CARDIOMETABOLIC HEALTH IN SOUTH ASIANS LIVING IN CANADA: CANADIAN COMMUNITY HEALTH SURVEY 2000-2014 & CANADIAN HEALTH MEASURES SURVEY 2007-2013

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Abstract

Background: South Asians (SAs) have low physical activity (PA) levels and elevated cardiovascular risk. **Objective:** To examine the relationship between cardiometabolic health and PA among SAs (20+y) using the Canadian Community Health Survey (CCHS) 2000-2014 and Canadian Health Measures Survey (CHMS) 2007-2013. **Methods:** Multiple logistic regression was used to estimate the odds of 1+ cardiometabolic conditions and metabolic syndrome (MetS) according to PA level. **Results:** In the CCHS, 22.6% of SAs had 1+ cardiometabolic conditions, whereas in the CHMS, 26.4% of SAs had MetS. In the CCHS, self-reported active (>3.0 KKD) recent immigrants and moderately active (1.5-3.0 KKD) non-immigrants and established immigrants had the lowest odds of cardiometabolic conditions. In the CHMS, participants with ≥ 10 000 steps and ≥ 232 minutes/week of MVPA had the lowest odds of MetS. **Conclusions:** Given discrepancies in the relationship between PA and cardiometabolic health, the optimal dose of PA amongst SA subgroups warrants further investigation.

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Introduction

In the 5 years leading up to 2011, over 1.1 million foreign-born individuals immigrated to Canada, representing 17.2% of Canada's total foreign-born population (Statistics Canada, 2011b). In these 5 years, Asia has been the largest source of immigrants to Canada. The 3 largest visible minority groups, South Asians, Chinese, and Blacks, represented approximately 61.3% of Canada's total visible minority population in 2011. Of these 3 ethnicities, South Asians are the largest and one of the fastest growing visible minority groups in Canada, representing approximately 25.0% of the total visible minority population in the country (Statistics Canada, 2011b).

Approximately two-thirds of the visible minority population are born outside of Canada (Statistics Canada, 2011b). The "healthy immigrant effect" suggests that immigrants are healthy when they arrive to the host country, but their health deteriorates with a longer length of stay and acculturation (Creatore et al., 2010; Gerber, Barker, & Pühse, 2012). South Asian immigrants in Canada have a higher prevalence of cardiometabolic risk factors even after adjusting for age, immigration category, time since arrival, education and income (Creatore et al., 2010). These risk factors include type 2 diabetes mellitus, insulin resistance, lower high-density lipoprotein (HDL), and physical inactivity (Fernando, Razak, Lear, & Anand, 2015).

Recently, efforts to identify and treat cardiometabolic risk factors has begun to focus on early markers of disease such as metabolic syndrome (MetS), a cluster of cardiometabolic risk factors that increase risk of cardiovascular disease and type 2 diabetes (Ardern & Janssen, 2007). In Canada, approximately 25% of the South Asian population meets the criteria for MetS (Anand et al., 2003). Physical activity and lifestyle interventions have been shown to be particularly effective for the prevention and management of MetS (Ghouri et al., 2013; Misra et al., 2009).

Unfortunately, the South Asian population reports very low levels of physical activity (Lesser, Yew, MacKey, & Lear, 2012).

Adding to the uncertainty around the importance of physical activity are issues in the measurement and reporting in this population, including large discrepancies between self-reported and objectively measured physical activity. In the U.S., a study comparing direct and self-reported physical activity found that 62% of individuals were "active" based on self-report as compared to only 9.6% when using accelerometer data (Tucker, Welk, & Beyler, 2011). Nevertheless, many Canadian surveys with immigration and ethnicity information have focused solely on self-reported physical activity. Only recently, with the completion of the first three cycles of the Canadian Health Measures Survey (CHMS) is it possible to examine issues of newcomer health with more objective measures of physical activity within the Canadian context.

Despite the growing body of literature focused on the cardiometabolic health of South Asian adults, much of this work has focussed on individuals from select countries and does not examine both women and men in the same analysis. As a result, this data cannot be generalized to the entire South Asian population in Canada, where different social conditions, physical activity patterns, and health risks may be present. Of the studies that have examined South Asians specifically (Liu et al., 2010, Chiu et al., 2015; Chiu, Austin, Manuel, & Tu, 2010), no study has solely focused on immigration status and physical activity. Intersectionality work is required to examine the effects of immigration to Canada in comparison to their native counterparts, and South Asian ethnicity, as separate issues. Therefore, this thesis will provide insight into the cardiometabolic health and physical activity of South Asians in Canada.

Literature Review

Demographic Trends

Statistics Canada most recent consensus data reports Canada's foreign-born population to represent 20.6% of the country's total population (Statistics Canada, 2011b). From 2006 to 2011, 17.2% of the total foreign-born population had immigrated to Canada, representing over 1.1 million foreign-born individuals. During these 5 years, Canada experienced a surge of immigrants from Asia who represented 57% (~670 000 individuals) of the foreign-born population (Statistics Canada, 2011b). This number is in contrast to the mere 8.5% of immigrants from Asia before the 1970s (Statistics Canada, 2011b). As such, the high number of immigrants from Asia to Canada is a new phenomenon and important new population of interest. In 2011, approximately 65% of the total visible minority population was born outside of Canada. South Asians were also the largest and fastest growing visible minority group in Canada, representing approximately 25.0% of the total visible minority population (Statistics Canada, 2011b).

Seventy-five percent of the South Asians that have immigrated to Canada have done so in the last 20 years (Rana, de Souza, Kandasamy, Lear, & Anand, 2014), and approximately 20.6% of South Asian immigrants came to Canada between 2006 and 2011 (Statistics Canada, 2011b). In 2001, South Asians represented 3.0% of the Canadian population (~1M individuals), and by 2011, this number had grown to 4.8% (~1.57 M individuals) (Statistics Canada, 2011b).

Future Projections

The most recent complete Statistics Canada consensus data (2011) allows for estimates of ethnic diversity in Canada to be made until 2031 (Statistics Canada, 2011a). Foremost, the age of immigrants differ from the rest of the Canadian population, as visible minorities are younger than the Canadian population as a whole. In 2011, the median age of the visible minority population was 33.4 years in comparison to a median age of 40.1 years for the rest of the

Canadian population (Statistics Canada, 2011). As expected, recent immigrants are also younger than non-immigrants. Of those who came to Canada since 2006, approximately 59.0% were within the core working age group of 25 to 54 years (Statistics Canada, 2011).

The immigrant population in Canada is projected to increase to approximately 25.0% by 2031 from 19.8% in 2006 (Statistics Canada, 2011a). In comparison to 2006, the age range of this population is also projected to increase, as the number of individuals over the age of 15 who are immigrants or who have at least one immigrant parent, will rise from 39.0% to 46.0% by 2031. Over this 25-year period, South Asians and Chinese are still anticipated to remain the 2 largest visible minority groups in Canada (Statistics Canada, 2011a).

The "Healthy Immigrant Effect" and Cardiovascular Risk

Immigrants arrive to the host country healthy, however with longer length of stay and acculturation, their health deteriorates, a phenomenon known as the "healthy immigrant effect" (Creatore et al., 2010; McDonald & Kennedy, 2004; Caperchione et al., 2009; Gerber, Barker, & Pühse, 2012; Salas et al., 2016; Kim et al., 2013). The deterioration of self-reported general health in South Asian immigrants in Canada is seen as early as 2 years post-immigration (Kim et al., 2013), and increases in overweight (BMI between 25 and 29.9 kg/m^2) and obesity (BMI over 30 kg/m^2) amongst immigrants are seen as early as 10 years post-migration (Delavari et al., 2013). In particular, South Asian immigrants in Canada have a higher prevalence of cardiometabolic risk factors and diabetes even after adjusting for age, immigration category, time since arrival, education and income in comparison to other ethnic groups (Creatore et al., 2010). These include type 2 diabetes mellitus, insulin resistance, higher visceral adiposity, higher body fat, lower high-density lipoprotein (HDL), and physical inactivity (Fernando, Razak, Lear, & Anand, 2015). In Ontario, immigrants up to the age of 74 had higher rates of diabetes in comparison to those who were long-term residents of that province (Creatore et al., 2010). High rates of diabetes have also been found among South Asian immigrants in Canada in comparison to other Asian sub groups (Nie & Ardern, 2014) and other major ethnic groups (Tu et al., 2015). The CANHEART Immigrant Study in Canada also reported a cardiac risk score, which was defined as hospitalizations for various cardiometabolic conditions (acute myocardial infarction, stroke, revascularization with percutaneous coronary intervention or coronary artery bypass graft surgery, or death for CVD), to be higher among immigrants who left Canada before the end of the 10-year study period in comparison to those immigrants who completed the full study period. South Asians were also found to have a high burden of metabolic syndrome due to their high rates of cardiometabolic risk factors (obesity, diabetes, hypertension and low HDL) (Tu et al., 2015).

The effects of migration on health are present even when individuals move from rural to urban areas within their country of birth. As South Asians begin to migrate from rural to urban areas within South Asia, increases in number of individuals with diabetes and elevated waist circumference are apparent (O'Keefe, DiNicolantonio, Patil, Helzberg, & Lavie, 2016). Diabetes prevalence is predicted to increase from approximately 3.0% in rural areas to 7.0-18.0% in urban cities within India (Gill, Celis-Morales, & Ghouri, 2014). This trend of increased number of cardiometabolic risk factors among South Asians strengthens upon migrating from these urban areas to westernized countries (Das et al., 2017). The prevalence of pre-diabetes was also found to be higher among South Asians residing in westernized countries such as the United States in comparison to those in South Asia (Das et al., 2017). For example, South Asians living in the United States have higher median glucose, higher diabetes medication use and higher impaired fasting glucose prevalence in comparison to Whites, African Americans, Chinese Americans and

Latinos (Kanaya et al., 2014). The high rate of diabetes among South Asians in comparison to the other four ethnic groups was increased after adjustments for demographics and lifestyle factors. Sex differences were also found as South Asian men had the highest rates of diabetes in comparison to all four ethnic groups (South Asian men>South Asian women>African American>Chinese American>Latino>White) (Kanaya et al., 2014).

Metabolic Syndrome

To date, a number of international diabetes and obesity groups have recommended operational criteria for screening of cardiometabolic risk (Grundy et al., 2005). The concept of MetS has been around for more than 80 years (Alberti, Zimmet, & Shaw, 2005), and over the years, many organizations have proposed operational criteria for MetS with components they deem important to cardiovascular health. The World Health Organization (WHO) was the first to release a formal definition in 1999. This definition emphasized insulin resistance, as the presence of diabetes, impaired glucose tolerance, or impaired fasting glucose with 2 other components of metabolic health (obesity, elevated triglycerides or low HDL, high blood pressure and microalbuminuria) (Alberti et al., 2005; Grundy et al., 2005). The American Association of Clinical Endocrinologists (AACE) proposed clinic criteria for MetS with the following risk factors: obesity, elevated triglycerides, low HDL, elevated blood pressure, fasting glucose, and other risk factors such as family history of cardiometaoblic conditions, age, ethnicity, and sedentary lifestyle. However, the AACE does not propose any specific number of risk factors required for diagnoses of MetS – this is left to clinical judgement (Alberti et al., 2005). Although there have been many different definitions for MetS over time, the US National Cholesterol Education Program: Adult Treatment Panel III (ATP III) definition gives equal emphasis to all components (elevated waist circumference, blood pressure, fasting glucose, triglycerides, and low HDL) and therefore, was agreed to be a good starting point for MetS definitions (Alberti et al., 2005). In 2005, a Harmonized definition (Grundy et al., 2005) was proposed. According to this definition, MetS is classified by the presence of 3 or more of the following: elevated waist circumference, low HDL, high triglycerides, high blood pressure, and high fasting plasma glucose. Due to the large amounts of evidence linking waist circumference with cardiovascular disease and other MetS components, importance was placed on ethnic-specific cut offs for this component in order to better predict health risk (Alberti et al., 2005). Using this most recent definition, individuals with MetS were found to have a 2-fold increased risk for atherosclerosis cardiovascular disease, and a 5-fold increased risk of type 2 diabetes compared to those without MetS (Grundy et al., 2005). In Canada, approximately 25.0% of the South Asian population meets the criteria for MetS (Anand et al., 2003).

