ASSOCIATION BETWEEN OBESITY AND CARDIOMETABOLIC HEALTH IN ASIAN-CANADIAN SUB-GROUPS

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ABSTRACT

Purpose: To examine the association between the WHO's Asian specific trigger points representing 'increased risk' (BMI ≥23 kg/m^2) and 'high risk' (BMI ≥27.5 kg/m^2) with cardiovascular-related conditions in Asian-Canadian sub-groups.

Methods: Six cycles of the Canadian Community Health Survey (2001-2009; N=18 794) were pooled and weighted; multivariable logistic regression was used to estimate the odds of cardiovascular outcomes.

Results: Versus South Asians, Filipinos had higher odds of '≥1 cardiometabolic condition' (OR=1.29). Compared to the normal weight category in each ethnic group, the association between excess adiposity on '≥1 cardiometabolic condition' was highest among Chinese ('increased risk': OR=3.6; 'high risk': OR=8.9). Compared to 'normal weight' South Asians, those in the 'high risk' groups (except Southeast Asian, Arab, and Japanese) were approximately 3-times as likely to report '≥1 cardiometabolic condition'.

Conclusions: The relationship between overweight, obesity, and health risk varied within Asian sub-groups, and was strongest for South Asian and Filipino.

Keywords:

Ethnicity, body mass index, cardiovascular disease, obesity, diabetes, hypertension, heart disease

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ABBREVIATIONS

BF%	Body Fat Per Cent
BMI	Body Mass Index
BP	Blood Pressure
CCHS	Canadian Community Health Survey
CHD	Coronary Heart Disease
CI	Confidence Interval
CRP	C-reactive protein
CVD	Cardiovascular Disease
FM	Fat Mass
LDL	Low Density Lipoprotein
OB	Obese
OR	Odds Ratio
OW	Overweight
PA	Physical Activity
SES	Socioeconomic Status
TG	Trigylcerides
T2DM	Type II Diabetes
VAT	Visceral adipose tissue
VLDL	Very low-density lipoprotein
WC	Waist circumference
WHO	World Health Organization

INTRODUCTION

The health implications of excess weight are well established; overweight and obesity have been shown to be strongly associated with higher rates of cardiovascular disease (CVD), type II diabetes mellitus (DM), hypertension, stroke, dyslipidemia, osteoarthritis, and some cancers (1, 2). Despite this awareness, trends in body-mass index (BMI) have continued to increase around the world (3-6). A recent study using data from a range of health examination surveys and epidemiological studies (representing 96 country-years and 9.1 million participants in 199 countries and territories) showed that between 1980 and 2008, mean BMI worldwide increased by 0.4 kg/m^2 per decade for men, and 0.5 kg/m^2 per decade for women (3). In Canada, the 2011 self-reported prevalence of overweight and obesity among those aged 18 and older was 60.1%, or 7.6 million adults (7). Given these trends and the risks associated, overweight and obesity are serious public health concerns in both developed and developing countries.

While the health risks associated with overweight and obesity are well-accepted, the strength of these associations have been shown to differ across ethnicity, and are complicated by the fact that the relationship between excess weight and cardiometabolic health is largely derived from studies from Occidental groups or persons of European ancestry (8). In Asian populations, the health risk associated with a given level of adiposity has been shown to be higher when compared with Caucasians/Europeans, a finding that has been attributed at least in part due to differences in body fat distribution and body build and frame size (8-12).

In light of this, the World Health Organization (WHO) in 2004 created Asian-specific BMI trigger points for public health action. BMI cut-off points traditionally used for overweight and obesity ($\geq$25 kg/m^2 and $\geq$30 kg/m^2, respectively) were lowered to $\geq$23 kg/m^2 and $\geq$27.5 kg/m^2 to represent 'increased' and 'high' risk categories, respectively, under the proposed Asian-specific BMI trigger points (13). Moreover, research has also shown that within Asian sub-groups, differences exist in the association between excess weight and cardiometabolic risk (14, 15).

A report from the *American Heart Association* in 2010 called for increased research to examine differences in cardiovascular disease (CVD) risk and occurrence in Asian-American sub-groups (16). While the available research suggests that Asian-Americans are at increased risk of complications and death from CVD (17-19), differences in health risk profiles across Asian sub-groups are less understood, as it is common to study this population as a homogenous group (19-21). Statistics Canada has projected that by 2031, the visible minority population in Canada could increase to 14.4 million people, more than double the 5.3 million reported in 2006 (22). The largest contributors to this increase are the South Asian population, which could more than double from 1.3 million in 2006 to 4.1 million in 2031, and the Chinese population, projected to grow from 1.3 million to 3 million in the same time period (22). These dramatic demographic changes highlight the importance of delineating the associations between overweight and obesity on cardiometabolic health conditions among Asian sub-groups.

REVIEW OF THE LITERATURE

Race And Ethnicity In Biomedical Research

The use of race and ethnicity in biomedical research is complex and imprecise due to the fluidity of self-identification. Race is understood as a biological basis for socially constructed categories and implies genetic homogeneity within broadly defined, heterogeneous population groups (23). Ethnicity, on the other hand, refers to membership in a wide range of groups defined by culture, heritage, or national origin, and is often conceptualized more narrowly for research or surveillance purposes (24, 25). Racial/ethnic health disparities, nonetheless, reflect intricate interactions between genetics, host susceptibility and environmental factors such as class and access to health care (21, 26-28). These complex associations have therefore contributed to considerable debate on the use of "race" and "ethnicity" within biomedical research. Those against their use have argued that classifying people into categories of race and ethnicity could be used negatively to reinforce various racial and ethnic stereotypes (29-31). On the other hand, those in favor of using race and ethnicity in biomedical research highlight the importance of documenting health disparities (e.g. underserved communities), especially among subpopulations generally aggregated into larger population groups (21, 32-34).

A 2003 special communication article in the *Journal of the American Medical Association* (26) underscores the challenges in writing about race and ethnicity, and provides a framework for authors to follow when reporting on race and ethnicity in biomedical publications. The three challenges described are: i) understanding and accounting for the limitations of race/ethnicity data, ii) distinguishing race/ethnicity as risk factor or as risk marker, and iii) finding a way to write about race/ethnicity that does not contribute to stigmatization. In particular, it must be emphasized that racial/ethnic self-identification can be complex and multilayered, as many individuals will not have a fixed race/ethnicity that is easily determined. Consequently, these identities are unlikely to sort themselves into mutually exclusive categories to which individuals can be validly and reliably assigned, as there are individuals who identify with more than one racial/ethnic category. Self-identification can also evolve over time as an individual's self-image changes and/or as categories take on new social or political meanings for specific populations or the larger society. To this point, self-report is recommended as the optimal method for collecting racial/ethnic data (26).

In Canada, self-ascribed "ethnicity" is often used in reference to racially or culturally identifiable sub-groups of the Canadian population. The question posed in the Canadian Community Health Survey (CCHS) states (35): "People living in Canada come from many different cultural and racial backgrounds. Are you: 1. White? 2. Chinese? 3. South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)? 4. Black? 5. Filipino? 6. Latin American? 7. Southeast Asian (e.g., Cambodian, Indonesian, Laotian, Vietnamese, etc.)? 8. Arab? 9. West Asian (e.g., Afghan, Iranian, etc.)? 10. Japanese? 11. Korean? 12. Aboriginal Peoples of North America (North American Indian, Métis, Inuit/Eskimo)? 13. Other – Specify".

The use of ethnicity in the CCHS is based on Statistics Canada's definition of "Population group of person", approved as a departmental standard on Jun 15, 2009 (36).

> *"Population group refers to the population group or groups to which the person belongs, for example, White, Chinese, South Asian, Black, Filipino, Latin American, Southeast Asian, Arab, West Asian, Korean or Japanese. These population groups are the groups used on questionnaires which collect data on the visible minority population for Employment Equity purposes. The Employment Equity Act defines visible minorities as*

"persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour".

The disaggregated collection of this data based on self-reports along with other conceptually relevant factors (e.g. SES, age, diet and nutrition, education level, language spoken, country of birth, length of time in country, and place of residence) provides an opportunity for ethnic-specific research and for making meaningful interpretations of health disparities.

Obesity Trends And Prevalence

Obesity (operationalized as body mass index (BMI) $\geq$30 kg/m^2) is an established risk factor for hypertension, diabetes, coronary artery disease and congestive heart failure (1, 2, 37). In spite of this knowledge, the mean BMI around the world has increased dramatically from 1980-2008 (3-6). A study of adults over 20 years of age in 199 countries showed that the global age-standardized prevalence of obesity nearly doubled from 6.4% in 1980 to 12.0% in 2008 (38). Expectedly, the rates of obesity are higher in developed nations. In the United States, in 2009-2010, the prevalence of obesity was 35.5% among adult men and 35.8% among adult women (4, 39). In Canada, the prevalence of obesity in Canada has been on the rise and affects approximately 23% of Canadian adults (28, 40). When those who fall in the overweight category (BMI 25-30 kg/m^2) are included, self-reported rates of overweight and obesity among those aged 18 and older was 60.1%, or 7.6 million Canadian adults in 2011 (7).

Compared to 1981, statistics from the 2007-2009 Canadian Health Measures Survey indicates that the percentage of Canadians who had an elevated waist circumference (>102 cm in men and >88 cm in women), were obese by BMI, or had body composition scores in the fair/needs improvement category (41) more than doubled in all age groups for both men and women (6). To illustrate this, in 2007- 2009, the average 45-year-old Canadian man was about 9.2 kg (20 pounds) heavier than his 1981 counterpart, resulting in a 2 unit increase in BMI and a 6.4 cm (2.5 inches) increase in waist circumference. Similarly, the typical 45-year-old Canadian woman was 5.2 kg and 2 BMI units heavier with a 7.1 cm larger waist circumference (6). These trends have placed obesity on the forefront of the public health agenda.

