Country	0.0670	0.0678	0.3224	
Comorbidity				
Comorbidity1*Diet1*Country	0.4462	0.7647	0.5595	0.2870
Comorbidity1*Diet2*Country	0.6394	0.7886	0.4175	
Comorbidity2*Diet1*Country	0.2805	0.6729	0.6768	
Comorbidity2*Diet2*Country	-0.4732	0.6237	0.4480	
Gender				
Gender*Diet1*Country	-0.7054	0.4181	0.0916	<.0001
Gender*Diet2*Country	1.0640	0.4652	0.0222	
Household income adequacy				
Income1*Diet1*Country	-0.7504	0.3888	0.0536	0.1196
Income1*Diet2*Country	0.2695	0.7581	0.7223	
Income2*Diet1*Country	-0.5897	0.6496	0.3640	
Income2*Diet2*Country	0.2320	0.8783	0.7917	
Education				
Edu1*Diet1*Country	-0.1051	0.6714	0.8756	0.5713
Edu1*Diet2*Country	-0.2919	0.5466	0.5933	
Edu2*Diet1*Country	-0.8983	0.8623	0.2976	
Edu2*Diet2*Country	-0.0477	0.8972	0.9576	
Marital status				
Marital1*Diet1*Country	-0.1008	0.7099	0.8871	0.9214
Marital1*Diet2*Country	0.0631	0.7188	0.9301	

[a] Individual significance; [b] Overall significance for variables with 2 or more categories
Age: continuous variable
Comorbidity1: having 1 condition; Comorbidity2: having 2+ conditions; Income1: middle level; Income2: highest level; Education1: secondary school graduation; Education2: post-secondary school graduation; Marital status1: non-married; Diet1: traditional dietary pattern; Diet2: unhealthy dietary pattern
Reference group – Canada; absence of comorbidity; women; lowest income level; less than secondary school graduation; married or common-law; prudent dietary pattern.

Appendix N-1. Results of multiple logistic regression analysis to predict MetS (Full model) in Canadian older adults aged 60 to 79 years

			95% CI		
Parameter		OR	Lower	Upper	Sig.
Age	-	1.02	0.97	1.06	0.4524
Comorbidity	Absence [ref.]	-	-	-	-
	Having 1	1.30	0.88	1.91	0.3567
	Having 2+	1.32	0.76	2.29	
Gender	Women [ref.]	-	-	-	-
	Men	0.73	0.48	1.09	0.1259
Household income adequacy	Lowest [ref.]	-	-	-	-
	Middle	0.58	0.32	1.03	0.1750
	Highest	0.58	0.30	1.14	
Education	< Secondary [ref.]	-	-	-	-
	Secondary	0.93	0.50	1.73	0.7288
	≥ Post-secondary	0.77	0.40	1.48	
Marital status	Married [ref.]	-	-	-	-
	Non-married	0.39	0.24	0.63	<.0001
Physical activity	Active [ref.]	-	-	-	-
	Inactive	1.26	0.82	1.96	0.2950
Dietary pattern	Prudent [ref.]	-	-	-	-
	Traditional	1.29	0.80	2.09	0.5271
	Unhealthy	1.13	0.57	2.23	
Smoking	Lifetime abstainer [ref.]	-	-	-	-
	Former	1.83	0.88	3.80	0.2606
	Current	1.35	0.51	3.59	
Alcohol consumption	Lifetime abstainer [ref.]	-	-	-	-
	Former	0.36	0.09	1.36	0.0424
	Occasional	0.24	0.07	0.83	
	Regular	0.35	0.13	0.92	
Psychological distress	Absence [ref.]	-	-	-	-
	Presence	1.78	0.88	3.59	0.1075
Duration of sleep	< 6 hours/day [ref.]				
	6-7 hours/day	0.57	0.25	1.31	0.1420
	≥ 8 hours/day	0.75	0.29	1.93	

Age: continuous variable; [ref.]: reference group

Appendix N-2. Model goodness of fit statistics in each logistic regression model to predict MetS in Canadian older adults aged 60 to 79 years

Step	Model tested	DF	Likelihood Ratio Chi-Square	Wald Chi-Square	Pr>ChiSq
0	Full model	20	60.4645	182.6005	<.0001
1	After removing "Physical activity"	19	59.2724	398.3764	<.0001
2	After removing "Duration of sleep"	17	55.6668	4304.2862	<.0001
3	After removing "Dietary pattern"	15	54.3621	254.9949	<.0001
4	After removing "Education"	13	52.0978	233.1221	<.0001
5	After removing "Comorbidity"	11	49.6642	186.5708	<.0001
6	After removing "Age"	10	48.0001	48.6142	<.0001
7	After removing "Gender"	9	45.6725	43.3204	<.0001
8	After removing "Smoking*" [A parsimonious model]	7	36.0355	35.0533	<.0001
9	After adding "interactions"	24	54.2583	187.7939	<.0001
10	After removing "non-significant interactions" [The final model]	9	41.1110	585.2971	<.0001