Cardiovascular Risk in South Asians

South Asians in Canada appear to have a higher prevalence of cardiovascular disease in comparison to Chinese and Europeans. This may be due to the higher abdominal obesity in South Asian women, and higher plasma lipids and glucose in comparison to the other two ethnic groups (Anand et al., 2000). Visceral adipose tissue, which is more detrimental to health, is also more prevalent among South Asians in comparison to other ethnic groups (WHO, 2004). Indeed, South Asians have been shown to have more body fat for a given BMI and consequently higher health risks (Lear et al., 2007). Results from the Study of Health Assessment and Risk in Ethnic groups (SHARE) show that South Asians have higher prevalence of cardiovascular disease in comparison to Europeans and Chinese living in Toronto, Hamilton, and Edmonton, Canada (Anand et al., 2000). South Asians in this sample also had higher rates of total cholesterol, low-density lipoprotein (LDL) cholesterol, plasma lipids, glucose, and triglycerides in comparison to

Chinese and Europeans (Anand et al., 2000), all of which are components of metabolic dysfunction. Further, it is evident that even within Asian ethnic groups, there is a variation in cardiometabolic risk factors and conditions as only South Asians had the second highest odds of having at least one cardiometabolic condition in comparison to Japanese, Southeast Asians, Koreans, Chinese, Arabs and West Asians (Nie & Ardern, 2014). In turn, CVD mortality occurs at earlier ages amongst Indian Asians (individuals from India, Pakistan, Bangladesh, and Sri Lanka)), a large number of which occur during the working years (O'Keefe et al., 2016; Das et al., 2017).

Mets and Physical Activity

Metabolic dysfunction, including MetS, can be viewed as an early warning sign for impending health risk (Grundy et al., 2005). As such, physical activity and lifestyle interventions have been shown to be particularly effective for the prevention and management of MetS (Misra & Shrivastava, 2013; Ghouri et al., 2013; Andersen, Høstmark, & Anderssen, 2012; McKeigue, Shah, & Marmot, 1991; Misra et al., 2009; Balasubramanyam, Rao, Misra, Sekhar, & Ballantyne, 2008). As well, physical activity allows people to prolong their disease free years of life and improve their quality of life (American Heart Association, 2015) and is beneficial to health whether individuals accrue minutes through leisure, daily activity or their occupation (O'Keefe et al., 2016). Unfortunately, the South Asian population reports very low levels of physical activity (Lesser, Yew, MacKey, & Lear, 2012). Indeed, it is estimated that physical activity accounts for more than 20% of the excess risk of coronary heart disease in the South Asian population living in the United Kingdom (Fernando et al., 2015). Independent of the other cardiometabolic risk factors, physical *in*activity is a risk factor for diabetes (Lesser et al., 2012), whereas participation in regular physical activity is associated with weight maintenance and prevention of weight gain (Donnelly et al., 2009).

Dose-Response and Cardiometabolic Risk

A systematic review of the dose-response relationship between physical activity and health reinforces the benefits of activity on all-cause mortality, stroke, and CHD risk factors (Oja et al., 2001). While the most robust effects are typically seen for total physical activity, the work of Oja et al. (2001) suggests that the intensity of activity may be more closely aligned with reductions in risk (Oja et al., 2001). In general, an inverse relationship exists between all-cause mortality and physical activity, with a reduction in all-cause mortality of 20.0% to 30.0% when individuals meet the physical activity recommendation of 1000 kcal/week (Lee & Skerrett, 2001). For CVD, a similar dose-dependent association has been found, with even stronger effects for coronary heart disease (Kohl 3rd, 2001).

Although the general shape of the activity – health relationship is well known, most of this work has been conducted on participants of European descent. Moreover, the details of the *optimal* type, intensity and frequency in which this dose of physical activity should be accumulated is unclear (Kohl 3rd, 2001). Comparing European and South Asian men living in Scotland who were matched for age and BMI, South Asian men required 266 minutes of moderate intensity physical activity (MVPA) in order to reap the same level of cardiometabolic risk as European men participating in 150 minutes of MVPA per week (Gill et al., 2014). In a later study it was found that South Asian men and women required ≥ 232 minutes of MVPA per week in order to achieve the same cardiometabolic risk as men and women of European descent who participated in ≥ 150 minutes of MVPA (Illodromiti et al., 2016). While these studies do not provide a clear consensus, it is evident that more research needs to be conducted in order to understand the amount and intensity of physical activity required for South Asians, specifically South Asian immigrants, to decrease cardiometabolic risk factors in this population.

Physical activity and sedentary time

To date, most research on physical activity and health has focussed on the identification of minimal thresholds for health, as evidenced by the Canadian Physical Activity Guidelines, which promote 150 minutes of MVPA per week (Canadian Society for Exercise Physiology, 2012; Public Health Agency of Canada, 2012). While important, guidelines such as these neglect that movement occurs across a continuum, and that even breaks in sedentary time, or small bouts of light intensity activity such as household chores, when accrued throughout the day, may incrementally contribute to health (Canadian Society for Exercise Physiology, 2012). The Canadian Health Measures Survey (CHMS) accelerometer data concludes that Canadian men and women spend approximately 68.0% and 69.0% of waking hours, respectively, sedentary (Colley et al., 2011). Sedentary behaviour is defined as movement during waking hour in which the individual expends ≤ 1.5 METS and is in a sitting or reclined position (Sedentary Behaviour Research Network, 2012). Using accelerometer data, sedentary time is defined as every minute with <100 cpm (Carson et al., 2014). Accelerometer derived data found that sedentary time is associated with higher prevalence of cardiometabloic risk, with each additional hour of total sedentary time being associated with a 3.0% increase in plasma insulin levels (Carson et al., 2014). By contrast, each additional 10 breaks per day from sedentary time were associated with a 4.0% decrease in triglycerides and insulin. A linear relationship exists between sedentary breaks and cardiometabolic health as an increase in breaks leads to lower waist circumference, systolic blood pressure, HDL cholesterol and insulin. However, in Canada, accelerometer data showed that Canadians spend an average 11 hours per day sedentary with approximately 6 hours in sedentary bouts of 20 minutes or more (Carson et al., 2014). As South Asians immigrate to Canada, the prevalence of sedentary time is projected to increase (Das et al., 2017).

Measurement Concerns: Self-Report and Objectively Assessed Physical Activity

In general, there are large discrepancies between self-reported and objectively measured physical activity, both because of challenges of self-report and response bias in large population-based work, but also because of inherent differences in the perception of what "counts" as physical activity. In the United States, a study comparing direct and self-reported physical activity found that 62.0% of individuals were "active" based on self-report, but only 9.6% using accelerometer data (Tucker, Welk, & Beyler, 2011). Beyond the imprecision of the questionnaire and potential for recall bias, these differences may be influenced by, and vary, according to level of education, sex, and age (Dyrstad et al., 2014). Individuals with an education level of high school or less reported longer total activity by 21.0% in comparison to those with higher education, however, these differences were not found using accelerometer data. Similarly, no differences were found between men and women through direct physical activity measure; however, using self-reported data, men reported 47.0% higher MVPA (Dyrstad et al., 2014). Nevertheless, many Canadian surveys with immigration and ethnicity information have focused solely on self-reported physical activity. For example, the National Population Health Survey (1994-2011), General Social Survey (GSS, 1985-2012), Health Promotion Survey (1985-1995), Survey of Young Canadians (SYC, 2010-2011), Canadian Community Health Survey (CCHS, 2000-2014) and the National Longitudinal Survey of Children and Youth (NLSCY, 1995-2009) all contain data on self-reported physical activity (Statistics Canada, 2016). Only recently, with the completion of the first 3 cycles of the Canadian Health Measures Survey (CHMS) is it possible to examine issues of newcomer health with more objective measures of physical activity within the Canadian context. The CHMS data illustrates that only 15.0% of Canadian adults meet the physical activity guidelines of 150 minutes of MVPA in 10-minute bouts, and only 35.0% of Canadian adults are accumulating at least 10 000 steps per day (Colley et al., 2011).

Physical Activity Guidelines

The development of the physical activity guidelines that suggest 150 minutes per week of MVPA were conducted on individuals of European descent, therefore, these guidelines may not be suitable for all ethnicities (Misra et al., 2012; Illodromiti et al., 2016; Gill et al., 2014). In order to increase fitness and reap health benefits, it has been suggested that South Asians may need to partake in more physical activity than that recommended by the physical activity guidelines (Gill et al., 2014). A consensus statement for physical activity guidelines for Asian Indians recommends 30 minutes of moderate intensity aerobic activity per day, 15 minutes of work-related activity per day (such as carrying heavy loads and climbing stairs), and 15 minutes of muscle strengthening exercises 3-4 times per week (Misra et al., 2012). However, the evidence behind these guidelines is unclear (Illodromiti et al., 2016).

Conclusion

Despite the growing body of literature focused on the cardiometabolic health of South Asian adults (e.g. cardiovascular disease (Misra et al., 2010; McKeigue et al., 1991; Balasubramanyam et al., 2008; Lui et al., 2010; Parikh, Aurora, Dash, Shin, & Palaniappan, 2015; Chiu, Maclagan, Tu, & Shah, 2015), diabetes (Misra et al., 2010; McKeigue et al., 1991; Lui et al., 2010; Chiu et al., 2015), and/or MetS (Gadgill, Anderson, Kandula, & Kanaya, 2015; Khan & Jackson, 2016; Andersen et al., 2012; Misra et al., 2010; Rianon & Rasu, 2010; Kousar, Burns, & Lewandowski, 2008; McKeigue et al., 1991; Balasubramanyam et al., 2008)), much of this work has focussed on individuals from select countries and does not examine both women and men in the same analysis. Although studies have been conducted throughout Canada to understand the unique health risks for South Asians, this data cannot be generalized to the entire South Asian population in Canada. South Asian immigrants in Canada as a whole may experience different social conditions and health risks. Moreover, very few studies also focus on immigration status (Khan & Jackson, 2016; Andersen, et al., 2012; Misra et al., 2010; Rianon & Raso, 2010; Kousar et al., 2008; Balasubramanyam et al., 2008). Of these, no studies have been conducted in Canada, and only three to date have examined patterns of physical activity (Andersen et al., 2012; Kousar et al., 2008; Balasubramanyam et al., 2008). Examination of physical activity through the work in this thesis will allow for analysis on total volume of physical activity with a large and generalizable sample, and also examine physical activity with a more direct and objective measure. Intersectionality work is required in order to examine the effects of immigration to Canada in comparison to their native counterparts, and South Asian ethnicity as inter-connected issues, and distinct contributors to one's identity. Therefore, this thesis will provide insight into the cardiometabolic health and physical activity of South Asians who are both born in, and outside of Canada.

Objectives

The overarching objective of this thesis is to explore the relationship between physical activity (PA) and cardiometabolic health in South Asians living in Canada.

Objective 1: To explore the relationship between *self-reported* PA and cardiometabolic conditions among non-immigrant, recent immigrant (<10 years) and established immigrant (≥ 10 years) South Asians.

Objective 2: To explore the relationship between *objectively measured* PA and MetS among recent immigrant (<10 years) and established immigrant (≥10 years) South Asians.

a) Aim 1: To explore the relationship according to number of steps per day.
b) Aim 2: To explore the relationship using the current physical activity recommendation of ≥ 150 minutes of moderate-to-vigorous intensity activity (MVPA) per week.
c) Aim 3: To explore the relationship using the hypothesized ethnic-specific physical activity recommendations of ≥ 232 minutes of MVPA per week.