Overweight And Obesity Among Asian Sub-Groups

Epidemiological studies have also shown that there is considerable variation in the prevalence of obesity across ethnic groups (9, 28, 42-45). Of all ethnic groups, Asians (and Asians sub-groups) have consistently been shown to have the lowest prevalence of overweight and obesity in studies of ethnic variations in Canada (42, 44). In a representative sample of the Canadian population, Tremblay et al. showed that Canadian East/Southeast Asians had the lowest self-reported prevalence of overweight and obesity at 22%, followed by South Asians at 40% and West Asians/Arabs at 45% (28). When Asian sub-groups are disaggregated further, those of Chinese descent have subsequently been shown to have the lowest prevalence of overweight (13.7%) and obesity (3.8%), followed by Japanese/Koreans (OW: 18.5%, OB: 6.1%), Filipino/Southeast Asian (OW:24.2%, OB: 5.5%), South Asian (OW: 26.1%, OB: 8.4%), and Arab/West Asian (OW: 27.1%, OB: 12.7%) (44). In the same study, the prevalence of overweight and obesity was over 2-fold higher in White individuals (OW: 29%, OB: 14.8%) (44).

Healthy Immigrant Effect And Acculturation

While new immigrants to Canada have been observed to have superior health compared to Canadian-born populations (i.e. the healthy immigrant effect), this health advantage is lost over time (46-49). The healthy immigrant effect is a result of immigration procedures that result in the selection of individuals on the basis of wealth, education, language ability, and job skills (characteristics that facilitate social and economic integration and go hand-in-hand with healthy lifestyles), while excluding immigrants with serious medical conditions. However, migration to new social and cultural environments may be stressful for some individuals, and stress coupled with inadequate social support, changes in income, health behaviours and the underutilization of health services may, in turn, be risk factors for ill health (47-49). Acculturation is another factor for why immigrants lose their health advantage. The process of acculturation suggests that the health behaviours (e.g. diet and exercise) of immigrants converge to native-born levels within a decade of living in Canada (49). For example, *'Westernization'* may induce immigrants to adopt a diet higher in total calories and fat but lower in fibre, while simultaneously encouraging reduced expenditure of energy (48).

Research has shown increases in mean BMI in immigrants to Canada with longer length of stay (that after ~20-30 years in Canada, meet or exceed that of non-immigrants) (46, 50), and most minority groups experience a 2 to 6 fold greater risk of developing non-insulin dependent diabetes compared to White Europeans (47, 51). Compared to their siblings in their countries of origin, new immigrants also experience an acceleration in the development of metabolic and vascular dysfunction (52, 53). The 'thrifty genotype', an evolutionary theory to explain adaptations that promote survival in situations of energy scarcity, may account for increasing levels of macronutrient consumption and a predisposition towards obesity and diabetes (45, 54, 55). This highlights the complex interaction between genetics and the environment.

Complicating these relationships even further is the fact that the influence of acculturation on the prevalence of obesity in ethnic minorities is not consistent across Asian sub-groups. In Canada, Chinese women immigrants are 30% less likely to be overweight than native-born White women on arrival (and 10% less likely to be overweight than native born Chinese women), but have been shown to gain weight or remain at the same BMI level after many years in Canada (49). Female Southeast Asian immigrants are similarly less likely to be overweight than native born Whites or Southeast Asians, and although there is a gradual increase with time in country, the prevalence of overweight amongst new immigrants remains considerably lower than individuals of all ethnic groups who were born in Canada (49). A similar pattern is evident for Filipino immigrants and Arab immigrants; however, South Asian immigrant women are initially around 10% less likely to be overweight than native born Whites, and this gap is closed within 15 years (49).

Differences In Cardiometabolic Risk In Asian Sub-Groups

Despite having lower prevalence of obesity, Asians are known to be at elevated risk of cardiovascular events compared with those of European descent (14, 16, 19, 56-60). South Asians in the UK experience approximately 50% higher age-standardized CHD mortality than European Whites (61). The Southall study showed that, in age adjusted analyses, among men with similar BMI, South Asians had higher diabetes prevalence (20% vs. 5%), fasting insulin levels, systolic blood pressure, waist/hip ratio (0.98 vs. 0.94) and triglyceride levels, and lower high density lipoprotein cholesterol levels compared with European men (62). It has also been reported that South Asians develop T2DM 11 years earlier than Europeans (46 y.o vs. 57 y.o) and at a BMI lower than their European counterparts (28.7 kg/m2 vs 29.9 kg/m2) (14, 63). Diabetes prevalence rates in South Asians are 2 to 6 fold higher than age and sex matched Caucasian adults (64, 65).

Chinese people have been shown to exhibit high incidence of stroke despite having CHD mortality rates generally lower than or similar to Caucasians. Chinese generally had a more favourable risk factor profile with lower levels of obesity, total and LDL cholesterol and levels of smoking, but notably they had higher levels of blood pressure (66). Current trends in Canada also show a rapid increase in diabetes incidence among Chinese Canadians compared to the European population between 1996 and 2005 (67).

Moreover, CVD risk factors associated with excess weight also vary across Asian sub-groups (14, 19, 20, 42, 44, 54, 58, 65, 68, 69). Analyses from the National Health Interview Survey (NHIS) showed that while Asian Americans are 30-50% more likely to have type 2 diabetes mellitus than their White counterparts despite having lower BMI, Asian Indians had the highest odds of prevalent type 2 diabetes, followed by Filipinos, other Asians, and Chinese (57). Insulin resistance has also shown to be higher in Asian Indians, and higher prevalence of metabolic syndrome is seen among Filipino and Japanese compared to other Asian groups (59, 70-72). South Asians and Filipinos have been shown to have higher prevalence of coronary heart disease (CHD) and CHD mortality compared to other ethnicities, whereas Japanese and Chinese Americans have lower rates of CHD, but higher rates of stroke compared to Whites (14, 16, 19, 73). Japanese and Chinese Americans also tend to have higher levels of blood pressure despite lower levels of obesity, total and LDL cholesterol and levels of smoking (9, 27, 54, 74-76).

Several representative Canadian studies have quantified ethnic differences in obesity and cardiovascular risk factors (42, 44, 77, 78). For example, Chiu et al. examined cardiovascular risk among people of White, South Asian, Chinese and black ethnicity living in Ontario, Canada (42). Here, the prevalence of cardiovascular risk factors, heart disease and stroke were analyzed after pooling respondent data from 5 cross-sectional health surveys (National Population Health Survey (NPHS) and Canadian Community Health Survey (CCHS)) conducted between 1996 and 2007. Results suggest considerable variation in the prevalence of smoking, obesity, diabetes mellitus and hypertension, and that the prevalence of heart disease and stroke was lowest in the Chinese population (3.2% and 0.6% respectively) and highest among South Asians (5.2% and 1.7%). However, other Asian sub-groups were not included in this study.

In a related study, Liu et al. pooled data from three cycles of the CCHS to examine the prevalence of CVD and associated risk factors in the various Canadian ethnic groups (44). Compared to White individuals, all Asian ethnicities were less likely to smoke, more likely to be physically inactive (except for Korean and Japanese) and were less likely to be obese (except for Arab and West Asian). Hypertension was also more prevalent among those of Filipino or South East Asian ethnicity (odds ratio [OR]= 1.54) (44). While all Asian sub-groups were disaggregated in this study, the classification of overweight and obese still relied on the standard BMI categories. Further, the effect of increasing obesity within each Asian sub-groups were not examined.

Taken as a whole, while Asians overall had a lower prevalence of obesity than White Europeans, they also experienced poorer cardiometabolic health risks at a given BMI. Further work is therefore necessary to examine the BMI-health relationship within Asian sub-groups using Asian-specific BMI cut-off points (8, 10).

Ethnic Differences In Fat Distribution And Body Build

Notwithstanding the above, differences in the association between excess weight and cardiometabolic health risks among Asian sub-groups is attributed at least in part to differences in body fat distribution and body build and frame size (9, 12, 79-81). It has been shown that for a given BMI or waist circumference, the body fat per cent (BF%) is greater in Asians than Caucasians (81-86). In general, for a given BMI, Asians had 3-5% higher BF% compared to Caucasians, and for the same BF%, their BMI was 3-4 units lower (10). Several recent Canadian studies provide further insight into differences in body composition and health risk in Asian sub-groups. In the Multicultural Community Health Assessment Trial (M-CHAT), while BMI and WC were highly correlated with total and regional measures of adiposity in each ethnic group, at a given BMI, Chinese participants had a similar percentage body fat to that of Europeans, whereas South Asians had 3.9% more (79). Above a WC of 71cm, Chinese participants had considerably *more* visceral adipose tissue (VAT) than European-Canadians, whereas South Asians had significantly more VAT than Europeans at all but the most extreme WC (above 105cm) (9, 11, 79). The ratio of total body fat to lean mass was also higher in South Asians when compared to Chinese and European-Canadians.

In turn, this ethnic variation in body fat distribution results in a poorer cardiometabolic risk profile (at the same BMI) as European men and women (14, 87). It has been shown that at similar or lower BMI levels, South Asian men and women present with: significantly higher levels of triglycerides (TG), glucose, insulin, blood pressure (BP), C-reactive protein (CRP), lower levels of high density lipoprotein cholesterol and a higher prevalence of diabetes mellitus, hypertension, and dyslipidemia than European men and women (87). Among Chinese, for a given BMI, elevated levels of glucose-, lipid- and blood pressure related factors were also more likely to be present compared to Europeans (79).