* Removed due to insufficient sample size in lifetime non-smoker

Appendix N-3. Results of testing a parsimonious logistic regression model with interactions to predict MetS in Canadian older adults aged 60 to 79 years

			95% CI		
Parameters		OR	Lower	Upper	Sig.
Income Adequacy	Lowest [ref.]	-	-	-	-
	Middle	0.18	0.01	3.30	0.4226
	Highest	0.17	0.01	3.33	
Marital status	Married [ref.]	-	-	-	-
	Non-married	0.66	0.08	5.32	0.6929
Alcohol consumption	Lifetime abstainer [ref.]	-	-	-	-
	Former	0.12	0.01	1.01	0.1027
	Occasional	0.07	0.01	0.58	
	Regular	0.06	0.01	0.98	
Psychological distress	Absence [ref.]	-	-	-	-
	Presence	1.34	0.08	21.5	0.8379
Income adequacy*	Lowest*Marital status [ref.]	-	-	-	-
Marital status	Middle*Marital status	0.28	0.11	0.72	0.0190
	Highest*Marital status	0.28	0.07	1.11	
Income adequacy*	Lowest*lifetime abstainer [ref.]	-	-	-	-
Alcohol consumption	Middle*Former	4.52	0.39	52.1	0.3694
	Middle*Occasional	4.23	0.16	109.1	
	Middle*Regular	6.82	0.27	173.6	
	Highest*Former	1.73	0.09	32.6	
	Highest*Occasional	2.87	0.11	72.9	
	Highest*Regular	8.32	0.22	313.1	
Income adequacy*	Lowest*Absence [ref.]	-	-	-	-
Psychological distress	Middle*Presence	6.39	0.92	44.4	0.1291
	Highest*Presence	3.79	0.88	16.2	
Marital status*	Married*Lifetime abstainer [ref.]	-	-	-	-
Alcohol consumption	Non-married*Former	1.42	0.10	20.2	0.9793
	Non-married*Occasional	1.35	0.16	11.8	
	Non-married*Regular	1.73	0.11	26.5	
Marital status*	Married*Absence [ref.]	-	-	-	-
Psychological distress	Non-married*Presence	1.69	0.47	6.10	0.4223
Alcohol consumption*	Lifetime abstainer*Absence [ref.]	-	-	-	-
Psychological distress	Former*Presence	0.42	0.01	17.2	0.1836
	Occasional*Presence	0.44	0.02	12.5	
	Regular*Presence	0.22	0.01	5.26	

[ref.]: reference group

Appendix O-1. Results of multiple logistic regression analysis to predict MetS (Full model) in Korean older adults aged 60 to 79 years

Parameter		OR	95% CI Lower	95% CI Upper	Sig.
Age	-	1.01	0.99	1.03	0.3150
Comorbidity	Absence [ref.]	-	-	-	-
	Having 1	1.20	0.98	1.47	0.0525
	Having 2+	1.31	1.04	1.65	
Gender	Women [ref.]	-	-	-	-
	Men	0.58	0.43	0.79	0.0006
Income adequacy	Lowest [ref.]	-	-	-	-
	Middle	0.92	0.69	1.22	0.6855
	Highest	1.07	0.81	1.42	
Education	< Secondary [ref.]	-	-	-	-
	Secondary	0.88	0.70	1.10	0.0522
	≥ Post-secondary	0.58	0.37	0.90	
Marital status	Married [ref.]	-	-	-	-
	Non-married	1.20	0.96	1.49	0.1082
Physical activity	Active [ref.]	-	-	-	-
	Inactive	1.13	0.94	1.36	0.2043
Dietary pattern	Prudent [ref.]	-	-	-	-
	Traditional	0.68	0.55	0.84	0.0008
	Unhealthy [ref.]	0.93	0.72	1.22	
Smoking	Lifetime abstainer [ref.]	-	-	-	-
	Former	1.15	0.84	1.57	0.5041
	Current	0.97	0.71	1.33	
Alcohol consumption	Lifetime abstainer [ref.]	-	-	-	-
	Former	1.04	0.80	1.34	0.5008
	Occasional	0.93	0.72	1.19	
	Regular	0.86	0.67	1.11	
Psychological distress	Absence [ref.]	-	-	-	-
	Presence	1.00	0.82	1.22	0.9789
Duration of sleep	< 6 hours/day [ref.]	-	-	-	-
	6-7 hours/day	1.10	0.88	1.37	0.5979
	≥ 8 hours/day	1.13	0.88	1.46	