Association between Physical Activity and Cardiometabolic Disease in South Asians: Canadian Community Health Survey, 2000-2014[1]

Summary

Background: Individuals of South Asian descent have a high prevalence of cardiometabolic risk factors such as type 2 diabetes and hypertension. **Objective:** This study aims to examine the relationship between cardiometabolic health and physical activity among South Asians based on immigration status. **Methods:** Data from South Asian participants of the 2000 – 2014 Canadian Community Health Survey were pooled and used in the current analysis (20 y+). PA was defined by self-report [Inactive: <1.5 kcal/kg/day (KKD); Moderately Active (MA): 1.5-3.0 KKD, and; Active (A): >3.0 KKD)]. South Asians were stratified by immigration status [recent immigrant (<10 years), established immigrant (≥ 10 years) and non-immigrant]. Multiple logistic regression was subsequently used to estimate the odds of 1+ cardiometabolic condition (self-reported diabetes, hypertension, coronary heart disease, or stroke) according to PA stratified by immigration status. **Results:** Approximately 23% of South Asians had 1+ cardiometabolic condition. Compared to inactive non-immigrants (OR=1.00, referent), males (OR 0.14, 95% CI 0.08-0.20) and females (OR 0.10, 95% CI 0.04-0.16) who were moderately active had lower odds of 1+ cardiometabolic condition. Active male and female recent immigrants also had lower odds of 1+ cardiometabolic condition in comparison to inactive individuals (M: OR 0.19, 95% CI 0.15-0.22; F: OR 0.13, 95% CI 0.10-0.16), whereas moderately active male and female established immigrants had lower odds of 1+ condition in comparison to those who were inactive (M: OR 0.41, 95% CI 0.39-0.42; F: OR 0.30, 95% CI 0.28-0.31). **Conclusions:** Regular PA is associated with better cardiometabolic health, results of which vary according to immigration status. Further research is necessary to understand the optimal threshold of PA required for prevention of risk in individuals of South Asian descent.

Key words: immigration, ethnicity, exercise, cardiovascular disease, diabetes, epidemiology

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Introduction

The "healthy immigrant effect" suggests that immigrants are healthy when they arrive to the host country (Kim, Carrasco, Muntaner, McKenzie, & Noh, 2013), but their health deteriorates with a longer length of residence and acculturation (Kim et al., 2013; Tremblay, Bryan, Perez, Ardern, & Katzmarzyk, 2006). With immigration policies, immigrants migrating to Canada are healthy and without serious chronic conditions (Sohail et al., 2015). Although it is known that South Asians develop increased risk factors with longer length of residence, information on their longer-term outcomes is limited (Sohail et al., 2015). South Asian immigrants in Canada have higher prevalence of cardiometabolic conditions including type 2 diabetes mellitus (T2DM) and physical inactivity in comparison to other ethnic groups (Fernando, Razak, Lear, & Anand, 2015). They also experience metabolic conditions such as coronary artery disease, stroke and heart failure at younger ages (Fernando et al., 2015). Although physical activity (PA) has been shown to be effective for the prevention and management of these conditions, PA levels remain low (Lesser, Yew, MacKey, & Lear, 2012; Canadian Society for Exercise Physiology, 2012). Indeed, it is estimated that physical inactivity accounts for more than 20% of the excess risk of coronary heart disease in the South Asian population living in the United Kingdom (Fernando et al., 2015).

Along with the increased risk of metabolic conditions upon arrival to the host country, the health of immigrants may become worse than that of individuals born in the host country (Tu et al., 2015). In Ontario, immigrants up to the age of 74 had higher rates of T2DM in comparison to those who were long-term residents. When comparing South Asian immigrants to other ethnic groups, South Asians had higher rates of T2DM even after adjusting for age, immigration category, time since arrival, education and income (M: OR 4.01, 95% CI 3.82– 4.21; F: OR 3.22, 95% CI 3.07–3.37) (Creatore et al., 2010). In 2011, Canada's foreign-born population represented 20.6% of the country's total population, with the three largest visible minority groups (South Asian, Chinese, and African-Caribbean) representing approximately 61% of Canada's total visible minority population (Statistics Canada, 2011b). Although the foreign-born population in Canada is increasing, the relationship between metabolic conditions and PA has not been studied in South Asians according to time in country in Canada.

The purpose of this study is to therefore explore the relationship between PA and cardiometabolic risk factors among non-immigrant, recent immigrant (<10 years) and established immigrant (≥ 10 years) South Asians. Understanding this relationship has implications for PA and health promotion efforts in a growing segment of Canada's population.

Methods

Data Source

Data for this analysis was accessed through a limited term data application to the Statistics Canada Research Data Centre in Toronto (York University). This study was based on data from cycles 1.1, 2.1, 3.1, 4.1 and cycles from years 2007-2014 of the Canadian Community Health Survey (CCHS). The resulting sample was therefore representative of all provinces and territories in Canada between the years 2000 and 2014.

The CCHS collects information on diseases and health conditions, lifestyle, healthcare use, and prevention and detection of disease. For the purpose of the present analysis, self-reported chronic diseases such as cardiovascular disease (CVD), hypertension and diabetes, and PA regimens are provided. The target population of the CCHS includes those over the age of 12, but excludes 3% of the Canadian population (those who are living on reserves or other Aboriginal settlements, members of the Canadian Forces, institutionalized populations and certain communities within Quebec (health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James)). Coverage in Nunavut included the top 10 communities, accounting for ~70% of the population from 2000 until 2013 at which point the coverage increased to 92%.

Overall, the CCHS provides a representative sample and ensures generalizability through three sampling frames; area frame, list frame, and Random Digit Dialing (RDD). Sample units were defined as all eligible household members. Household members selected from the area frames answered the questionnaire through Computer-Assisted Personal Interviewing (CAPI) method, whereas household members from the list frame and RDD answered through Computer-Assisted Telephone Interviewing (CATI) method. Starting in 2013, certain cases from the area frames were selected to answer the questionnaire through the CATI method (Appendix A).

The CCHS collected data every two years from Cycle 1.1 (2000) to 2005. Starting in 2007, data was collected annually. All available cycles of the CCHS were combined in order to produce a sample size large enough for analysis by immigration status of South Asians.

Ethnicity and Time-Since-Immigration

South Asian ethnicity was defined by the question *"You may belong to one or more racial or cultural groups on the following list, are you South Asian (e.g., East Indian, Pakistani, Sri Lankan)?"* where individuals who answered "yes" were included in this study. Length of time in Canada since immigration (<10 years vs. ≥ 10 years) was derived from the year of birth of the participant and the question *"In what year did you come to Canada to live?"*. Immigrant was classified as yes or no using the "*country of birth*" variable by categorizing participants as born in Canada versus those who were not. In total, 12.7% of South Asians were born in Canada, 34.0% were classified as recent immigrants, and 53.3% were established immigrants.

Outcome variables, exposures, and confounders

Outcome Variable

The outcome variable for this analysis was the presence of one or more of self reported CVD, hypertension, and diabetes. A combination of variables were used from the CCHS to form a complete list of cardiometabolic conditions: i) CVD included "*ever had a heart attack*" or "*suffered effects of a stroke*"; ii) hypertension included "*has high blood pressure*", "*ever been diagnosed with high blood pressure*", or "*taking medication for high blood pressure*", and; iii) diabetes included "*has diabetes*", "*taking insulin for diabetes*" or "*taking medication for diabetes*". Cardiometabolic outcomes were pooled (i.e. 1+ conditions vs. no condition) to produce a dichotomized outcome, yes or no (Chiu et al., 2015; Nie & Ardern, 2014). Medication use for any of the aforementioned conditions resulted in a positive classification for each respective condition.

Exposure Variables

The main independent variable was PA, defined as: inactive <1.5 KKD (kcal/kg/day), moderately active 1.5 – 3.0 KKD, and active >3.0 KKD according to the derived PACDEE variable (Appendix B). This variable includes leisure time activities such as gardening and dance, sports such as volleyball and basketball, and purposeful exercise (Statistics Canada, 2009). A total of 21 leisure activities performed over the past 3 months were combined to calculate an average daily energy expended during leisure time activities. The equation used to derive the energy expenditure (EE) was:

EE (for each activity) = (N X D X METvalue) / 365

N is the number of times a respondent engaged in an activity over a 12 month period, D is the average duration in hours of the activity, and MET value is the energy cost of the activity, expressed as kilocalories expended per kilogram of body weight per hour of activity (kcal/kg per hour) (Statistics Canada, 2011a).

Covariates

Demographic characteristics included age (young adult - 20-44 years, middle-aged adult - 45-64 years, and older adult - 65+ years), sex (male vs. female), marital status (single, separated, divorced vs. married, common-law), household income (lowest, lower middle, middle and upper middle income grouping), and education (secondary or less vs. some post-secondary education). Additional adjustments for health history, focusing on factors that are known to be confounders of the relationship between PA and health included: smoking status (former or never smoker vs. daily or occasional smoker), drinking status (non-drinker vs. regular or occasional drinker), and daily consumption of total fruits and vegetables (<5 servings/day vs. ≥ 5 servings/day). Finally, lifestyle factors such as sedentary behaviours (e.g. sedentary hours in the past 3 months based on TV, video games, computer, and reading (≥ 15 hours per week of television/video screen time vs. <15 hours per week of television/video screen time, and ≥ 11 hours per week computer use vs. <11 hours per week of computer use)) were also adjusted for (Shields & Tremblay, 2008).

Statistical Analysis and Data Handling

Weighting was required in order to ensure the characteristics were representative of a sample Canadian population. For accurate weighting of the merged dataset, weights were applied by a constant factor, 1/k where k represents the number of cycles merged (Thomas & Wannell, 2009). Study inclusions were age 20 and over, and South Asian ethnicity. Participants without reported country of birth were excluded. After exclusions, the final analytic sample was weighted to represent 743 745 individuals of South Asian descent.

Participants were grouped according to the presence of cardiometabolic conditions (0 vs 1+ of CVD, hypertension, or diabetes) to examine differences in age, sex, demographics, health history, and lifestyle factors using chi-square tests for independence.

Multivariable logistic regressions were performed to assess the relationship between PA and cardiometabolic conditions in 4 stratified models (Model 1: non-immigrant; Model 2: recent immigrant; Model 3: established immigrant, Model 4: overall). All models were adjusted for age, sex, demographics, health history and lifestyle factors that were significant at the bivariate level. Although total sedentary time was significant at the bivariate level, it was not included in any adjusted models because approximately one third of the sample was missing this variable. Odd ratios (OR) and 95% confidence intervals (CI) were estimated for variables within each model.

Models were stratified by immigration status, as the interaction with PA was significant ($p<0.001$). Due to a low sample size and high coefficient of variation, immigration models could not be stratified by sex (interaction with PA, $p <0.0001$), therefore an interaction term was added into each immigration model. In order to display the marginal effect of the interaction between PA and sex, the following equation was used to calculate the odds of cardiometabolic conditions based on PA and sex for each immigration category:

$$\text{Log (OR)} = \beta_0 + \beta_1(\text{PA}) + \beta_2(\text{sex}) + \beta_3(\text{PA*sex}) + \text{covariates}$$

Sample weights and SAS survey procedures (version 9.4) were used to ensure the representativeness of the sample. Statistical significance was set at alpha = 0.05.