Ethnic differences in body build and frame size further influences fat distribution described above (10). More specifically, differences between ethnic groups in relative leg length have been widely reported. For example, blacks generally have longer legs than Whites, while Chinese and Malays have shorter legs (8). Thus, if two people have the same BF%, the one with shorter legs will have a higher BMI (more mass per cm length in the trunk). Frame size would also affect the BMI/BF% relationship in that for the same BMI, the person who has a bigger frame will have a lower BF% (i.e. more skeletal mass, more muscle mass, and more connective tissue) (10, 82, 88-90).

The Use Of BMI And Rationale For Redefining Obesity In Asians

Despite many common criticisms of BMI (such as the inability to separate weight of adipose tissue from the weight of lean mass) (91, 92), the World Health Organization (WHO) still advocates for its use as a simple anthropometric index of excess weight that is suitable for use in population surveys to categorize individuals into weight categories, and for the screening and tracking of obesity-related health risks. BMI is easy to measure, inexpensive and is widely used for categorizing individuals into weight categories. BMI has been shown to have high validity (0.85-0.97) when based on self-report (93) and with a higher inter-observer reliability than waist circumference (94), making it an ideal measure when working with large cohorts and epidemiological data. Moreover, BMI is a strong predictor of morbidity and mortality (95-97), as it has been shown to be linearly associated with cardiometabolic risk factors such as systolic blood pressure, fasting glucose levels, plasma total cholesterol, very low-density lipoprotein

(VLDL) cholesterol, and low density lipoprotein (LDL) cholesterol levels, and inversely and linearly associated with HDL cholesterol levels in non-smoking men and women (95).

However, the current Canadian (98) and American (99) healthy body weight cut-offs using BMI and waist circumference (WC) were derived from studies of predominantly White and European populations (100), and it is generally agreed upon that the universal BMI criteria are not suitable for all ethnic groups (92, 101, 102). As described previously, obesity-related health risk of Asians tends to be greater than that of Caucasians (101, 103, 104). For Asians, it is not the excess weight (as measured by BMI) that carries the excess health risk; rather, it is the difference in obesity phenotype (that for a given BMI, the percent of fat in Asians is greater than Caucasians). The standard BMI cut-offs may therefore be too high for Asians, consequently masking higher cardiovascular risks associated with excess fat in this population (15, 100, 101, 104-106).

World Health Organization's (WHO) Asian-Specific BMI Guidelines

Given that current healthy body weight cut-offs using BMI were derived from studies of predominantly White and European populations, there has been a movement recommending that these cut-points be revised for use in other ethnic groups, particularly those within the Asia-Pacific region. In 2004, the WHO concluded that the proportion of Asian people with a high risk of diabetes and CVD within the generic 'normal' weight (18.5-24.9 $kg.m^2$) and overweight (25-29.9 $kg.m^2$) BMI categories was substantial. As a result, Asian-specific BMI trigger points for public health action were identified as BMI $\geq$23 kg/m^2 representing 'increased' risk and BMI $\geq$27.5 kg/m^2 representing 'high' risk categories (13).

While the appropriateness of Asian-specific BMI thresholds have since been examined, because of significant gene-environment interactions (such as varying degrees of urbanization, social and economic conditions, and nutrition transitions), it has been suggested that they be applied with caution to Asian immigrants in Western countries (43, 107). These cut-off points are nonetheless important to establish reliable prevalence figures for obesity, and to facilitate the development of appropriately tailored prevention efforts for overweight and obesity amongst Asians (10, 100). To date, only limited research has explored these associations within the Canadian setting, and further work is necessary to understand the implications of the lower BMI cut-points for Asians in Canada

Summary

On the basis of the above, it is clear that the association between obesity and cardiometabolic health risk amongst Asian sub-groups is not well understood. Despite the lower prevalence of overweight and obesity in Asian populations, the health risk associated with a given level of adiposity has been shown to be higher when compared to White Europeans, attributable to differences in body composition and fat distribution. As a consequence, obesity-related health risk amongst Asian sub-groups would be underestimated by the use of the conventional BMI cut-points. With the introduction of the WHO Asian-specific BMI thresholds, population-specific classifications may now be explored. The cumulative effect of the increasing prevalence of obesity and the demographic transition signals the need for further research to understand the associations between overweight and obesity on cardiometabolic health conditions among Asian sub-groups.

OBJECTIVE

To quantify the association between the World Health Organizations' Asian-specific BMI trigger points for public health action of BMI ≥23 kg/m^2 (representing 'increased risk') and BMI ≥27.5 kg/m^2 (representing 'high risk' categories) with cardiovascular risks in Asian sub-groups

Specific Aims:

Aim 1: To examine cardiometabolic risks for each Asian subgroup as compared to South Asians.

Aim 2: To quantify the association between BMI and cardiometabolic disease outcomes.

This manuscript uses data from the Canadian Community Health Survey, obtained through the limited data access program at the York University chapter of the Toronto Research Data Center of Statistics Canada. While the research and analysis are based on data from Statistics Canada, the opinions expressed do not represent the views of Statistics Canada

Abstract

Objectives: To quantify the association between the World Health Organizations' Asian-specific trigger points for public health action ['increased risk': body mass index (BMI) ≥23 kg/m^2, and; 'high risk': BMI ≥27.5 kg/m^2] with self-reported cardiovascular-related conditions in Asian-Canadian sub-groups.

Methods:

Six cycles of the Canadian Community Health Survey (2001-2009) were pooled to examine BMI and health in Asian sub-groups (South Asians, Chinese, Filipino, Southeast Asians, Arabs, West Asians, Japanese and Korean) form (N=18 794 participants, ages 18-64 y), Multivariable logistic regression, adjusting for demographic, lifestyle characteristics and acculturation measures, was used to estimate the odds of cardiovascular-related health (high blood pressure, heart disease, diabetes, 'at least one cardiometabolic condition') outcomes across all eight Asian sub-groups.

Results: Compared to South Asians (OR=1.00), Filipinos had higher odds of having 'at least one cardiometabolic condition' (OR=1.29, 95% CI: 1.04-1.62), whereas Chinese (0.63, 0.474-0.9) and Arab-Canadians had lower odds (0.38, 0.28-0.51). In ethnic-specific analyses (with 'acceptable' risk weight as the referent), 'increased' and 'high' risk weight categories were the most highly associated with 'at least one cardiometabolic condition' in Chinese ('increased': 3.6, 2.34-5.63; 'high': 8.9, 3.6-22.01). Using normal weight South Asians as the referent, all individuals in the 'high' risk weight category across ethnic groups (except for Southeast Asian, Arab, and Japanese) were approximately 3-times as likely to have report 'at least one

cardiometabolic condition'.

Conclusion:

Differences in the association between obesity and cardiometabolic health risks were seen among Asian sub-groups in Canada. The use of WHO's lowered Asian specific BMI cut-offs identified obesity-related risks in South Asian, Filipino and Chinese sub-groups that would have been masked by traditional BMI categories. These findings have implications for public health messaging, especially for ethnic groups at higher odds of obesity related health risks.

Keywords:

Ethnicity, body mass index, cardiovascular disease, obesity, diabetes, hypertension, heart disease

Introduction

Asians currently represent the fastest growing ethnic group in Canada, with South Asians (4.0% of total Canadian population) and Chinese (3.9%) currently ranked as the first and second largest visible minority groups, respectively (108). Statistics Canada has projected that by 2031, the visible minority population in Canada could increase to 14.4 million people, more than double the 5.3 million reported in 2006 (22). The largest contributors to this increase are the South Asian population, which is expected to increase 3-fold from 1.3 million in 2006 to 4.1 million in 2031, and the Chinese population, projected to grow from 1.3 million to 3 million (22).

Our knowledge of obesity and cardiometabolic health risks has been historically derived from studies of Occidental groups or persons of White European or American ancestry. These assumptions and developed prediction models have generally been assumed to hold true when applied to other ethnic groups (8, 14). Despite having a lower prevalence of obesity, Asians are known to be at an increased risk of cardiovascular (CVD) risk factors compared with those of European descent (14, 16, 56-59), a finding that has been attributed at least in part due to differences in body fat distribution and body build and frame size (9-12, 101). Moreover, CVD risk factors associated with excess weight also vary by Asian sub-groups (14, 19, 20, 42, 44, 54, 58, 68). For example, despite lower mean BMIs, Asian Americans are 30-50% more likely to have type 2 diabetes mellitus than their White counterparts. In this analysis, Asian Indians had the highest odds of prevalent type 2 diabetes, followed by Filipinos, other Asians, and Chinese (57). Insulin resistance has also shown to be higher in Asian Indians, and higher prevalence of metabolic syndrome is seen among Filipino and Japanese compared to other Asian groups (59, 70-72).

Given that in Asian populations, the health risk associated with a given level of adiposity has been shown to be higher when compared with Caucasians/Europeans, the use of conventional BMI cut-off points of 25 kg/m^2 (overweight) and 30 kg/m^2 (obesity) may underestimate the prevalence of obesity in Asians and its associated health risk (8, 10, 16). In light of this, the World Health Organization (WHO) in 2004 created Asian-specific BMI trigger points for public health action. BMI cut-off points traditionally used for overweight and obesity ($\geq$25 kg/m^2 and $\geq$30 kg/m^2, respectively) were lowered to $\geq$23 kg/m^2 and $\geq$27.5 kg/m^2 to represent 'increased risk' and 'high-risk' categories, respectively (13).