Age: continuous variable; [ref.]: reference group

Appendix O-2. Model goodness of fit statistics in each logistic regression model to predict MetS in Korean older adults aged 60 to 79 years

Step	Model tested	DF	Likelihood Ratio Chi-Square	Wald Chi-Square	Pr>ChiSq
0	Full model	20	150.6503	120.5279	<.0001
1	After removing "Alcohol consumption"	17	147.4007	107.7135	<.0001
2	After removing "Household income adequacy"	15	146.1404	104.9811	<.0001
3	After removing "Psychological distress"	14	146.1371	103.9352	<.0001
4	After removing "Duration of sleep"	12	144.4368	101.4206	<.0001
5	After removing "Age"	11	142.5588	101.8934	<.0001
6	After removing "Smoking" [A parsimonious model]	9	139.7159	100.7608	<.0001
7	After adding "interactions"	42	214.5400	158.1592	<.0001
8	After removing "non-significant interactions" [The final model]	13	181.3927	115.4106	<.0001

Appendix O-3. Results of testing a parsimonious logistic regression model with interactions to predict MetS in Korean older adults aged 60 to 79 years

Parameter		OR	95% CI Lower	95% CI Upper	Sig.
Comorbidity	Absence [ref.]	-	-	-	-
	Having 1	0.99	0.99	1.61	0.9827
	Having 2+	1.05	0.61	1.81	
Gender	Women [ref.]	-	-	-	-
	Men	0.44	0.27	0.71	0.0007
Education	< Secondary [ref.]	-	-	-	-
	Secondary	0.53	0.32	0.88	0.0067
	≥ Post-secondary	0.20	0.06	0.64	
Marital status	Married [ref.]	-	-	-	-
	Non-married	1.10	0.61	1.97	0.7579
Physical activity	Active [ref.]	-	-	-	-
	Inactive	1.22	0.73	2.02	0.4455
Dietary pattern	Prudent [ref.]	-	-	-	-
	Traditional	0.65	0.41	1.02	0.1581
	Unhealthy	0.72	0.35	1.45	
Comorbidity*	Absence*Women [ref.]	-	-	-	-
Gender	Having 1*Men	0.74	0.45	1.19	0.4478
	Having 2+*Men	0.95	0.54	1.65	
Comorbidity*	Absence*<Secondary [ref.]	-	-	-	-
Education	Having 1*Secondary	1.37	0.83	2.24	0.6046
	Having 1*Post-secondary	1.81	0.73	4.47	
	Having 2+*Secondary	1.05	0.54	2.03	
	Having 2+*Post-secondary	1.30	0.28	6.15	
Comorbidity*	Absence*Married [ref.]	-	-	-	-
Marital status	Having 1*Non-married	1.86	1.13	3.06	0.0485
	Having 2+*Non-married	1.32	0.74	2.36	
Comorbidity*	Absence*Active [ref.]	-	-	-	-
Physical activity	Having 1*Inactive	0.76	0.50	1.16	0.4280
	Having 2+*Inactive	0.83	0.51	1.34	
Comorbidity*	Absence*Prudent [ref.]	-	-	-	-
Dietary pattern	Having 1*Traditional	1.23	0.79	1.90	0.2191
	Having 1*Unhealthy	1.33	0.77	2.30	
	Having 2+*Traditional	1.67	1.00	2.82	
	Having 2+*Unhealthy	0.95	0.45	2.02	
Gender*	Women*<Secondary [ref.]	-	-	-	-
Education	Men*Secondary	2.05	1.31	3.22	0.0025
	Men*Post-secondary	3.54	1.26	9.90	
Gender*	Women*Married [ref.]	-	-	-	-
Marital status	Men*Non-married	1.14	0.62	2.06	0.6772
Gender*	Women*Active [ref.]	-	-	-	-
Physical activity	Men*Inactive	1.40	0.87	2.27	0.2665
Gender*	Women*Prudent [ref.]	-	-	-	-
Dietary pattern	Men*Traditional	0.79	0.48	1.30	0.6258
	Men*Unhealthy	1.02	0.55	1.88	

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Appendix O-3. Results of testing a parsimonious logistic regression model with interactions to predict MetSvi in Korean older adults aged 60 to 79 years - continued