Results

Metabolic Conditions in South Asians

In total, the sample was weighted to represent 703 850 South Asians **(Table 1).** Approximately half (53.3%) of the sample were established immigrants (≥ 10 years), 34.0% were recent immigrants (<10 years) and 12.7% were non-immigrants. Over three-quarters

(77.4%) of the sample had 0 metabolic conditions and 22.6% had one or more. Of those who reported 0 conditions, 74.2% were young adults (20-44 y), whereas the majority of the 1+ condition group (47.8%) were middle-aged (45-64 y). As expected, self-reported excellent/very good general health was higher among South Asians with 0 conditions (62.7% vs. 28.7%, and daily energy expenditure in leisure activities also differed between the groups (0 conditions: 59.3% were inactive and 19.9% active; 1+ conditions: 65.9% inactive and 14.9% active). Although the number of South Asians with obesity (≥ 27.5 kg/m²) was lower among those without any conditions (18.0% vs. 31.2%), the number of overweight South Asians among those with 0 conditions and those with 1+ conditions was similar (41.1% vs. 43.5%) **(Table 1).** The independent relationships between MetS, and PA and the confounders were stratified by immigration status and unadjusted odds ratios were calculated **(Table 2).**

Metabolic Conditions and Immigration Status

Non-Immigrants

Due to the interaction between PA and immigration status, the multivariable logistic models were stratified by immigration status (P <0.05) **(Table 3)**. Moderately active (1.5-3.0 KKD) non-immigrant South Asian males had 86.2% lower odds of 1+ metabolic condition (OR 0.14, 95% CI 0.08-0.20) in comparison to inactive males (<1.5 KKD; OR=1.00, referent) (Appendix C). Paradoxically, active non-immigrant males (>3.0 KKD) had only 67.2% lower odds of 1+ metabolic condition (OR 0.33, 95% CI 0.28-0.38) in comparison to inactive males. Non-immigrant South Asian females had similar trends in that those who were moderately active had 89.7% lower odds of 1+ metabolic condition (OR 0.10, 95% CI 0.04-0.16) and those who were active had 53.3% lower odds of 1+ metabolic condition (OR 0.47, 95% CI 0.42-0.51) in comparison to inactive females (<1.5 KKD; OR=1.00, referent). In general, age was a strong predictor of metabolic conditions as middle-aged and older adults were at an 8.1 (95% CI 7.20-9.08) and 8.8 (95% CI 7.30-10.70) times greater odds of metabolic conditions, respectively in comparison to young non-immigrant adults. Individuals with excellent and very good health, and regular or occasional smokers had low odds of metabolic conditions.

Short-Term Immigrants

A total of 211 817 recent South Asian immigrants were represented in the adjusted multivariable logistic model **(Table 3)**. For the recent immigrant category, moderately active (1.5-3.0 KKD) males and females had 72.7% and 79.8% lower odds of 1+ metabolic condition (OR 0.27, 95% CI 0.25-0.30; OR 0.20, 95% CI 0.18-0.23) respectively, in comparison to those who were inactive (<1.5 KKD; OR=1.00, referent). However, males and females in the "active" group (>3.0 KKD) had 81.3% and 87.3% lower odds of 1+ metabolic condition, respectively (OR 0.19, 95% CI 0.16-0.22; OR 0.13, 95% CI 0.10-0.16). In comparison to young adults, middle-aged and older adults had higher odds of metabolic conditions with the risk increasing with older age. Individuals of higher education (some post-secondary or higher), higher income, daily or occasional drinkers, regular or occasional smokers, and individuals of excellent or very good health had low odds of metabolic conditions.

Long-Term Immigrants

A total of 331 963 established South Asian immigrants were represented in the final model **(Table 3)**. For established immigrants, males in the moderately active (1.5-3.0 KKD) group had 59.2% (OR 0.41, 95% CI 0.39-0.42) lower odds of 1+ metabolic condition in comparison to those who were inactive, whereas females who were moderately active had 70.4% (OR 0.30, 95% CI 0.28-0.31) lower odds of 1+ metabolic condition in comparison to inactive females. Surprisingly, the relationship between activity and 1+ metabolic condition was slightly more modest in the "active" (>3.0 KKD) group (M: OR 0.49, 95% CI 0.48-0.51; F: OR 0.56, 95% CI 0.55-0.58). Older age, individuals who were married or in common-law relationships, and those who had more than some post-secondary education were all associated with higher odds of metabolic conditions in this established immigration group, whereas individuals with high income, regular or occasional smokers, and individuals with excellent or very good health had low odds of metabolic conditions.

Discussion

This study examined the effect of time in country on metabolic conditions and PA in South Asians living in Canada between 2000 and 2014. In this large representative sample, both cardiometabolic health and the amount of PA performed by South Asians was dependent on time in country (non-immigrant, recent immigrant and established immigrant). Although PA was negatively related to metabolic health in all groups, the effects were greatest amongst moderately active (1.5-3.0 KKD) non-immigrants, moderately active established immigrants, and "active" (>3.0 KKD) recent immigrants.

To our knowledge, this is the first study to investigate the relationship between metabolic conditions and PA in South Asians living in Canada based on time in country. However, cardiometabolic health profiles of South Asians in Canada have been studied extensively. Two common metabolic conditions, diabetes and hypertension, are consistently shown to be more prevalent among South Asian populations in Canada (Chiu, Austin, Manuel, & Tu, 2010; Liu et al., 2010). A study by Chiu and colleagues (2010) used the National Population Health Survey of 1996 and CCHS 2000 to 2007 and found the overall prevalence of diabetes, hypertension, heart disease or stroke higher in South Asians in comparison to other ethnicities and at younger ages, consistent with our findings (Chiu et al., 2010). Along with high prevalence of metabolic conditions, immigrants have lower PA levels in comparison to non-immigrant counterparts (Dogra, Meisner & Ardern, 2010; Pérez, 2002). Studies using the CCHS have reported physical inactivity was most prevalent among South Asians and Chinese (Chiu et al., 2010; Liu et al., 2010), which is consistent with the current finding that 60.8% of the South Asian sample is inactive (<1.5 KKD). Another CCHS study found that the largest difference in the amount of PA between recent and established immigrants was among South Asian men, and that female immigrants were less active than their male counterparts regardless of time since immigration (Tremblay et al., 2006).

Length of Time in Country

Due to the large number of foreign-born population in North America, it has been suggested that cardiovascular health risk should be studied by country of birth and duration of residence in order to account for short- vs long-term resident health discrepancies (Sohail et al., 2015). An association with a progressive decline in health of recent immigrants with increasing length of residence in the host country, despite better health than non-immigrants upon arrival also exists (Gerber, Barker, & Pühse, 2012; Pérez, 2002). The findings of the current study are consistent with the above studies as 23.9% and 72.9% of the total number of South Asians with 1+ metabolic condition were recent and established immigrants, respectively. As the number of years in Canada increases, the number of immigrants who have metabolic conditions also increases. However, only 3.2% of non-immigrants had 1+ metabolic condition. This discrepancy may be due to the low number of South Asian non-immigrants in this study and within Canada. Only 30.9% of visible minorities are born in Canada (Statistics Canada, 2011), South Asians specifically, approximately 29% are born in Canada (Tran, Kaddatz, & Allard, 2005).

The Cardiovascular Health in Ambulatory Care Research Team (CANHEART) Immigrant Study concluded that the cardiovascular health of immigrants is superior to that of long-term residents in Ontario (Tu et al., 2015). However, the authors note that this finding contradicts several studies in Europe and the United States where immigrants have poorer health than that of the host population. The findings of our study are also in contrast to those of the CANHEART study in that the 1+ metabolic condition group consisted mostly of established immigrants. Specifically, only South Asian males in the CANHEART Immigration Study had *worse* cardiovascular health than that of the host population. This discrepancy may be due to the definition of cardiovascular health as the CANHEART studied defined it by cardiovascular events that led to hospitalization for stroke, heart disease, coronary heart disease or heart attack (Tu et al., 2015).

The extent to which differences in acculturation may directly impact the PA-health relationship observed is unclear, but it has been speculated that acculturation may lead established immigrants to adapt an active lifestyle similar to non-immigrants (Dogra et al., 2010). To this end, immigrants with higher acculturation scores tend to report higher leisure-time activity than those who have low acculturation (Tang, MacDougall, & Gasevic, 2015; Koya & Egede, 2007). In this study, moderately active established immigrants and non-immigrants had lower odds of metabolic conditions than those who were active in these two immigration categories. Therefore, this similarity in risk among established and non-immigrants may be the result of acculturation. It is also possible that differences in PA preference with acculturation may also play a role. For example, South Asians are more likely to participate in conventional exercises such as home-based exercises and weight training than other ethnicities (Dogra et al., 2010); however, established immigrants are more likely to participate in these activities than recent immigrants (Dogra et al., 2010). Regardless of time since immigration, female immigrants are less active than male immigrants (Tremblay et al., 2006). This may be explained in part by differences in acculturation, as male immigrants may be more accepting of their new culture, as shown by a greater range of PA types and overall PA level upon arrival to the host country (Tang et al., 2015). Nonetheless, participation in light-intensity PA can also be beneficial, as it has a significant association with 2-g plasma glucose independent of MVPA (Healy et al., 2007), and may explain the finding of lower odds of metabolic conditions amongst moderately active non-immigrant and established immigrant female South Asians.

Strengths and Limitations

Among the strengths of the current study is the pooling of data from routinely collected national-level health surveys (2000 to 2014), which provided a basis on which to explore the health of South Asians by time in country. The findings of this study are therefore generalizable to the South Asian population in Canada as immigrants and non-immigrants were included in our study. The PA components of this dataset also captured a total of 21 leisure activities performed over the past 3 months, and is consistent with previous examinations of the PA – health relationship in other ethnic groups (Nie & Ardern, 2014; Liu et al., 2010; Tremblay et al., 2006; Perez, 2002). Limitations of this study should also be noted. First, this cross-sectional survey does not allow for casual links to be made between PA and metabolic health. Second, the CCHS is based on self-reported data, which is subject to healthy responder and response bias. Third, self-reported leisure time PA may cause overestimation of activity (Tucker, Welk, & Beyler, 2011). Fourth, non-leisure PA such as occupational PA was not considered, and would therefore underestimate total energy expenditure (Pérez, 2002; Tremblay et al., 2006). Finally, because cardiometabolic conditions were also self-reported, actual metabolic risk may be underestimated.

Conclusions

Length of time in Canada was associated with cardiometabolic health and PA of South Asians. Moderately active non-immigrants and established immigrants (1.5-3.0 KKD) and physically active (>3.0 KKD) recent immigrants had the lowest odds of metabolic conditions in comparison to those who were inactive (<1.5 KKD). Future research using longitudinal data and objective measures of physical activity are needed to replicate these findings and understand the causal relationship between immigration and cardiometabolic health in ethnic-specific populations.

Table 1: Descriptive characteristics of South Asians in Canada by Metabolic Conditions

	Overall 743 745 %	**0 Metabolic Conditions** 575 664 (77.40) %	**1+ Metabolic Condition** 168 081 (22.60) %	**Unadjusted model** OR (CI)
Immigration status				
Non-immigrant	12.72	15.53	3.19	1.00
Recent Immigrant	34.02	37.01	23.89	3.14 (3.04-3.23)
Established immigrant	53.26	47.45	72.92	7.47 (7.26-7.69)
Daily Energy Expenditure Leisure				
Inactive (<1.5 KKD)	60.79	59.32	65.89	1.00
Moderately Active (1.5-3.0 KKD)	20.42	20.78	19.17	0.83 (0.82-0.84)
Active (>3.0 KKD)	18.80	19.91	14.94	0.68 (0.67-0.69)
Age				
Young adult (20-44 y)	62.96	74.22	24.39	1.00
Middle-aged adult (45-64 y)	27.55	21.64	47.82	6.72 (6.63-6.82)
Older adult (65+ y)	9.49	4.14	27.79	20.41 (20.03-20.79)
Sex				
Males	51.38	50.63	53.93	1.00
Females	48.52	49.37	46.07	0.88 (0.87-0.89)
Marital Status				
Single, divorced, separated, widowed	27.41	30.50	16.82	1.00
Married/common-law	72.59	69.50	83.18	2.17 (2.14-2.20)
Education				
Secondary or less	69.00	71.44	60.62	1.00
Some post-secondary or higher	31.00	28.56	39.38	1.63 (1.61-1.64)
Household Income				
Lowest income grouping	8.81	8.27	10.64	1.00
Lower middle income grouping	23.40	22.95	24.95	0.85 (0.83-0.86)
Middle income grouping	31.63	31.60	31.74	0.78 (0.76-0.80)
Upper middle income grouping	36.16	37.18	32.67	0.68 (0.67-0.70)
Alcohol				
Did not drink last 12 months	53.20	52.33	56.18	1.00
Daily or occasional	46.80	47.67	43.82	0.86 (0.85-0.87)
Smoking				
Never or former	89.90	89.16	92.42	1.00
Daily or occasional	10.10	10.84	7.58	0.68 (0.66-0.69)
General Health				
Good/ Fair/ Poor	44.98	37.28	71.35	1.00
Excellent/ Very Good	55.02	62.72	28.65	0.24 (0.24-0.24)