In order to improve public health screening and to develop ethnic-specific CVD prevention strategies in Canada, the relationship of obesity to cardiometabolic risk factors requires additional study. Therefore, the objective of this analysis is to determine the association between the World Health Organization's Asian-specific BMI trigger points with self-reported cardiometabolic health in Asian-Canadian sub-groups.

Methods

Data source

This analysis is based on data from six cycles of the Canadian Community Health Survey (CCHS; Cycles 1.1, 2.1, 3.1, 2007, 2008, and 2009), obtained through the limited data access program at the York University chapter of the Toronto Research Data Center of Statistics Canada.

The CCHS is a national cross-sectional survey that collects information related to health status, health care utilization and health determinants for the Canadian population. It relies upon a large sample of respondents and is designed to provide reliable estimates at the health region level. Data collection occurred every two years prior to 2007 (i.e. cycles 1.1 (2001), 2.1 (2003) and 3.1 (2005)) and annually starting in 2007 (cycles 2007, 2008 and 2009). Interviews were conducted both in person and over the telephone. Three sampling frames were used to select the sample of households: 49% of the sample of households came from an area frame, 50% came from a list frame of telephone numbers and the remaining 1% came from a Random Digit Dialing (RDD) sampling frame.

The CCHS targets persons aged 12 years or older who are living in private dwellings in the ten provinces and the three territories. Excluded from this survey are persons living on Indian Reserves or Crown lands, residents of institutions, full-time members of the Canadian Armed Forces and residents of certain remote regions. Its coverage is in the range of 98% in the provinces, but varies across other regions (Territories: 98%; Yukon: ~90%; Northwest Territories: 97%, and; Nunavut: 71% (due to the exclusion of some remote regions). To provide reliable estimates, a sample of 65 000 respondents is required on an annual basis for a total of approximately 130 000 respondents per every 2-year cycle.

Consistent with previous studies (28, 44, 109), the six survey cycles were pooled to obtain a sufficient sample size for the exploration of sub-group differences (110, 111).

Study Sample

After combining the six cycles of the CCHS, there were a total of 27 531 participants from the eight Asian ethnic groups. All respondents with missing ethnicity or with multiple responses for ethnicity or missing height and weight measurement were excluded from the onset. Following study exclusions for age <18 or ≥65 (n=6 254), those who were pregnant at time of interview (n=330), those missing BMI measurements (n=619), those in the top 1% of BMI (i.e.

BMI>35.7, n=203) and those who were underweight (i.e. BMI<18.5, n=1 331), the final analytic sample included 18 794 survey participants. The survey population was then weighted to become representative of the Canadian population between the survey years (2001-2009) (111).

Study Variables

Independent (exposure) variables

All participants were asked to self-ascribe which cultural and racial background they were from. To assess Asian ancestry, only participants who self-ascribed an ethnicity as Chinese, South Asian (e.g., East Indian, Pakistani, Sri Lankan), Filipino, Southeast Asian (e.g., Cambodian, Indonesian, Laotian, Vietnamese), Arab, West Asian (e.g., Afghan, Iranian), Japanese, and Korean were retained for further analysis. Self-reported height without shoes (in metres) and weight (in kilograms) was used to place respondent's into the WHO's Asian specific trigger points for public health action representing 'increased risk' (BMI $\geq$23 kg/m^2) and 'high risk' (BMI $\geq$27.5 kg/m^2) (13).

Dependent (outcome) variables

Participants were asked about "long-term conditions" which were expected to last (or had already lasted) 6 months or more and that had been diagnosed by a health professional. Obesity-related cardiovascular conditions in the current analysis included self-reported high blood pressure (yes/no), diabetes (yes/no), heart disease (yes/no), and a composite variable of the presence of 'at least one cardiometabolic condition'.

Covariates

Demographic characteristics included sex, age of participant at time of survey, marital status (single never married vs. other), highest level of education attained (less than secondary school graduation, secondary school graduation, some post-secondary, post-secondary graduation), household income, urban versus rural dwelling, immigrant status (non-immigrant vs. immigrant), length of time since immigration (years), and ability to 'converse in English' (yes/no). Income adequacy (i.e., lowest, lower-middle, upper-middle and highest income) was subsequently estimated using annual household income and household size as defined by Statistics Canada (112, 113). Lifestyle characteristics included sedentary leisure time, leisure time physical activity, daily fruit and vegetable consumption, stress level, smoking status ("never smoked" vs "ever smoked") and alcohol consumption ("did not drink in the last 12 months", "occasional drinker", and "regular drinker"). Sedentary leisure time (defined as the total number of hours per week respondents spent reading, watching television or videos, playing video games and on the computer) was categorized into 3 groups by tertiles (≤14 hrs/week, 15-24 hrs/week, and ≥25 hrs/week). A leisure time physical activity index (PAI; kcal/kg/day; kkd) was created; this variable reflects the average daily energy expenditure of leisure time activities in the past three months and is based on self-reported frequency and duration of physical activity along with the metabolic equivalent of each activity. Daily consumption of fruits and vegetables was quantified as the number of times (frequency) per day, rather than the amount consumed. Participants were asked to rate their self-perceived life stress on most days ("not at all stressful", "not very stressful", "a bit stressful", "quite a bit stressful", and "extremely stressful").

Statistical Analysis

The combination of data from different cycles required a recalculation of sample weights to represent the characteristics of the pooled sample, which covers the combined time periods of the individual cycles. The original sampling weights were rescaled by a constant factor ($\alpha_i = 1/k$, where k is equal to the number of cycles used), and the weighted proportions (%) of each variable was estimated. Statistical significance for continuous and categorical variables was assessed by ANOVA and χ^2, respectively, for the overall sample and for each ethnic group. To check for effect modification by ethnicity, a general linear model (GLM) was used to test for interactions between BMI and ethnicity on cardiometabolic conditions. In all models (unadjusted, adjusted for demographics, and adjusted for demographics and lifestyle), there were significant interactions between ethnicity and BMI on all disease outcome measures ($p<0.05$).

Three logistic regression models were subsequently used to explore the independent and joint effects of ethnicity and overweight / obesity on cardiometabolic-related health. First, the odds of obesity-related chronic disease in Asian sub-groups (compared to South Asians; OR=1.00) was estimated after accounting for various demographic, lifestyle, and acculturation characteristics. Second, logistic regression was used to estimate the odds of cardiometabolic diseases by BMI categories (compared to the 'acceptable risk' BMI category ($\geq$18.5-23 kg/m^2; OR=1.00)) within each ethnic group. Finally, an overall analysis using South Asians in the 'acceptable risk' category as the referent group was conducted to examine the effect of obesity on chronic conditions across all BMI and Asian ethnic groups concurrently. Consistent with Statistics Canada guidelines, all cells with less than 10 observations, or a coefficient of variation

≥33% were suppressed (111). All analyses were conducted using SAS version 9.2 (Cary, NC, U.S.A) with statistical significance was set at alpha <0.05.

Results

Descriptive Characteristics

Characteristics of participants are presented in **Table 1**. The mean age of the pooled sample was 38.7 years, and 52.8% were male. Of the eight Asian ethnic groups, Chinese and South Asians accounted for the majority of the study sample (approximately 31% each), while Japanese accounted for the fewest (1.6%). The mean BMI overall was 24 $kg \cdot m^{-2}$, with a distribution of 43.4%, 41.5% and 15.1% in the 'acceptable risk', 'increased risk' and 'high risk' categories, respectively, based on WHO's Asian-specific BMI trigger points. Eighty-five percent of the sample identified themselves as immigrants to Canada. Furthermore, the majority of respondents had a household education level of at least college or university, and belonged to the 'Upper Middle' or the 'Highest' income quartiles.

Table 2 presents the full descriptive characteristics of the sample by Asian sub-groups. Among Asian sub-groups, Arabs (29.2%), West Asians (19.5%), and South Asians (19.3%) had the highest prevalence of individuals in the 'high risk' BMI category, while Chinese (8.2%) had the lowest. The Chinese sub-group also had the highest percentage of respondents in the 'acceptable risk' BMI category (56.2%). Similarly, mean BMI was highest among Arabs (25.5 $kg \cdot m^{-2}$) and lowest in Chinese (23 $kg \cdot m^{-2}$). While Japanese and Koreans were most likely to report having ever smoked cigarettes (50.8% and 49.8%, respectively) and being regular drinkers of alcohol (60.7% and 58.5%, respectively), they were also most likely to be classified as physically active (23% and 26.7%, respectively).

Figure 1 presents the prevalence of self-reported cardiovascular conditions according to ethnicity. In general, Filipinos were most likely to report having high blood pressure (15.4%) and 'at least one cardiometabolic condition' (18.4%), whereas South Asians (6.2%) and West Asians (6.0%) were most likely to report having diabetes. West Asians also reported the highest prevalence of heart disease (6.5%).

Association between ethnicity and cardiometabolic conditions

The odds of reporting a physician-diagnosed cardiometabolic condition (i.e. high blood pressure, diabetes, heart disease, or 'at least one cardiometabolic condition') for each ethnic group compared to South Asians (OR=1.00) is presented in **Table 3** (unadjusted model is presented in **Table 5** of **Appendix A**). After adjusting for covariates, when compared to South Asians, Filipinos reported 60% greater likelihood of high blood pressure *(OR, lower CI-upper CI)* (1.6, 1.05-2.44). As expected, nearly all Asian sub-groups had lower odds of diabetes compared to South Asians. Finally, compared to South Asians, the odd of having 'at least one cardiometabolic condition' was significantly lower in Chinese (0.63, 0.44-0.90) and Arabs (0.38, 0.28-0.51), but significantly higher in Filipinos (1.29, 1.04-1.62); no differences were observed in the other Asian ethnic groups.