Parameter		OR	95% CI Lower	95% CI Upper	Sig.
Education*	<Secondary*Married [ref.]	-	-	-	-
Marital status	Secondary*Non-married	1.04	0.56	1.94	0.9919
	Post-secondary* Non-married	0.99	0.23	4.23	
Education*	<Secondary*Active [ref.]	-	-	-	-
Physical activity	Secondary*Inactive	0.77	0.50	1.19	0.3752
	Post-secondary*Inactive	0.64	0.29	1.39	
Education*	<Secondary*Prudent [ref.]	-	-	-	-
Dietary pattern	Secondary*Traditional	1.19	0.71	1.98	0.7391
	Secondary*Unhealthy	1.24	0.69	2.24	
	Post-secondary*Traditional	1.05	0.31	3.60	
	Post-secondary*Unhealthy	1.72	0.75	3.93	
Marital status*	Married*Active [ref.]	-	-	-	-
Physical activity	Non-married*Inactive	1.04	0.64	1.68	0.8810
Marital status*	Married*Prudent	-	-	-	-
Dietary pattern	Non-married*Traditional	0.62	0.37	1.01	0.2560
	Non-married*Unhealthy	0.82	0.41	1.64	
Physical activity*	Active*Prudent	-	-	-	-
Dietary pattern	Inactive*Traditional	1.06	0.69	1.65	0.9601
	Inactive*Unhealthy	1.06	0.61	1.82	

[ref.]: reference group

Appendix P. The association between alcohol consumption and HDL-C abnormality by alcohol consumption

Type of alcohol consumption	OR*	95% CI Lower	95% CI Upper	Sig.
Korean women – lifetime abstainer and former drinker [Ref]	-	-	-	
Korean women – Occasional and regular drinker	0.59	0.45	0.76	<.0001
Korean men – lifetime abstainer and former drinker	0.32	0.22	0.45	<.0001
Korean men – Occasional and regular drinker	0.19	0.14	0.26	<.0001
Canadian women – Lifetime abstainer and former drinker	0.54	0.29	1.02	0.06
Canadian women – Occasional and regular drinker	0.13	0.09	0.19	<.0001
Canadian men – Lifetime abstainer and former drinker	0.31	0.16	0.60	0.0006
Canadian men – Occasional and regular drinker	0.13	0.08	0.21	<.0001

[ref.]: reference group
* ORs adjusted for age, comorbidity, household income adequacy, education, marital status, physical activity, dietary pattern, smoking, psychological distress, and duration of sleep

Appendix Q. Association between metabolic abnormalities and Korean dietary patterns

			95% CI	
Components of MetS	Dietary pattern	OR*	Lower	Upper
Abdominal obesity	Prudent [ref.]			
	Traditional	0.84	0.66	1.07
	Unhealthy	1.19	0.85	1.68
High blood pressure	Prudent [ref.]			
	Traditional	0.91	0.72	1.14
	Unhealthy	0.91	0.71	1.18
Hyperglycemia	Prudent [ref.]			
	Traditional	0.80	0.64	0.99
	Unhealthy	1.19	0.92	1.54
Hypertriglyceridemia	Prudent [ref.]			
	Traditional	0.96	0.75	1.23
	Unhealthy	1.03	0.76	1.40
Low HDL-C	Prudent [ref.]			
	Traditional	0.83	0.63	1.08
	Unhealthy	0.76	0.57	1.03

* ORs after adjusting for all study variables and the other individual components of MetS
[ref.]: Reference group

Appendix R. Association between metabolic abnormalities and smoking status among Korean older adults aged 60 to 79 years

			95% CI		
Components of MetS	Smoking status	OR*	Lower	Upper	Sig.
Abdominal obesity	Lifetime abstainer [ref.]	-			
	Former smoker	0.75	0.54	1.03	0.0343
	Current smoker	0.59	0.40	0.88	
High blood pressure	Lifetime abstainer [ref.]	-			
	Former smoker	1.15	0.86	1.53	0.0636
	Current smoker	0.79	0.56	1.10	
Hyperglycemia	Lifetime abstainer [ref.]	-			
	Former smoker	1.25	0.93	1.68	0.3420
	Current smoker	1.15	0.84	1.56	
Hypertriglyceridemia	Lifetime abstainer [ref.]	-			
	Former smoker	1.33	0.96	1.84	0.1945
	Current smoker	1.28	0.90	1.81	
Low HDL-C	Lifetime abstainer [ref.]	-			
	Former smoker	1.00	0.69	1.44	0.0201
	Current smoker	1.51	1.04	2.19	

* ORs after adjusting for all study variables and the other individual components of MetS

[ref.]: Reference group