Fruit & Vegetable Intake				
<5 servings per day	59.59	59.59	59.62	1.00
≥ 5 servings per day	40.41	40.41	40.38	1.00 (1.00-1.01)
Total Sedentary Hours				
≥ 35 hours/week	9.03	8.58	10.65	1.00
20 - 34 hours/week	21.13	20.27	24.24	0.96 (0.94-0.99)
≤ 19 hours/week	69.84	71.15	65.11	0.74 (0.72-0.76)

Table 2: Unadjusted odds ratios for Metabolic Conditions in South Asians in Canada stratified by immigration status

	Non-immigrants OR (CI)	**Recent Immigrants** OR (CI)	**Established Immigrants** OR (CI)
Daily leisure energy expenditure			
Inactive (<1.5 KKD)	1	1	1
Moderately Active (1.5-3.0 KKD)	0.52 (0.48-0.56)	1.10 (1.07-1.13)	0.81 (0.80-0.83)
Active (>3.0 KKD)	0.93 (0.87-0.99)	0.62 (0.60-0.64)	0.69 (0.67-0.70)
Age			
Young adult (20-44 years)	1	1	1
Middle-aged adult (45-64 years)	7.97 (7.27-8.73)	6.63 (6.46-6.80)	5.56 (5.46-5.66)
Older adult (65+ years)	28.31 (24.06-33.31)	14.50 (13.90-15.12)	17.78 (17.36-18.20)
Sex			
Males	1	1	1
Females	1.53 (1.45-1.62)	0.77 (0.75-0.79)	0.90 (0.89-0.91)
Marital status			
Single, divorced, separated, widowed	1	1	1
Married/common-law	3.11 (2.94-3.29)	2.45 (2.37-2.53)	1.42 (1.39-1.44)
Education			
Secondary or less	1	1	1
Some post-secondary or higher	2.06 (1.93-2.20)	1.43 (1.40-1.46)	1.40 (1.38-1.42)
Household income			
Lowest income grouping	1	1	1
Lower middle income grouping	4.09 (3.28-5.12)	0.97 (0.93-1.00)	0.68 (0.66-0.70)
Middle income grouping	2.55 (2.05-3.18)	0.77 (0.75-0.80)	0.63 (0.61-0.65)
Upper middle income grouping	1.84 (1.48-2.29)	0.80 (0.77-0.83)	0.53 (0.51-0.54)
Alcohol intake			
Did not drink last 12 months	1	1	1
Daily or occasional	1.25 (1.17-1.34)	0.74 (0.72-0.76)	0.90 (0.89-0.92)
Smoking			
Never or former	1	1	1
Daily or occasional	1.09 (1.02-1.18)	0.75 (0.72-0.79)	0.65 (0.63-0.67)
General health			
Good/ Fair/ Poor	1	1	1
Excellent/ Very Good	0.37 (0.35-0.39)	0.31 (0.30-0.31)	0.23 (0.23-0.23)
Fruit & vegetable intake			
<5 servings per day	1	1	1
≥ 5 servings per day	1.06 (1.00-1.13)	0.97 (0.95-0.99)	0.99 (0.98-1.00)
Total sedentary hours			
≥ 35 hours/week	1	1	1
20 - 34 hours/week	1.28 (1.15-1.43)	0.62 (0.59-0.65)	1.03 (1.00-1.07)
≤ 19 hours/week	0.93 (0.83-1.04)	0.76 (0.73-0.79)	0.63 (0.61-0.65)

Table 3: Adjusted odds ratios for Metabolic Conditions in South Asians in Canada stratified by immigration status

	Non-immigrants N = 77052	**Recent Immigrants** N = 211817	**Established Immigrants** N = 331963
Daily Energy Expenditure Leisure			
Inactive (<1.5 KKD)	1.00	1.00	1.00
Moderately Active (1.5-3.0 KKD)	0.62 (0.59-0.66)	1.13 (1.11-1.16)	0.89 (0.88-0.91)
Active (>3.0 KKD)	1.47 (1.40-1.54)	0.78 (0.75-0.80)	1.08 (1.06-1.10)
Age			
Young adult (20-44 years)	1.00	1.00	1.00
Middle-aged adult (45-64 years)	8.09 (7.20-9.08)	6.37 (6.18-6.57)	4.61 (4.51-4.70)
Older adult (65+ years)	8.83 (7.30-10.70)	16.03 (15.17-16.93)	14.15 (13.77-14.54)
Sex			
Males	1.00	1.00	1.00
Females	1.15 (1.11-1.20)	0.74 (0.72-0.75)	0.90 (0.89-0.91)
Marital Status			
Single, divorced, separated, widowed	1.00	1.00	1.00
Married/common-law	2.95 (2.75-3.15)	2.31 (2.20-2.408)	1.34 (1.30-1.37)
Education			
Secondary or less	1.00	1.00	1.00
Some post-secondary or higher	2.45 (2.27-2.65)	0.62 (0.60-0.64)	1.09 (1.07-1.11)
Household Income			
Lowest income grouping	1	1	1
Lower middle income grouping	6.70 (5.23-8.57)	1.13 (1.08-1.18)	0.68 (0.66-0.71)
Middle income grouping	3.71 (2.91-4.73)	0.95 (0.91-0.10)	0.70 (0.67-0.72)
Upper middle income grouping	3.03 (2.38-3.85)	0.88 (0.84-0.92)	0.63 (0.61-0.66)
Alcohol			
Did not drink last 12 months	1.00	1.00	1.00
Daily or occasional	1.32 (1.22-1.42)	0.78 (0.75-0.80)	1.22 (1.20-1.24)
Smoking			
Never or former	1.00	1.00	1.00
Daily or occasional	0.86 (0.79-0.94)	0.75 (0.72-0.79)	0.83 (0.80-0.85)
General Health			
Good/ Fair/ Poor	1.00	1.00	1.00
Excellent/ Very Good	0.42 (0.40-0.45)	0.41 (0.40-0.42)	0.31 (0.31-0.32)
Fruit & Vegetable Intake			
<5 servings per day	1.00	1.00	
≥ 5 servings per day	0.10 (0.93-1.06)	1.02 (0.99-1.05)	
Cycle Number			
Cycle 1 (2000-2004)	1.00	1.00	1.00
Cycle 2 (2005-2006)	1.38 (1.22-1.56)	2.47 (2.36-2.59)	1.11 (1.07-1.15)
Cycle 2 (2007-2008)	1.28 (1.14-1.44)	2.59 (2.47-2.71)	1.45 (1.40-1.49)
Cycle 4 (2009-2010)	0.80 (0.71-0.91)	1.80 (1.71-1.89)	1.48 (1.43-1.53)
Cycle 5 (2011-2012)	1.22 (1.10-1.36)	2.22 (2.12-2.32)	1.76 (1.71-1.81)
Cycle 6 (2013-2014)	0.40 (0.36-0.45)	2.75 (2.63-2.87)	1.55 (1.50-1.59)

* interaction term between sex and leisure time activity was included in each model

Association between Physical Activity and Metabolic Syndrome in South Asians: Canadian Health Measures Survey, 2007-2013[2]

Summary

Background: Individuals of South Asian (SA) descent have a high prevalence of cardiometabolic risk factors such as fasting glucose and hypertension, and low levels of physical activity (PA). **Objective:** This study aims to examine the relationship between metabolic syndrome (MetS) and PA among SAs. **Methods:** Data from SA participants (20+y) of the 2007-2013 Canadian Health Measures Survey were pooled and used in the current analysis (N=546). Objectively assessed levels of sufficient PA were defined by activity monitor data with thresholds as follows: daily accumulation of steps: ≥ 10 000 steps; recommended moderate-to-vigorous intensity physical activity (MVPA): ≥ 150 minutes/week, and; a newly proposed SA MVPA threshold ≥ 232 minutes/week. Multivariable logistic regression was used to estimate the odds of MetS (waist circumference, fasting glucose, triglycerides, HDL cholesterol, and blood pressure) according to the three measures of PA. **Results:** Approximately 26% of SAs had MetS. Compared to male and female SA recent immigrants who took <10 000 steps per day (OR=1.00, referent), those who averaged ≥ 10 000 steps per day had 84% and 72% lower odds of MetS, respectively (M: OR 0.16, 95% CI 0.15-0.17; F: OR 0.28, 95% CI 0.27-0.28). Male and female recent immigrants who met the guidelines of ≥ 150 minutes/week of MVPA had 51% and 59% lower odds of MetS, respectively, than those averaging <150 minutes/week; however, male and female recent immigrants who engaged in ≥ 232 minutes/week of MVPA had 59% and 66% lower odds of MetS, respectively, in comparison to those who engaged in <232 minutes/week of MVPA (M: OR 0.41, 95% CI 0.40-0.41; F: OR 0.34, 95% CI 0.33-0.34). Established immigrants had similar trends as higher amounts of MVPA led to lower odds of MetS. **Conclusions:** Regular PA is associated with better cardiometabolic health. SAs may need to engage in longer durations of MVPA to acquire benefits to health. Further research is necessary to understand the optimal threshold of PA required for prevention of MetS in SAs.

Key words: ethnicity, exercise, metabolic syndrome, cardiovascular disease, epidemiology

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Introduction

Metabolic syndrome (MetS) encompasses key cardiometabolic risk factors that increase risk of morbidity and mortality, most notably cardiovascular disease (CVD) and type 2 diabetes. Individuals with MetS are at a 2 fold increased risk for CVD, and a 5 fold increased risk for developing type 2 diabetes compared to those without MetS (Alberti et al., 2009). Because MetS is composed of modifiable risk factors that can be managed with therapeutic lifestyle change, including diet, physical activity, and weight management, the true clinical value of MetS as a screening tool may be the early intervention opportunity. Indeed, results of the HERITAGE Family study suggest that for every three individuals with MetS who are treated with exercise, one will no longer have MetS (Katzmarzyk et al., 2003).

The Canadian Physical Activity Guidelines recommend 150 minutes of moderate-to-vigorous physical activity (MVPA) per week for individuals between the ages of 18 and 64 years (Canadian Society for Exercise Physiology, 2012). Through direct measures of physical activity, it was found that 15% of adults in the Canadian Health Measures Survey (CHMS) 2007-2009 engaged in ≥ 150 minutes per week of MVPA (Colley et al., 2011). In cycle 3 (2012-2013) of the CHMS, it was found that 1 in 5 Canadians were meeting these guidelines (Statistics Canada, 2015). Although these guidelines are universal, research has continued to discover vast differences in physical activity and cardiometabolic health between individuals of different ethnicities. For example, approximately 25% of the South Asian population, one of Canada's largest ethnocultural groups, meets the criteria for MetS (Anand et al., 2000), but they engage in very low levels of physical activity (Lesser, Yew, MacKey, & Lear, 2012). In some settings, it has been estimated that physical inactivity may account for more than 20% of the excess risk of coronary heart disease in South Asians living in the U.K. (Fernando et al., 2015). Although ethnicity and time-in-country relationships have been previously explored in Canada (Tremblay, Bryan, Perez, Ardern, & Katzmarzyk, 2006; Perez, 2002; Dogra, Meisner, & Ardern, 2010), self-report measures have been consistently shown to overestimate usual activity (Tucker, Welk, & Beyler, 2011). To date, the CHMS data has not been used to understand physical activity patterns based on ethnicity or immigration status.

Given emerging evidence that South Asians may need to perform more MVPA to obtain similar cardiometabolic risk profiles as their European counterparts (Celis-Morales, Ghouri, Bailey, Sattar, & Gill, 2013), confirmation of these patterns with activity monitor data is a critical next step. The purpose of this study is to therefore explore the relationship between PA and MetS among recent immigrant (<10 years) and established immigrant (≥ 10 years) South Asians. Understanding this relationship has implications for ethnic-specific physical activity guidelines in a growing segment of Canada's population.