Association between ethnicity, BMI category and 'at least one cardiometabolic condition'

Table 4 shows the adjusted odds of 'at least one cardiometabolic condition' for individuals in the 'increased risk' and 'high risk' BMI categories compared to those in the 'acceptable risk' BMI category in each ethnic sub-group. Overall, Asians in the 'increased' and 'high' risk categories were two- and four- times more likely to report 'at least one cardiometabolic condition' compared to those in the 'acceptable risk' category. However, this effect was not consistent across sub-groups. Specifically, odds were greatest for Chinese (increased: 3.6, 2.34-5.63; high: 8.9, 3.6-22.01), lower for South Asian (increased: 1.74, 1.23-2.46; high: 3.37, 2.02-5.65), and only reaching statistical significance in the 'high' risk category for Filipinos (2.39, 1.27-4.47), Southeast Asians (3.38, 1.4-8.16) and Koreans (3.15, 1.36-7.33).

Finally, we calculated the adjusted OR of 'at least one cardiometabolic condition' for each BMI category in each Asian sub-group compared to South Asians in the 'acceptable risk' weight category (**Table 4**). South Asians (increased: 1.79, 1.18-2.71; high: 3.55, 2.26-5.59) and Filipinos (increased: 2.59, 1.5-4.46; high: 3.26, 2.18-4.89) had significantly higher odds of 'at least one cardiometabolic condition' than South Asians in the 'acceptable risk' weight category. Among the other ethnic sub-groups, only the 'high risk' weight category for Chinese (3.05, 1.21-7.67), West Asians (2.75, 1.26-6.01), and Koreans (3.17, 1.04-9.67) were at higher odds versus South Asians in the 'acceptable risk' category. Chinese in the 'acceptable risk' category had significantly lower odds of having 'at least one cardiometabolic condition' than normal weight South Asians (0.41, 0.24-0.69).

Discussion

While Asians are often studied as a broad group, the results of this study suggest that the relationship between obesity and cardiometabolic conditions varies across Asian ethnicities. When compared to a common referent group (i.e. South Asians in the 'acceptable risk' weight category), the relationship between excess weight and poor cardiometabolic health is strongest in the Filipino and South Asian sub-groups. Within sub-groups, the association between 'increased' and 'high' risk BMI categories and 'at least one cardiometabolic condition' also varies by sub-group and is highest among Chinese.

Asians Are Different From Each Other In Their BMI And CVD Risks

These analyses confirm previous findings that the classification of Asians as a homogenous group can mask health risk amongst diverse Asian populations (19-21). Results of this analysis demonstrate that Asian sub-groups differed from each other in cardiovascular risk factors such as smoking, physical activity level, alcohol, BMI, high blood pressure, diabetes and heart disease. Compared to South Asians, only Filipinos had higher odds of 'at least one cardiometabolic condition', whereas Chinese and Arabs had lower odds, and no difference was observed in the other ethnic sub-groups. All Asian sub-groups had lower odds of diabetes compared to South Asians, except for West Asians and Koreans (where no difference was observed).

Two notable Canadian studies have examined ethnic differences in obesity and cardiovascular disease that corroborate our findings (42, 44). In the first, Chiu et al. (2010) examined cardiovascular risk among people living in Ontario, Canada (between 1996 and 2007) who self-ascribed their ethnicity as White, South Asian, Chinese or black (42). They found considerable variations by ethnicity in the prevalence of smoking (South Asian: 8.6%, Chinese: 8.7%, black: 11.4% and White: 24.8%), obesity (Chinese: 2.5%, South Asian: 8.1 %, black: 14.1%, and White: 14.8%), diabetes mellitus (White: 4.2%, Chinese: 4.3%, South Asian: 8.1%, and black: 8.5%) and hypertension (White: 13.7%, Chinese: 15.1%, South Asian: 17%, and black: 19.8%). Age- and sex- standardized mean BMI was lowest among the Chinese respondents (22.3 $kg.m^{-2}$), followed by South Asian (24.2 $kg.m^{-2}$), White (25.3 $kg.m^{-2}$) and black

(25.5 $kg.m^{-2}$) populations. Overall, Chinese respondents had the most favourable cardiovascular risk factor profile, with 4.3% of the population reporting two or more major cardiovascular risk factors, followed by the South Asian (7.9%), White (10.1%) and black (11.1%) respondents.

In the second study, Liu et al. pooled data from three cycles (2000, 2003 and 2005) of the CCHS to examine the prevalence of CVD and associated risk factors in the various Canadian ethnic groups (44). The prevalence of cardiovascular risk factors in this study are consistent with the Liu paper. Compared to White individuals, people from most visible minorities were less likely to smoke, more likely to be physically inactive, and were less likely to be obese. After adjustment for socio-demographic characteristics and chronic conditions, Liu et al. found that diabetes and hypertension were significantly more prevalent amongst South Asians (adjusted OR 2.17 for diabetes and 1.18 for hypertension), Filipino or South-East Asian respondents (adjusted OR 1.58 for diabetes and 1.54 for hypertension) than White respondents. No differences were seen for other Asian ethnicities as compared to Whites.

Ethnic Variation in Health Risk Associated with Obesity

Building on the work of others (42, 44), this study examines the relationship between obesity and cardiometabolic risk among Asian sub-groups in Canada. In the present study, when all Asian sub-groups were collapsed, those within the 'increased' or 'high' BMI categories were 2- to 4- times more likely to have 'at least one cardiometabolic condition'. When analyses were repeated within each Asian ethnic group, differences emerged. Most strikingly, the relationship between BMI and 'at least one cardiometabolic condition' was strongest in Chinese being 3.6 and 9 times higher in the 'increased' and 'high' risk BMI categories, respectively.

Our results are consistent with other literature on the effect of obesity on cardiovascular health risk in Asian populations (15, 100, 114-122). Several studies have shown that the association between BMI and cardiometabolic risks is steepest in Chinese compared to other ethnicities (116, 119, 122). Katz et al. showed that the adjusted incidence difference for hypertension per 1000 persons in young adults with a BMI of 25 vs. those of BMI of 21 was 83 for Chinese, 50 for Blacks and 30 for Whites. Among middle-aged adults, similar patterns are seen with incidence differences of 137 for Chinese, 49 for Blacks, and 54 for Whites (119).

There are several possible explanations for the observed differences in the relationship between obesity and cardiometabolic risk factors between Asian ethnic sub-groups. Both environmental and genetic factors are likely to be important in determining CVD risk. Lifestyle changes and increasing affluence have led to a high prevalence of obesity, insulin resistance, T2DM and CVD among Asians living in the West. However, previous research indicates that differences in CVD cannot be explained by differences in conventional cardiovascular risk factors alone (123). Having adjusted for these modifiable/behavioural characteristics in this study, other factors such as differences in the relationship between BMI and BF% are likely contributors to the observed differences.

Differences in the association between excess weight and cardiometaolic health risks among Asian sub-groups is attributed at least to differences in BMI-Fat Mass (FM)% as a result of differences in body build and/or frame size. BMI does not distinguish between individuals or populations who have very long or short legs relative to torso length. BMI will tend to underestimate obesity among those with long legs and over estimate obesity among those with short legs relative to torso length (8, 91, 124). It is well known that ethnic groups differ in frame size and in relative leg length (relative sitting height) and that his has an impact on BMI (8, 10, 82, 83, 89, 124). The distribution of body fat is also different in Asians compared with Europeans whereby Asians show a greater proportion of VAT for a given total body fat compared with Europeans (51, 62, 80, 81, 84, 90, 125-127). VAT is an independent risk factor for CHD, hypertension, T2DM and impaired glucose tolerance through various physiological mechanisms in the body (14, 84, 89, 90, 128-130).

Several recent studies provide further insight into differences in body composition and health risk in Asian sub-groups. In the Multicultural Community Health Assessment Trial (M-CHAT) (11, 79), while BMI and WC were highly correlated with total and regional measures of adiposity in each ethnic group, at any BMI, Chinese participants had a similar percentage body fat to that of Europeans, whereas South Asians had 3.9% more. Above a WC of 71cm, Chinese participants had considerably more visceral adipose tissue (VAT) than European-Canadians, whereas South Asians had significantly more VAT than Europeans at all but the most extreme WC category (>105cm) (11, 79).

Strengths and Limitations

Notable strengths of the current analysis include the use of a large, nationally representative sample, disaggregated into each Asian sub-group, and the inclusion of important socio-demographic and lifestyle variables associated with obesity and cardiovascular risk factors. Unlike previous studies that have used the 'White' population as the referent group, the current analysis opted for an internal comparison group within the broader 'Asian' categorization, as even among persons classified as "White", there is considerable variation in factors such as country of origin, birth cohort, and acculturation that may confound the relationship between obesity and health risk (115, 131). By using the more sensitive WHO cut-points for BMI in

Asians, this analysis is able to capture variations in health risk that might otherwise have been missed.

There are also several limitations that need to be noted. First, the possibility of under-reporting BMI (via an underestimation of weight among females and an overestimation of height amongst males) cannot be excluded (132). Differential reporting of obesity have also been shown to vary by ethnicity (133). In addition, the way people experience and label diseases and symptoms differ across cultures and ethnic backgrounds (134-136), which has impact on their health behaviours and practices and therefore how they are reported. The underestimation of chronic conditions by participants is also a possibility, but would have biased our results towards the null. The limitations of using BMI cut-offs are also well known (89, 91, 137, 138); however, due to the relative ease of measurement and interpretation (94), and high specificity and validity (139, 140), BMI may be considered a reasonable proxy of weight-related health risk in *population-based* studies (98, 141). Furthermore, type of diabetes was not differentiated. Finally, despite the large overall sample size used in this study, analyses for heart disease within obese categories of some ethnic groups had to be suppressed.

Conclusion

Results of this study provide additional insight into the relationship between obesity and cardiovascular health across Asian sub-groups, as the appropriate classification of sub-populations is necessary if the mechanisms underlying such differences in health risk are to be understood and monitored. When taken together, higher odds of cardiovascular disease associated with overweight and obesity for the Chinese, Filipino and South Asian groups, and the steeper association between excess adiposity and cardiovascular risk in Chinese, has important public health implications for targeted screening and culturally-specific interventions focusing on susceptible Asian-ethnic communities. The results of this thesis also indicate to clinicians the need to address overweight and obesity specifically among the South Asians and Filipino sub-groups.

Figure legends:

Figure 1: Prevalence of cardiometabolic conditions by Asian sub-groups, 2001-2009.

Table 1: Characteristics of overall study sample, Canada, 2001-2009

Characteristic		**Weighted Frequency**	**Percent %**	***p***
Sex	Male	1 050 611	52.8	<0.001
	Female	940 441	47.2	
Self-reported Ethnicity	Chinese	628 857	31.6	<0.001
	South Asian	625 916	31.4	
	Filipino	231 719	11.6	
	Southeast Asian	156 683	7.9	
	Arab	141 199	7.1	
	West Asian	96 783	4.9	
	Japanese	32 682	1.6	
	Korean	77 213	3.9	
BMI Category (kg/m^2) – Asian	18.5-<23	863 919	43.4	<0.001
	23-<27.5	825 751	41.5	
	≥27.5	301 383	15.1	
Marital Status	Single, Never Married	549 683	27.6	<0.001
	Everyone else	1 441 370	72.4	
Highest Household Education Level	Less than high school graduation	58 448	3.2	<0.001
	High school graduation	173 816	9.4	
	Some post-secondary	102 668	5.6	
	College or university degree	1 515 356	81.9	
Household Income Quartile	Lowest income quartile	222 356	12.9	<0.001
	Lower middle income quartile	366 876	21.3	
	Upper middle income quartile	545 034	31.7	
	Highest income quartile	586 735	34.1	
Can have a conversation in English		1 792 143	90.0	<0.001
Immigrant to Canada		1 678 269	85.0	<0.001
Smoking	Never Smoked	1 300 063	65.3	<0.001
	Ever Smoked	690 990	34.7	
Alcohol	Regular	783 389	39.5	<0.001
	Occasional Drinker	386 550	19.5	
	Did not drink in last year	814 260	41.0	
Physician diagnosed high blood pressure		192 267	9.7	<0.001
Physician diagnosed diabetes		82 440	4.1	<0.001
Physician diagnosed heart disease		34 296	1.7	<0.001
At least 1 chronic disease		260 789	13.1	<0.001
Physical Activity Level	Active	376 597	19.4	<0.001
	Moderate	403 684	20.8	
	Inactive	1 163 972	59.9	
Sedentary time (Tertiles)	<=14 hrs/wk	396 700	36.5	0.004
	15-24 hrs/wk	364 421	33.5	
	25->45 hrs/wk	327 215	30.1	
Urban/Rural	Urban	1 950 562	98.0	<0.001
	Rural	40 490	2.0	
Stress	Not at all stressful	200 860	10.1	<0.001
	Not very stressful	441 059	22.2	
	A bit stressful	872 218	44.0	
	Quite a bit stressful	395 858	20.0	
	Extremely stressful	73 549	3.7	
Daily Energy Expenditure - kcal/kg/day (mean, 95% CI)		1.7 (1.54-1.88)		
Age – years (mean, 95% CI)		38.7 (38.38-39.03)		
Body Mass Index – kg/m^2 (mean, 95% CI)		24.0 (23.73-24.24)		
Frequency of Daily Fruits/Vegetable Consumption (mean, 95% CI)		4.7 (4.52-4.82)		
Household size		3.7 (3.53-3.85)		

Table 2: Characteristics of Asian sub-groups, Canada, 2001-2009

		Chinese (%)	South Asian (%)	Filipino (%)	Southeast Asian (%)	Arab (%)	West Asian (%)	Japanese (%)	Korean (%)
	Weighted Frequency	**n=628 857**	**n=625 916**	**n=231 720**	**n=156 683**	**n=141 199**	**n=96 783**	**n=32 682**	**n=77 213**
Sex	Male	52.9	54.3	44.7	54.9	58.7	55.4	43.5	48.6
	Female	47.1	45.7	55.3	45.1	41.3	44.6	56.5	51.5
BMI Category (kg/m^2) - Asian	18.5-<23	56.2	34.5	40.3	44.1	30.2	37.7	49.4	47.9
	23-<27.5	35.6	46.2	44.8	42.7	40.6	42.8	38.1	39.9
	≥27.5	8.2	19.3	14.9	13.2	29.2	19.5	12.5	12.2
Marital Status	Single, Never Married	29.2	23.6	30.5	26.8	31.3	29.2	27.3	31.9
	Everyone else	70.8	76.4	69.5	73.2	68.7	70.9	72.7	68.1
Highest Household Education Level	Less than high school	2.8	3.5	0.5	6.1	3.7	6.6	1.0	0.7
	High school graduation	10.2	10.8	3.3	13.5	5.2	11.1	5.9	8.0
	Some postsecondary	6.6	5.2	3.4	6.4	5.6	4.6	4.6	6.3
	College or university	80.5	80.5	92.7	73.9	85.5	77.7	88.5	85.0
Household Income Quartile	Lowest	13.4	11.5	7.8	11.6	22.5	21.9	9.4	12.9
	Lower middle	19.2	23.9	19.7	20.5	26.5	19.5	13.6	20.2
	Upper middle	30.6	30.9	35.9	36.2	29.8	27.6	22.2	37.6
	Highest	36.9	33.7	36.7	31.6	21.2	31.0	54.8	29.4
Can have a conversation in English		84.5	93.4	97.4	88.2	84.7	93.7	97.3	91.7
Immigrant to Canada		83.5	85.5	88.9	86.4	87.6	95.2	43.1	78.7
Smoking	Never Smoked	67.1	71.9	63.2	62.9	52.4	56.0	49.2	50.2
	Ever Smoked	32.9	28.1	36.8	37.1	47.6	44.0	50.8	49.8
Alcohol	Regular	39.7	35.9	37.1	45.6	34.1	42.4	60.7	58.5
	Occasional Drinker	25.8	12.2	28.8	19.6	11.2	15.8	16.9	19.6
	Did not drink in last year	34.4	51.9	34.2	34.8	54.7	41.8	22.4	21.9
Physician diagnosed high blood pressure		8.5	9.8	15.4	9.8	8.0	4.7	10.2	9.6
Physician diagnosed diabetes		2.3	6.2	4.5	3.8	2.3	6.0	3.4	2.9
Physician diagnosed heart disease		1.8	1.7	1.0	0.3	1.8	6.5	1.9	0.8
At least one cardiometabolic condition		11.1	14.7	18.4	12.3	9.2	11.7	11.7	11.8
Physical Activity Level	Active	17.3	19.7	20.4	20.8	17.3	21.9	23.3	26.7
	Moderate	21.1	21.1	21.0	18.7	20.4	18.8	29.0	19.0
	Inactive	61.6	59.3	58.6	60.5	62.3	59.3	47.8	54.4
Sedentary time (Tertiles)	<=14 hrs/wk	28.7	44.5	40.2	43.2	32.9	34.6	28.9	23.9
	15-24 hrs/wk	34.5	30.2	33.9	31.7	36.7	34.4	37.2	44.5
	25->45 hrs/wk	36.8	25.3	25.9	25.1	30.4	31.0	33.9	31.7
Urban/Rural	Urban	98.7	97.5	98.1	97.3	98.7	98.6	96.6	95.5
	Rural	1.4	2.5	1.9	2.7	1.3	1.4	3.4	4.5
Stress	Not at all stressful	8.9	12.1	11.2	11.0	8.4	7.5	8.8	6.2
	Not very stressful	23.8	20.5	26.3	20.7	15.5	15.5	33.3	30.6
	A bit stressful	45.6	43.0	42.2	47.4	41.7	43.5	41.5	43.4
	Quite a bit stressful	18.9	20.1	17.5	17.9	28.0	27.8	11.4	17.6
	Extremely stressful	2.7	4.4	2.9	3.1	6.3	5.8	5.0	2.2
Daily Energy Expenditure - kcal/kg/day (mean, 95% CI)		1.56 (1.43-1.7)	1.72 (1.51-1.93)	1.92 (1.64-2.2)	1.76 (1.52-2)	1.67 (1.36-1.98)	1.73 (1.41-2.05)	1.89 (1.6-2.19)	2 (1.8-2.21)
Age – years (mean, 95% CI)		39.72 (38.84-40.59)	38.04 (37.52-8.56)	39.24 (38.51-39.97)	38.16 (37.2-39.12)	36.7 (35.63-37.76)	37.94 (35.97-39.91)	43.03 (40.78-45.27)	38.07 (36.73-39.41)
Body Mass Index – kg/m^2 (mean, 95% CI)		23 (22.83-23.18)	24.62 (24.4-24.85)	24.15 (23.92-24.39)	23.76 (23.52-24)	25.5 (25.17-25.83)	24.63 (24.22-25.05)	23.4 (23.03-23.77)	23.44 (22.9-23.98)
Mean Frequency of Daily Fruits/Vegetable Consumption		4.35	4.85	4.76	4.63	4.82	4.99	4.7	4.87
Mean household size		3.33	4.07	3.86	3.82	3.70	3.51	2.94	3.25