Methods

Data Source

This study is based on cycles 1 (2007-2009), 2 (2009-2011) and 3 (2012-2013) of the cross sectional CHMS. The CHMS excludes 4% of the target population: persons living in the three territories, persons living on reserves or other Aboriginal settlements, members of the Canadian forces and the institutionalized population.

Sample

The target population was individuals over the age 20 of South Asian descent, which was confirmed by the question "*People living in Canada come from many different cultural and racial backgrounds. Are you: - South Asian*". Those who did not answer "yes" to this question were excluded from the study. Immigration status was classified by country of birth (Canada vs.

other) and length of time in Canada since immigration (<10 years vs. ≥ 10 years). Six hundred and three South Asians were captured in the CHMS from 2007 to 2013. Non-immigrant South Asians or those who did not provide country of birth (n=57) were excluded from the study. The descriptive table includes all South Asians (n=603), as there were no significant differences in sex, age, demographics, health history and lifestyle factors across the separate samples used in the analyses. Each physical activity analysis was treated separately due to their high correlation. All three variables capture physical activity, however, in two separate ways (intensity vs. steps), and two different intensity cut points (≥ 150 minutes vs. ≥ 232 minutes per week of MVPA). As each model was treated separately, each analysis has a different analytic sample to maximize statistical power for each relationship. The final analytic sample for the steps analysis was n=462, and the MVPA analyses had a sample of n=546 with complete variables of interest.

Information collected by the CHMS includes objective health measures as well as environmental and nutritional markers. Demographic and lifestyle information is collected in the household interview. Each respondent from the household interview made an appointment at a Mobile Examination Centre (MEC) **(Appendix A)**. Respondents with morning interviews were required to fast for 12 hours prior to the interview. The MEC visit captures objective measures on health such as physical measures, blood measures and urine measures, and physical activity. The CHMS provides objective physical activity information and direct measures of cardiometabolic risk (waist circumference, blood pressure, triglycerides, fasting glucose and HDL-cholesterol). Physical activity was assessed with a waterproof activity monitor that was to be worn on the waist for 7 days at all times except when sleeping (Statistics Canada, 2014) **(Appendix B)**. After the 7 days, participants were instructed to mail the monitor back. The activity monitor return rate with valid data of 10 hours and at least 4 days of wear time was approximately 42% (Garriguet & Colley, 2014).

Exposure, outcome variables, and confounders

Metabolic Syndrome

Metabolic Syndrome (yes/no) was classified as the presence of three or more of the following five components: waist circumference (men ≥ 90 cm, women ≥ 80 cm), systolic blood pressure (≥ 130 mmHg), diastolic blood pressure (≥ 85 mmHg), HDL cholesterol (men <40 mg/dL, women <50 mg/dL), fasting glucose (≥ 100 mg/dL), and triglycerides (≥ 150 mg/dL) (Alberti et al., 2009). The final average systolic and diastolic blood pressures were used, which were derived from the average of two measures, taken during standard resting conditions. Due to high amounts of visceral abdominal fat amongst South Asians, elevated waist circumference is defined as ≥ 90 cm in men, and ≥ 80 cm in women (Misra & Khurana, 2009). Participants who reported physician diagnosed hypertension, blood pressure medication, and diagnosed type 2 diabetes were considered to have each of the respective MetS components.

Physical Activity

The main independent variable is accelerometer-derived activity counts. In compliance with standard practice (Garriguet & Colley, 2014), only accelerometer data from participants with 4 days of 10+ hours of wear time was used. In order to inform potential measurement differences, measures of MVPA as well as total step counts consistent with the current activity guidelines were used. Data from the activity monitors was collected in one-minute epochs and the intensity of activity for each minute was captured, with a threshold of at least 1500 counts per minute (cpm) for MVPA (Garriguet & Colley, 2014). Using the 1500 cpm intensity threshold, minutes in MVPA were quantified, and used to classify participants according to i) the universal recommendation of ≥ 150 minutes of MVPA (Canadian Society for Exercise Physiology, 2012); ii) hypothesized ethnic specific guidelines of ≥ 232 minutes (Iliodromiti et al., 2016), and iii) step counts [inactive (<10 000 steps) vs. active (≥ 10 000 steps)] (Hills, Mokhtar, & Byrne, 2014).

Covariates

Additional information on study covariates were collected. Demographics included age (20-44 y, 45-64 y, 65+ y), sex (male vs. female), marital status (single/divorced/separated/widowed vs. married/common-law), household income (lowest, lower middle, middle, upper middle grouping), and educational attainment (secondary or less vs. some post-secondary or higher). Behavioural factors included smoking status (daily or occasional vs. never or former), drinking status (daily or occasional vs. did not drink last 12 months), daily consumption of fruits and vegetables (<5 vs. ≥ 5 servings per day), and self-reported sedentary behaviours (total sedentary hours per week accounting for computer time, TV time, videogame time, and reading time). Finally, self-reported general health was classified as low (good/fair/poor) or high (excellent/very good).

Statistical Analysis and Data Handling

All analyses were conducted with the merged cycles of the CHMS. Weighting of the analyses was performed to produce a representative sample of South Asians in Canada for the period 2007-2013.

Cross tabulation was used to calculate chi-square test of independence for MetS and covariates such as demographics (age, sex, marital status, income, and education), health history (smoking, alcohol consumption, and fruit and vegetable intake) and lifestyle factors (physical activity and sedentary behaviours).

Multivariable logistic regressions were preformed to assess the relationship between PA and MetS in three separate models (Model 1: adjusted for steps per day plus age, sex, demographics, health history and lifestyle factors that are significant at the bivariate level; Model 2: adjusted for the current recommendations of ≥ 150 minutes per week of MVPA plus age, sex, demographics, health history and lifestyle factors that are significant at the bivariate level, and; Model 3: adjusted for the proposed recommendations of ≥ 232 minutes per week of MVPA, plus age, sex, demographics, health history and lifestyle factors that are significant at the bivariate level). Odd ratios (OR) and 95% confidence interval (CI) estimates were calculated for variables within each model. Sex-by-activity and immigration-by-activity interactions were probed and found to be significant ($p<0.001$). Due to insufficient total sample size, interaction terms were retained in the final model, as stratification by sex or immigration status was not possible. To describe the interactions between activity, immigration and sex, the following equation was used to calculate the odds of metabolic syndrome for each subgroup:

$$\text{Log (OR)} = \beta_0 + \beta_1(\text{activity}) + \beta_2(\text{sex}) + \beta_3(\text{immigration}) + \beta_4(\text{activity*sex}) + \beta_5(\text{activity*immigration}) + \text{covariates}$$

Because the number of non-immigrant South Asians was insufficient for stratification by MetS they were not included in these analyses (n=57; 9.5%). SAS survey procedures (version 9.4) were used to ensure the representativeness of the sample. Statistical significance was tested at alpha = 0.05.

Results

Demographic characteristics of South Asians living in Canada included 603 individuals weighted to represent 1 979 368 South Asians in Canada **(Table 1)**. Overall, the sample has a high prevalence of young adults (57.1%), individuals with at least some post-secondary (63.4%)

or higher education (63.4%), and individuals who are married or in common-law relationships (72.1%). Only 22.4% of South Asians met the physical activity guidelines when using ≥ 10 000 steps per day cut off; 33.9% were meeting the guidelines of ≥ 150 minutes of MVPA per week, and 18.9% were meeting the proposed South Asian specific guidelines of ≥ 232 minutes of MVPA per week. Along with these low levels of physical activity, 21.8% of South Asians spent more than 35 hours per week in sedentary activities.

In general, participants reported high levels of overweight or obesity, low fruit and vegetable consumption (21.1% ≥ 5 servings/day), modest ratings of general health (40.3% rated as excellent or very good), and were moderate smokers (12.4% daily or occasional). Stroke (2.9%) and heart disease (5.4%) were rare, but 47.3% reported a physician diagnosis of high cholesterol, and 8.4% had type 2 diabetes. MetS was present in 26.4% of South Asians, with components as follows: 72.5% had an elevated waist circumference (M ≥ 90 cm, F ≥ 80 cm), 47.3% had elevated triglycerides (≥ 1.7 mmol/L), 47.8% had low HDL (M <1.0 mmol/L, F <1.3 mmol/L, and 10.2% had elevated glucose (≥ 5.6 mmol/L).

Physical Activity Defined by Step Counts

A total of 462 South Asians, weighted to represent 1 354 154 South Asians, were included in the multivariable logistic regression with average steps as the independent variable **(Table 2)**. In the unadjusted model, individuals with ≥ 10 000 steps had higher odds of MetS in comparison to those who took <10 000 steps **(Figure 1).** However, in the adjusted model, male recent immigrants who took ≥ 10 000 steps had 84.1% (OR 0.16, 95% CI 0.15-0.17) lower odds of MetS in comparison to male recent immigrants who took <10 000 steps per day (OR=1.00, referent) **(Figure 2)**, and female recent immigrants who took ≥ 10 000 steps had 89.1% (OR 0.11, 95% CI 0.10-0.12) lower odds of MetS in comparison to female recent immigrants who took <10 000 steps per day (OR=1.00, referent). Although the relationship was not as strong within the subgroup of established immigrants, odds of MetS remained inversely related to activity. Specifically, established male immigrants had 72.4% lower odds of MetS and females had 84.2% lower odds of MetS when they took ≥ 10 000 steps per day in comparison to those who took <10 000 steps per day (M: OR 0.28, 95% CI 0.27-0.28; F: OR 0.16, 95% CI 0.15-0.16). Middle-aged adults (45-64 y) had 16.6% (95% CI 0.82-0.85) lower odds, and older adults (65+ y) were at a 2.5 fold (95% CI 2.50-2.58) greater odds of MetS, in comparison to young adults (20-44y). Those in the middle-income grouping, daily or occasional smokers, and those with excellent/very good general health were all at lower odds of MetS. Individuals who were married or in common-law relationships, those who had some post-secondary education or higher, lower middle and upper middle income grouping individuals, daily or occasional drinkers, and those who consumed ≥ 5 servings per day of fruits and vegetables were more likely to have MetS. South Asians who spent ≤ 19 hours per week sedentary were at 66.4% (95% CI 0.33-0.34) lower odds of MetS and those who spent 20-34 hours per week sedentary had 65.2% (95% CI 0.34-0.35) lower odds of MetS compared to those who spent ≥ 35 hours per week sedentary.

Physical Activity Defined by Minutes of MVPA

A total of 546 South Asians, weighted to represent 1 695 939 South Asians, were included in the multivariable logistic regression with MVPA as the independent variable **(Table 4)**. South Asian male recent immigrants who met the current recommendation of ≥ 150 minutes per week of MVPA (Model 2) had 51.4% (OR 0.49, 95% CI 0.48-0.49) lower odds of MetS in comparison to those who performed <150 minutes per week of MVPA (OR=1.00, referent), even after adjustments for covariates. Recent male immigrants who met or exceeded the proposed

Iliodromiti et al. (2016) threshold of 232 MVPA minutes per week (Model 3) had 59.2% (OR 0.41, 95% CI 0.40-0.41) lower odds of MetS in comparison to those who performed <232 minutes per week of MVPA (OR=1.00, referent) **(Figure 2)**. Amongst women, those who met the current recommendations of ≥ 150 minutes of MVPA per week had 59.3% lower odds of MetS (OR 0.41, 95% CI 0.40-0.41) in comparison to those that did not meet the recommendations (OR=1.00, referent). Using the proposed ≥ 232 minutes per week of MVPA, recent female immigrants were at even lower odds of MetS (OR 0.34, 95% CI 0.33-0.34).