Figure 1

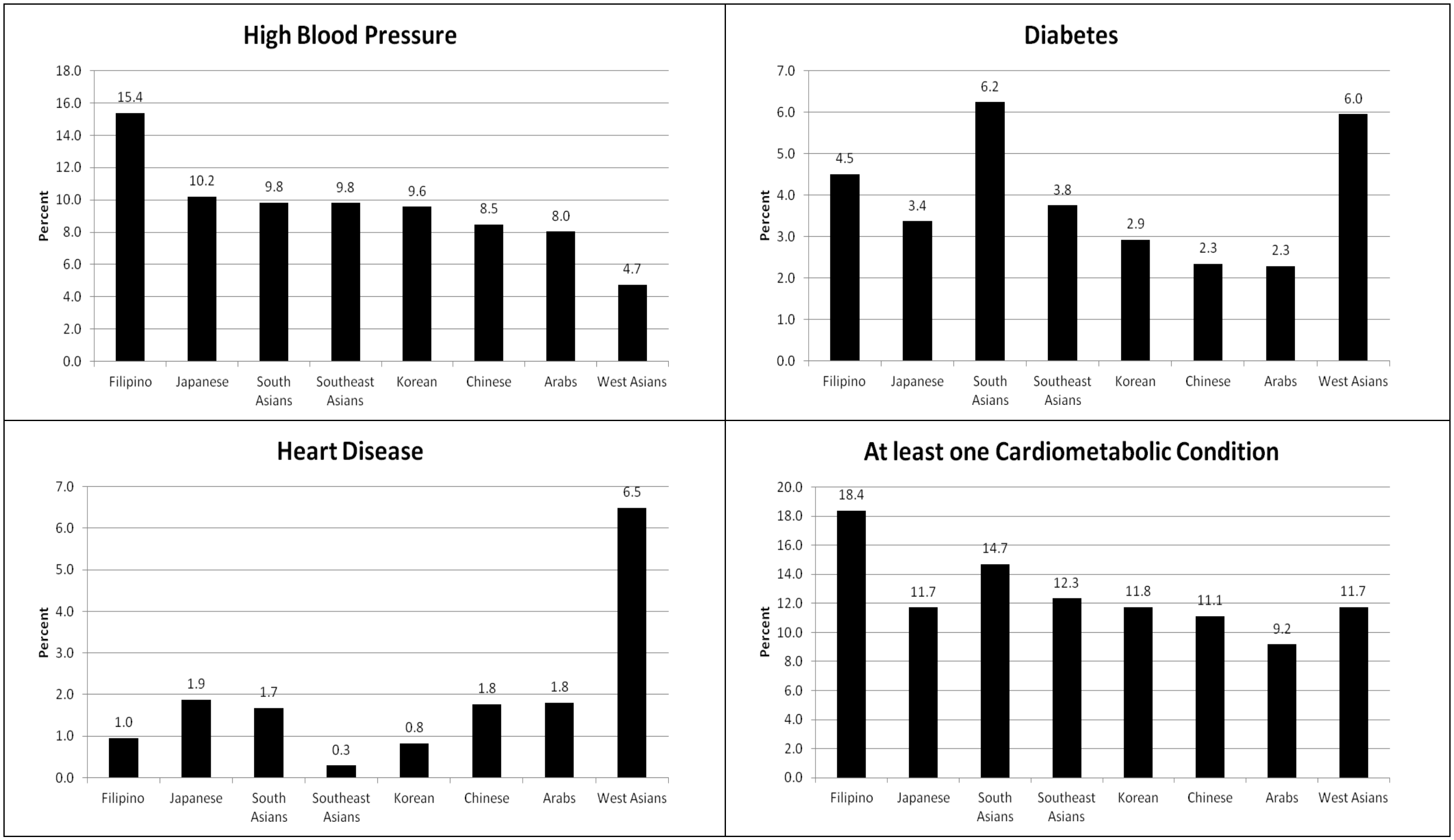
High Blood Pressure
Percent
Filipino 15.4
Japanese 10.2
South Asians 9.8
Southeast Asians 9.8
Korean 9.6
Chinese 8.5
Arabs 8.0
West Asians 4.7
Diabetes
Percent
Filipino 4.5
Japanese 3.4
South Asians 6.2
Southeast Asians 3.8
Korean 2.9
Chinese 2.3
Arabs 2.3
West Asians 6.0
Heart Disease
Percent
Filipino 1.0
Japanese 1.9
South Asians 1.7
Southeast Asians 0.3
Korean 0.8
Chinese 1.8
Arabs 1.8
West Asians 6.5
At least one Cardiometabolic Condition
Percent
Filipino 18.4
Japanese 11.7
South Asians 14.7
Southeast Asians 12.3
Korean 11.8
Chinese 11.1
Arabs 9.2
West Asians 11.7

Table 3: Multivariable-adjusted odds ratios of 'at least one cardiometabolic condition' for Asian sub-groups compared to South Asians

	High Blood Pressure		**Diabetes**		**Heart Disease**		**At least one Cardiometabolic Condition**	
Self-reported Ethnicity	**OR (95% CI)**							
South Asian	***1.00 (referent)***		***1.00 (referent)***		***1.00 (referent)***		***1.00 (referent)***	
Chinese	0.76	(0.55-1.06)	**0.25**	**(0.12-0.5)**	1.52	(0.47-4.9)	**0.63**	**(0.44-0.9)**
Filipino	**1.6**	**(1.05-2.44)**	**0.61**	**(0.39-0.97)**	0.92	(0.33-2.54)	**1.29**	**(1.04-1.62)**
Southeast Asian	1.09	(0.64-1.85)	**0.31**	**(0.15-0.67)**	**0.22**	**(0.05-0.89)**	0.72	(0.37-1.4)
Arab	**0.68**	**(0.51-0.91)**	**0.15**	**(0.07-0.3)**	1.24	(0.57-2.71)	**0.38**	**(0.28-0.51)**
West Asian	**0.31**	**(0.14-0.71)**	0.66	(0.4-1.1)	**3.86**	**(2.4-6.22)**	0.75	(0.47-1.21)
Japanese	0.53	(0.13-2.2)	**0.09**	**(0.02-0.45)**	1.51	(0.29-7.74)	0.46	(0.14-1.53)
Korean	1.03	(0.49-2.16)	0.50	(0.23-1.1)	1.06	(0.32-3.49)	0.87	(0.48-1.56)

*Adjusted for BMI, demographic (age, sex, marital status, stress level, smoking, alcohol, household education level, household income quartile, English proficiency, immigrant status, age at immigration, length of time since immigration, urban/rural), and lifestyle (sedentary time, daily energy expenditure, daily fruit and vegetable consumption) variables.

Table 4: Association between BMI and having 'at least one cardiometabolic condition'

		At least 1 Cardiometabolic Condition (referent = normal-weight BMI category in each ethnic group)		At least one Cardiometabolic Condition (referent = normal-weight South Asians)	
Self-reported Ethnicity	**BMI Category**	**OR (95% CI)**		**OR (95% Confidence Interval)**	
Chinese	18.5-<23	*1.00 (referent)*		0.41	(0.24-0.69)
	23-<27.5	3.63	(2.34-5.63)	1.27	(0.9-1.81)
	≥27.5	8.9	(3.6-22.01)	3.05	(1.21-7.67)
South Asian	18.5-<23	*1.00 (referent)*		*1.00 (referent)*	
	23-<27.5	1.74	(1.23-2.46)	1.79	(1.18-2.71)
	≥27.5	3.37	(2.02-5.65)	3.55	(2.26-5.59)
Filipino	18.5-<23	*1.00 (referent)*		1.33	(0.76-2.33)
	23-<27.5	2.12	(0.98-4.58)	2.59	(1.5-4.46)
	≥27.5	2.39	(1.27-4.47)	3.26	(2.18-4.89)
Southeast Asian	18.5-<23	*1.00 (referent)*		1.02	(0.5-2.09)
	23-<27.5	0.87	(0.51-1.5)	0.9	(0.42-1.9)
	≥27.5	3.38	(1.4-8.16)	2.5	(0.56-11.16)
Arab	18.5-<23	*1.00 (referent)*		0.67	(0.25-1.85)
	23-<27.5	0.97	(0.34-2.79)	0.58	(0.37-0.91)
	≥27.5	2.32	(0.97-5.55)	1.5	(0.88-2.55)
West Asian	18.5-<23	*1.00 (referent)*		0.96	(0.28-3.31)
	23-<27.5	1.21	(0.16-9.08)	1.47	(0.67-3.24)
	≥27.5	1.32	(0.15-11.67)	2.75	(1.26-6.01)
Japanese	18.5-<23	*1.00 (referent)*		0.53	(0.13-2.18)
	23-<27.5	0.86	(0.13-5.79)	0.49	(0.16-1.52)
	≥27.5	1.72	(0.06-48.39)	2.15	(0.18-25.95)
Korean	18.5-<23	*1.00 (referent)*		0.84	(0.39-1.77)
	23-<27.5	2.04	(0.9-4.62)	1.49	(0.79-2.83)
	≥27.5	3.15	(1.36-7.33)	3.17	(1.04-9.67)
Asians Overall	18.5-<23	*1.00 (referent)*			
	23-<27.5	2.09	(1.55-2.82)		
	≥27.5	4.16	(3-5.78)		

*Adjusted for demographic (age, sex, marital status, stress level, smoking, alcohol, household education level, household income quartile, English proficiency, immigrant status, age at immigration, length of time since immigration, urban/rural), and lifestyle (sedentary time, daily energy expenditure, daily fruit and vegetable consumption) variables.