Within the established immigrant group, males who engaged in ≥ 150 minutes of MVPA per week had 15.1% (OR 0.85, 95% CI 0.84-0.85) lower odds of MetS in comparison to those who engaged in <150 minutes per week (OR=1.00, referent). However, established male immigrants who engaged in ≥ 232 minutes of MVPA per week had 46.7% (OR 0.53, 95% CI 0.53-0.54) lower odds of MetS in comparison to those who engaged in <232 minutes of MVPA **(Figure 2)**. Similarly, established female immigrants had similar patterns in that the odds of MetS decreased with increased time in MVPA. Specifically, established female immigrants who met the current recommendations of ≥ 150 minutes of MVPA per week had 69.7% (OR 0.30, 95% CI 0.30-0.31) lower odds of MetS, and those with ≥ 232 minutes per week had even lower odds, 83.3% (OR 0.17, 95% CI 0.16-0.17). Older adults (65+ y), individuals who were married or in common-law relationships, those who were in the lower middle income grouping, those who consumed alcohol or smoked daily or occasionally, and those who consumed ≥ 5 servings per day of fruits and vegetables had higher odds of MetS with both MVPA thresholds. By contrast, middle-aged adults (45-64 y), individuals with at least some post-secondary education, middle and upper middle income, excellent or very good general health, and those who spent <35 hours per week sedentary were all protected against MetS with both MVPA thresholds.

Discussion

This study uses the nationwide Canadian Health Measures Survey cycles 1, 2 and 3 to study the relationship between MetS and physical activity in South Asians through objective measures. Activity monitors collected physical activity patterns, and the components of MetS were captured through direct measures at the MEC. These objective measures allow for a more accurate depiction of MetS and physical activity in South Asians, a growing population in Canada. Findings of this study suggest that physical activity at or above current recommendations are associated with lower odds of MetS, regardless of immigration status, but tended to vary by sex, immigration status, and threshold of activity. In particular, the benefits of greater total volume of MVPA were most apparent amongst established and recent immigrants. When taken together, the findings from this study provide additional support for the recently proposed South Asian guidelines of ≥ 232 minutes of MVPA per week for cardiometabolic health.

To our knowledge, this is the first study to investigate the relationship between MetS and physical activity with objective measures in the South Asian community within Canada. South Asians represent approximately 20% of the world's population (Celis-Morales et al., 2013; Gill et al., 2014; Statistics Canada, 2011b) and are the largest visible minority group in Canada (Statistics Canada, 2011b). Given that almost two-thirds of visible minorities are born outside of Canada, the health of immigrants requires more investigation. Distinctions should also be made between recent and established immigrants due to their differing health (Chiu et al., 2015; Liu et al., 2010). Specifically, recent immigrants tended to experience greater benefits from physical activity for each given physical activity measure in comparison to established immigrants. This difference may be due to the "healthy immigrant effect" that suggests immigrants are healthy when they arrive to the host country (Kim, Carrasco, Muntaner, McKenzie, & Noh, 2013), but that their health deteriorates with a longer length of residence and acculturation (Kim et al., 2013; Tremblay et al., 2006). This may be explained in part by a more sedentary lifestyle and high-calorie diet that is adapted upon arrival to the host country (Liu et al., 2010).

Approximately 26% of South Asians in the current study had MetS. While this prevalence is lower than that of other studies, several methodological differences exist with previous work. For example, Misra and colleagues (2010) found the prevalence of MetS in Asian Indians in the U.S. to be 32.7%, however, only individuals with both parents from India were included in the study. Using the South Asian specific waist circumference guidelines, waist circumference was the most prevalent component (61.2%) of MetS (Misra et al., 2010), similar to our findings of 72.5%. Another study of low income South Asians in the U.S. reported the prevalence of MetS to be 51% (Khan & Jackson, 2016), whereas the current study included South Asians of all income standings. Khan and Jackson (2016) found the most prevalent component of MetS to be low HDL, whereas the current study found elevated waist circumference (72.5%) to be the most prevalent. Nonetheless, 54.0% of South Asians had low HDL (Khan & Jackson, 2016), similar to the current findings of 47.8%. Finally, an earlier community-based study of South Asians living in Canada found the prevalence of MetS to be 25.9%, similar to the current findings (Anand et al., 2003). However, because the Asian specific waist circumference thresholds were only proposed in 2009 and are much lower than the thresholds Anand et al. (2003) applied (F: ≥ 88cm and M: ≥ 102 cm), the prevalence is likely an underestimate.

Cardiometabolic Health and Physical Activity

Although no direct ethnic comparison is made, results from this study are consistent with previous findings that cardiorespiratory fitness is 10-20% lower in South Asians compared to European counterparts (Ghouri et al., 2013), and more physical activity may be required to achieve the same cardiometabolic health as Europeans (Ghouri et al., 2013). The Canadian Physical Activity Guidelines for adults between the ages of 18 and 64 years recommend at least 150 minutes of MVPA per week, in bouts of 10 minutes or more (Canadian Society for Exercise Physiology, 2012). As these guidelines were developed based on data from individuals of white European descent, they may not be applicable to individuals of different ethnicities (Celis-Morales et al., 2013; Gill et al., 2014). The dose-response relationship between health and physical activity may also vary with different ethnicities, with greater cardiometabolic risk factors, diabetes, and CVD for a given amount of physical activity (Celis-Morales et al., 2013; Iliodromiti et al., 2016). A study matching South Asian and European men and women suggested that South Asians require ≥ 232 minutes of MVPA in order to attain the same cardiometabolic health as their European counterparts performing ≥ 150 minutes per week (Iliodromiti et al., 2016). In addition, this study suggests that MVPA of any length, even bouts of <10 minutes, may be beneficial to attenuate cardiometabolic risk factors (Iliodromiti et al., 2016). Consistent with the recommendation for higher levels of physical activity in South Asians, there was a dose-response relationship between activity and MetS. However, using 232 minutes of MVPA as a threshold, only 18.9% of South Asians would be considered physically active enough to improve their cardiometabolic health.

Strengths and Limitations

Among the strengths of the current study is the objectively measured physical activity captured by the CHMS, the first dataset in Canada to capture physical activity via activity monitors to allow for better and accurate estimations of the daily activity of Canadians. The direct measures of cardiometabolic risk factors is also a notable strength, and allows for MetS to be captured using Asian specific guidelines for waist circumference (Misra et al., 2009). Limitations of this study should also be noted. First, this cross-sectional survey does not allow for casual links to be made between PA and MetS. Second, although data was pooled from national-level health surveys (2007 to 2013), the sample size of South Asians was limited. Inclusion of non-immigrants in the analyses, and stratification by immigrant status and sex were also not possible due to the small sample size.

Conclusions

A higher dose of physical activity may be necessary for the prevention of MetS in South Asians living in Canada. MVPA performed for ≥ 232 minutes per week produced the lowest odds of MetS, whereas the current recommendations of ≥ 150 minutes of MVPA provided less benefit for metabolic health in this study. Future research using longitudinal data should determine the optimal threshold of physical activity for individuals of South Asian descent.

Table 4: Demographic characteristics of South Asians living in Canada

	Prevalence (%)
Metabolic Syndrome	
Yes – 3+ components	26.4
No - <3 components	73.6
Immigration status	
Recent Immigrant	36.0
Established Immigrant	64.0
Average steps	
< 10 000 steps	77.6
≥ 10 000 steps	22.4
Moderate-vigorous intensity minutes	
< 150 minutes/week	66.1
≥ 150 minutes/week	33.9
Moderate-vigorous intensity minutes	
< 233 minutes/week	81.0
≥ 233 minutes/week	18.9
Age	
Young adult (20-44 years)	57.1
Middle-aged adult (45-64 years)	26.5
Older adult (65+ years)	16.4
Sex	
Male	49.6
Female	50.4
Marital Status	
Single, divorced, separated, widowed	27.9
Married/common-law	72.1
Education	
Secondary or less	36.6
Some post-secondary or higher	63.4
Household Income	
Lowest income grouping	6.3
Lower middle income grouping	26.0
Middle income grouping	28.4
Upper middle income grouping	39.3
Alcohol Intake	
Did not drink last 12 months	58.3
Daily or occasional	41.7
Smoking	
Never or former	87.6
Daily or occasional	12.4
General Health	
Good/ Fair/ Poor	59.7
Excellent/ Very Good	40.3

Diastolic Blood Pressure	
< 85	89.4
≥ 85	10.6
Systolic Blood Pressure	
< 130	87.0
≥ 130	13.0
High Blood Pressure	
< 130/85	83.9
≥ 130/85	16.1
Blood Pressure Medication	
No	79.8
Yes	20.2
High Cholesterol	
No	52.7
Yes	47.3
Diabetes	
No	90.8
Yes	9.2
Type 1 Diabetes	
No	92.0
Yes	8.0
Type 2 Diabetes	
No	0.8
Yes	8.4
Not applicable	90.8
Heart Disease	
No	94.6
Yes	5.4
Stroke	
No	97.1
Yes	2.9
Glucose	
< 5.6 mmol/L	89.8
≥ 5.6 mmol/L	10.2
Triglycerides	
< 1.7 mmol/L	84.5
≥ 1.7 mmol/L	15.5
Glycated Hemoglobin	
< 6.1%	81.0
≥ 6.1%	19.0
High Density Lipoprotein (HDL) Cholesterol	
M ≥ 1.04, F ≥ 1.29 mmol/L	
M <1.04, F <1.29 mmol/L	52.2
	47.8

Waist Circumference	
M <90, F <80 cm	27.5
M ≥ 90. F ≥ 80 cm	72.5
Body Mass Index (BMI)	
Normal (18.0-22.9 kg/m²)	14.0
Overweight (23.0 – 27.5 kg/m²)	51.4
Obese (≥ 27.5 kg/m²)	34.6
Total Sedentary Hours	
≥ 35 hours/week	1.8
20 - 34 hours/week	31.3
≤ 19 hours/week	46.8
Fruit & Vegetable Intake	
<5 servings per day	78.8
≥ 5 servings per day	21.2

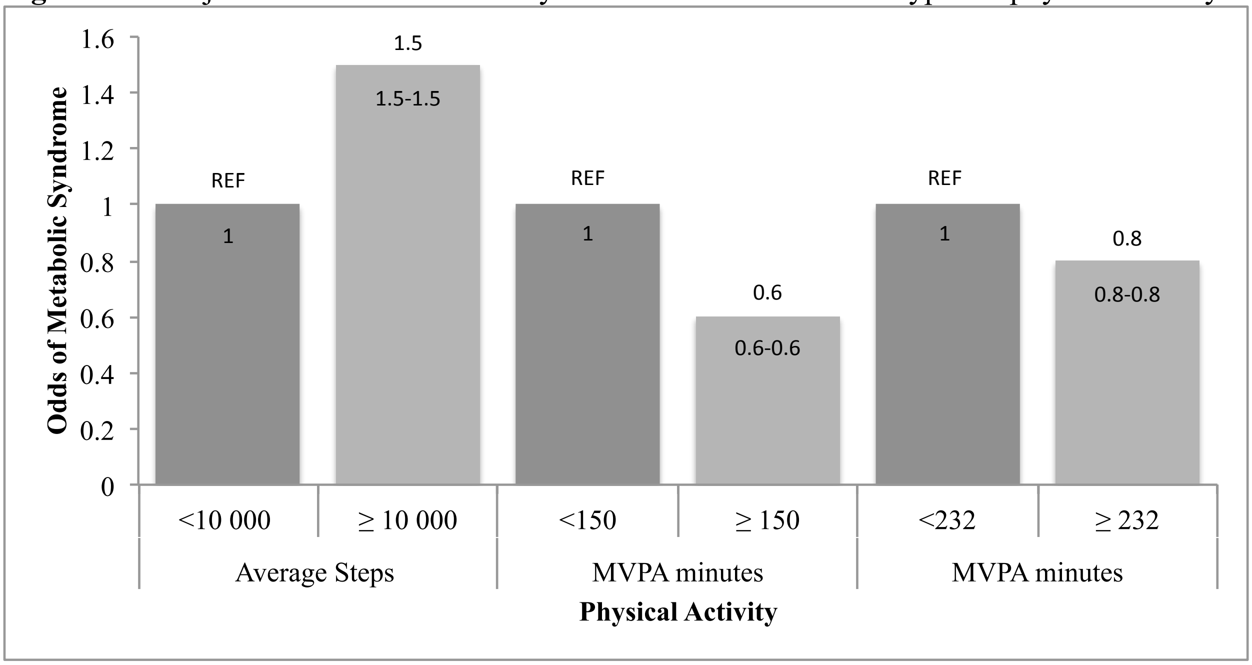
Table 5: Multivariable models of metabolic syndrome and physical activity