EXTENDED DISCUSSION

Limitations of the WHO Asian-specific BMI cut-offs

Clinicians and policy makers have advocated strongly for practical guidance on how to define overweight and obesity (thus the creation of BMI cut-offs). These cut-points have served as a standard worldwide and facilitate comparisons across studies. In 2000, the Regional Office for the Western Pacific Region of WHO, the *International Association for the Study of Obesity* and the *International Obesity Task Force (IOTF)* together proposed a separate classification for obesity in Asia, suggesting that for Asian adults, overweight be specified as BMI >23 and obesity as BMI≥27.5. Using the traditional BMI classification, in Japan for example, the percentage of the population with BMI>30 is no more than 2% in men and 3% in women (13).

However, there are researchers who argue that ethnic-specific BMI cut-offs to define overweight and obesity in Asians are not warranted (138). Most notably, the position held by June Stevens and others is that obesity cut-points would differ not only on ethnicity, but depending on the outcome being examined (e.g. mortality, diabetes, hypertension, etc.) and the type of measure used to quantify the risk (e.g. absolute risk, relative risk and risk difference), which would yield different results. Lastly, defining cut-points by ethnic groups, as opposed to other cultural, environmental or health-related factors is difficult to justify socially or politically, and multiple definitions of obesity may create confusion and decrease focus on the disease (138).

In response to these comments, Misra has argued that not only are the Asian specific cut-points scientifically justified, but it would help place obesity in the forefront of health ageneda of many developing countries in Asia (142). Moreover, there is evidence to suggest that the use of the lowered WHO BMI cut-off values may still be too liberal when assessing risk in ethnically diverse populations (15, 143).

As such, the practical implications of this research may be limited to identifying those groups who are more susceptible to the effects of obesity on cardiometabolic conditions for more targeted public health strategies. Further still, heterogeneity also exists *within* ethnic groups (14, 144, 145). The Southall study in West London showed that conventional risk factors such as smoking rates, hypertension and total cholesterol levels vary between sub-groups of South Asians. For example, Punjabi Sikhs tend to abstain from smoking as their religion prohibits it while Bangladeshi men and Gujarati Hindu men have smoking rates comparable to, or higher than, European Whites. In contrast, Sikh men tend to have higher levels of cholesterol and median blood pressure than other South Asian sub-groups (62). Beyond the potential differences attributable to lifestyle factors within groups, body composition analyses have confirmed differences in the relation between BMI and per cent body fat with Asian sub-groups (e.g. between Hong Kong Chinese and Beijing (northern) Chinese)(13).

Whereas BMI may be a useful population screening tool for overall health surveillance, as a clinical tool, the limitations of BMI are well known (89, 91). There is now a movement away from the utilization of measures of obesity in the clinical setting towards the treatment of obesity-related comorbidities. Although higher BMIs are generally associated with greater mental, medical and functional problems, anthropometric measures alone are not a good reflection of the severity or extent of obesity-related comorbidities. One such example is the Edmonton Obesity Staging System (EOS system), a clinical staging system to complement the BMI when describing the severity of obesity (146). This approach has been shown to be a superior indicator of premature mortality than BMI alone (147, 148). Most importantly, the stages of the EOS system make intuitive sense to clinicians, and are a more effective strategy to individualize patient management strategies.

Proxy Measures of Acculturation

Among studies looking at the effect of obesity on cardiometabolic health, the measurement and definition of acculturation is not standardized and may differ for each Asian sub-group. Most proxy measures of acculturation have relied on English proficiency and the number of years since immigration (17, 27). However, neither proxy is adequate, as i) English proficiency may not be an accurate estimate of acculturation among immigrants from regions where English is already widely spoken (e.g., Philippines, India, Hong Kong), and ii) years since migration (without taking into account age at migration) would fail to recognize the difference in assimilation and acculturation patterns over time (e.g. between, for example, a 10 year old and a 45 year old person who may have migrated to Canada at the same time).

To explore these effects further, additional adjustments for acculturation were performed, including: immigrant status, English proficiency, time since migration, and age at migration (**Appendix B, Table 5**). There is a small increase in the odds of 'at least one cardiometabolic condition' as more acculturation variables are included in the model. However, these increases are minimal and suggests that in understanding the relationship between overweight and obesity on cardiometabolic health among Asian ethnic sub-groups, adjusting for measures of acculturation is not necessary. In the absence or unavailability of acculturation measures, the aforementioned associations are still evident.

CONCLUSION

Results from this study indicate that the relationship between obesity and cardiometabolic conditions varies across Asian ethnicities. Through the pooling of six cycles of the CCHS, we were able to examine the effect of excess adiposity on cardiometabolic health risks among eight Asian sub-groups in Canada. The WHO Asian-specific BMI cut-points for ‘acceptable’, ‘increased’ and ‘high’ risk categories were used, which decreased the chance of misclassification in the standard BMI categories.

While cardiovascular risks due to obesity and ethnicity is a complex interaction between genetics and the environment, this study provides further insight into behavioural, demographic, and obesity-related differences in health risk in Asian ethnic groups in Canada. Given that this study is descriptive in nature, further work is necessary to identify the underlying mechanisms accounting for these ethnic differences. Nonetheless, this study highlights the opportunity for public health implications for population-wide interventions targeting obesity that are ethnically specific and sensitive.

AUTHOR CONTRIBUTION

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Author Contribution:
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Analysis and interpretation of data: Jason X. Nie and Chris I. Ardern
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APPENDIX A

Table 5: Unadjusted odds ratios of 'at least one cardiometabolic condition' for Asian sub-groups compared to South Asians

	High Blood Pressure		**Diabetes**		**Heart Disease**		**At least one Cardiometabolic Condition**	
Self-reported Ethnicity	**OR (95% CI)**							
South Asian	***1.00 (referent)***		***1.00 (referent)***		***1.00 (referent)***		***1.00 (referent)***	
Chinese	0.85	(0.71-1.02)	**0.36**	**(0.29-0.45)**	1.06	(0.69-1.63)	**0.73**	**(0.63-0.84)**
Filipino	**1.67**	**(1.28-2.18)**	**0.71**	**(0.58-0.87)**	0.56	(0.24-1.33)	**1.31**	**(1.10-1.55)**
Southeast Asian	1.00	(0.76-1.31)	**0.59**	**(0.41-0.83)**	**0.17**	**(0.09-0.34)**	0.82	(0.64-1.05)
Arab	0.80	(0.63-1.02)	**0.35**	**(0.24-0.52)**	1.08	(0.57-2.07)	**0.59**	**(0.47-0.73)**
West Asian	**0.46**	**(0.31-0.68)**	0.95	(0.43-2.11)	**4.09**	**(1.92-8.72)**	0.77	(0.44-1.36)
Japanese	1.04	(0.66-1.64)	0.52	(0.24-1.16)	1.13	(0.24-5.42)	0.77	(0.48-1.25)
Korean	0.97	(0.69-1.38)	**0.45**	**(0.29-0.72)**	0.49	(0.22-1.11)	0.77	(0.57-1.06)

APPENDIX B

Table 6: The effect of different acculturation measures on multivariate-adjusted* odds ratios of 'at least one cardiometabolic condition' for Asian sub-groups compared to South Asians

	Model 1	Model 2	Model 3	Model 4	Model 5
	OR (95% Confidence Interval)	**OR (95% Confidence Interval)**	**OR (95% Confidence Interval)**	**OR (95% Confidence Interval)**	**OR (95% Confidence Interval)**
South Asian	***1.00 (referent)***	***1.00 (referent)***	***1.00 (referent)***	***1.00 (referent)***	***1.00 (referent)***
Chinese	0.6 (0.42-0.86)	0.59 (0.42-0.83)	0.62 (0.44-0.89)	0.61 (0.43-0.88)	0.63 (0.44-0.9)
Filipino	1.28 (1.03-1.6)	1.28 (1.02-1.61)	1.27 (1.01-1.58)	1.29 (1.03-1.62)	1.29 (1.04-1.62)
Southeast Asian	0.71 (0.39-1.32)	0.71 (0.39-1.32)	0.73 (0.39-1.35)	0.72 (0.38-1.37)	0.72 (0.37-1.4)
Arab	0.37 (0.27-0.49)	0.36 (0.27-0.49)	0.37 (0.28-0.5)	0.37 (0.27-0.5)	0.38 (0.28-0.51)
West Asian	0.74 (0.45-1.22)	0.74 (0.45-1.22)	0.73 (0.45-1.19)	0.76 (0.46-1.24)	0.75 (0.47-1.21)
Japanese	0.38 (0.14-1.06)	0.35 (0.12-1.04)	0.38 (0.14-1.05)	0.44 (0.14-1.37)	0.46 (0.14-1.53)
Korean	0.82 (0.47-1.4)	0.79 (0.44-1.42)	0.82 (0.48-1.4)	0.84 (0.47-1.5)	0.87 (0.48-1.56)

*Adjusted for demographic and lifestyle variables

Model 1: Not adjusted for any acculturation measures
Model 2: Adjusted for immigrant status
Model 3: Adjusted for English proficiency
Model 4: Adjusted for time since migration
Model 5: Adjusted for time since migration, immigrant status, English proficiency and age at migration