	Adjusted with average steps (N= 1 354 154) OR (CI)	Adjusted with CPA guidelines (N= 1 695 939) OR (CI)	Adjusted with ethnic specific guidelines (N= 1 695 939) OR (CI)
Immigration status			
Recent Immigrant	1	1	1
Established Immigrant	1.73 (1.72-1.75)	1.75 (1.74-1.76)	1.31 (1.30-1.32)
Average steps			
< 10 000 steps	1		
≥ 10 000 steps	0.86 (0.86-0.87)		
Moderate-vigorous intensity minutes			
< 150 minutes/week		1	
≥ 150 minutes/week		1.015 (1.020-1.009)	
Moderate-vigorous intensity minutes			
<233 minutes/week			1
≥ 233 minutes/week			0.89 (0.88-0.89)
Age			
Young adult (20-44 y)	1	1	1
Middle-aged adult (45-64 y)	0.83 (0.82-0.85)	0.53 (0.52-0.53)	0.59 (0.58-0.60)
Older adult (65+ y)	2.54 (2.50-2.58)	2.45 (2.42-2.49)	2.55 (2.52-2.59)
Sex			
Male	1	1	1
Female	0.68 (0.68-0.69)	0.84 (0.83-0.84)	0.83 (0.82-0.83)
Marital Status			
Single, divorced, separated, widowed	1	1	1
Married/common-law	1.03 (1.02-1.05)	1.38 (1.37-1.40)	1.36 (1.34-1.38)
Education			
Secondary or less	1	1	1
Some post-secondary or higher	1.27 (1.25-1.29)	0.40 (0.40-0.41)	0.39 (0.39-0.39)
Household Income			
Lowest income grouping	1	1	1
Lower middle income grouping	6.57 (6.40-6.75)	1.94 (1.91-1.98)	1.95 (1.91-1.99)
Middle income grouping	0.71 (0.69-0.73)	0.30 (0.29-0.31)	0.30 (0.29-0.30)
Upper middle income grouping	2.63 (2.56-2.70)	0.60 (0.59-0.61)	0.52 (0.51-0.53)
Alcohol Intake			
Did not drink last 12 months	1	1	1
Daily or occasional	1.96 (1.94-1.99)	1.58 (1.56-1.59)	1.76 (1.74-1.78)
Smoking			
Never or former	1	1	1
Daily or occasional	0.31 (0.30-0.32)	1.16 (1.13-1.18)	1.00 (0.98-1.02)

General Health			
Good/ Fair/ Poor	1	1	1
Excellent/ Very Good	0.45 (0.44-0.46)	0.41 (0.41-0.42)	0.41 (0.41-0.42)
Total Sedentary Hours			
≥ 35 hours/week	1	1	1
20 - 34 hours/week	0.35 (0.34-0.35)	0.22 (0.22-0.22)	0.21 (0.20-0.21)
≤ 19 hours/week	0.34 (0.33-0.34)	0.32 (0.32-0.32)	0.35 (0.34-0.35)
Fruit & Vegetable Intake			
<5 servings per day	1	1	1
≥ 5 servings per day	3.08 (3.04-3.12)	1.75 (1.73-1.77)	1.78 (1.76-1.80)
Cycle Number			
Cycle 1	1	1	1
Cycle 2	0.12 (0.11-0.12)	0.13 (0.13-0.13)	0.13 (0.13-0.13)
Cycle 3	0.20 (0.20-0.20)	0.20 (0.19-0.20)	0.23 (0.23-0.24)

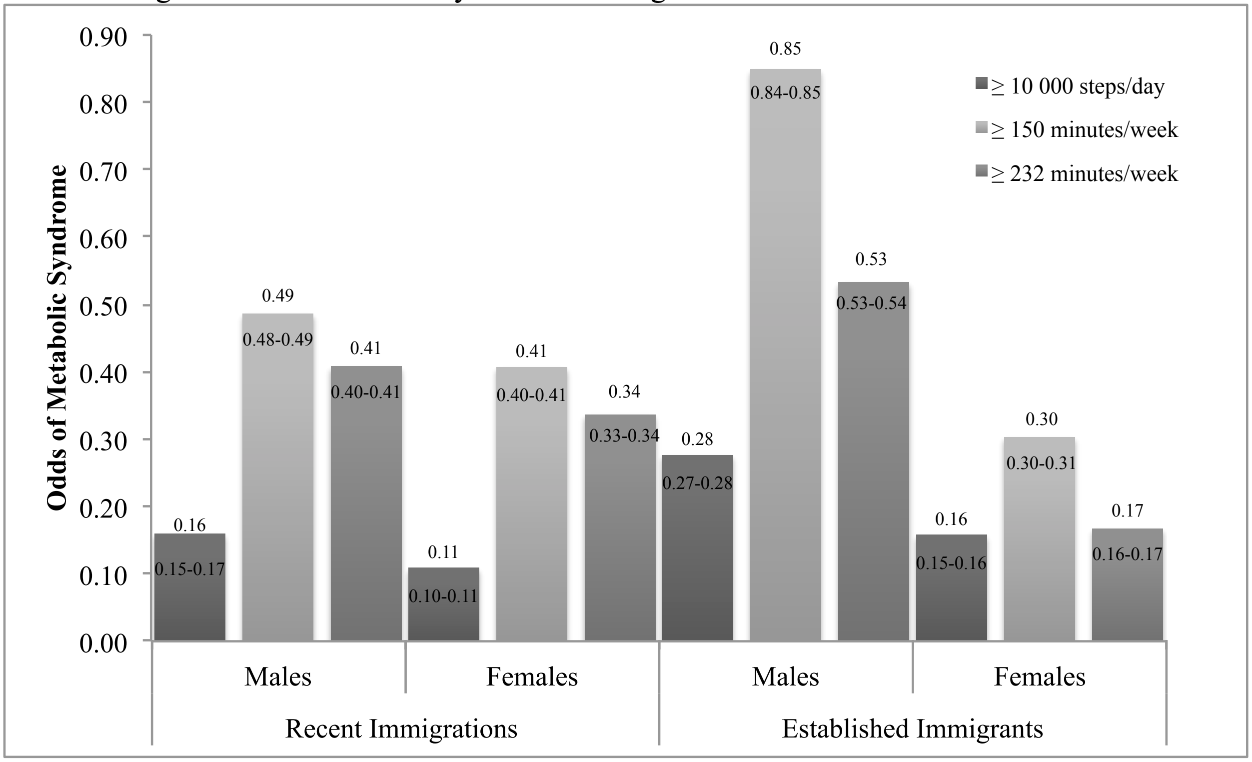
*OR – Odds Ratio, CI – Confidence Interval, interaction terms between physical activity and immigration, and physical activity and sex were included

Figure 1: Unadjusted odds of metabolic syndrome based on different types of physical activity



*MVPA – moderate-to-vigorous intensity physical activity

Figure 2: Adjusted odds of metabolic syndrome by various type of physical activity in South Asians living in Canada stratified by sex and immigration status



*Adjusted for immigration status, age, sex, marital status, education, income, alcohol, smoking, general health, sedentary hours, fruit and vegetable intake, survey cycle, PA*immigration, PA*sex

Extended Discussion

Comparison of CHMS and CCHS

Overall, findings from this thesis provide novel insight into the relationship between physical activity and cardiometabolic health amongst a growing, high-risk, segment of the Canadian population. When taken together, the two resulting manuscripts offer new perspectives on measurement challenges for population science. Specifically, the use of CCHS and CHMS allow for a direct comparison of self-report and objectively assessed activity data within the Canadian context. In the CCHS, 60.8% of individuals were classified as inactive, however, using the CHMS activity monitor data, 77.8% of South Asians did not accumulate ≥ 10 000 steps per day, and 66.1% did not meet ≥ 150 minutes of MVPA per week.

In the CCHS, 22.6% of South Asians had 1+ cardiometabolic conditions, whereas 26.4% of South Asians had MetS in the CHMS. Because MetS is a "pre-disease" state that represents a cluster of early markers of cardiovascular risk, the prevalence for study outcomes (CCHS: self-reported 1+ cardiometabolic conditions vs. CHMS: objectively assessed MetS (3+ risk markers)) are not directly comparable and should be interpreted with caution. Nonetheless, comparison of CHMS and CCHS findings provide evidence of cardiometablic health differences between South Asians based on *time in country*. In each case, established immigrants had higher odds of cardiometabolic conditions in comparison to recent immigrants in the CHMS and non-immigrants in the CCHS. In the CHMS, ≥ 10 000 steps per day and ≥ 232 minutes of MVPA per week revealed lower odds of cardiometabolic conditions in comparison to those who took <10 000 steps and <232 minutes of MVPA, respectively. This pattern was similar to that of recent immigrants in the CCHS, where being active (>3.0 KKD) resulted in lower odds of cardiometabolic conditions in comparison to those who were inactive (<1.5 KKD). However, moderately active (1.5-3.0 KKD) non-immigrants and established immigrants in the CCHS had lower odds of cardiometabolic conditions in comparison to those who were inactive. Odds of cardiometabolic conditions were even higher among non-immigrants and established immigrants who were physically active (>3.0 KKD).

Sex Differences in the CCHS

Sex differences in cardiometabolic health and physical activity are well known, however, the sample size in the CHMS did not allow for stratification into male and female strata. By contrast, the CCHS sample was sufficiently large that the three immigration groups could be pooled to explore sex-specific analyses. As the interaction between PA and sex (P <0.0001) was significant, cardiometabolic health was analyzed in a sex-stratified model. In these analyses, recent and established immigrant males had similar two-fold greater odds of metabolic conditions in comparison to non-immigrant men. In females, established immigrants (OR 1.45, 95% CI 1.38-1.52) but not recent immigrants had greater odds of metabolic conditions compared to non-immigrant. Specifically, moderately active (1.5-3.0 KKD) South Asian males had 8.2% (OR 1.08, 95% CI 1.06-1.11) greater odds of metabolic conditions, whereas active (>3.0 KKD) males had 17.1% (OR 0.83, 95% CI 0.81-0.85) lower odds. On the other hand, South Asian females had 25.4% (OR 0.75, 95% CI 0.73-0.77) lower odds of metabolic conditions when they were moderately active (1.5-3.0 KKD), whereas active (>3.0 KKD) compared to inactive females had higher (OR 1.15, 95% CI 1.11-1.19) odds of metabolic conditions (**Figure 1**). As immigration and sex are both related to health and physical activity, these results provide only initial preliminary insight, as stratification by immigration status and sex are necessary to provide a deeper understanding of these relationships in South Asians.

Implications for Primary Prevention

The CHMS study demonstrated the need for higher physical activity than the current recommendations of ≥ 150 minutes of MVPA per week, yet South Asians have low levels of physical activity. The gap in attaining even modest levels of MVPA remains a leading public health challenge for the prevention and management of non-communicable diseases. One promising area of work is in understanding how current PA guidelines can be tailored to specific ethnic groups; however, health care practitioners are a source of medical information for all patients, which may cause them to be perceived as a homogenous group. Therefore, providing practitioners with information on the low levels of physical activity among South Asians and the ethnic-specific physical activity may encourage them to prescribe physical activity to patients, either directly, or through initiatives such as *Exercise is Medicine Canada*. Although ethnic-specific physical activity can be promoted in other settings, patients are more likely to adhere to a physical activity prescription from their physician (Fortier et al., 2012). In terms of preferred modes of physical activity, South Asians are more likely to engage in conventional exercises such as home based exercise, aerobics or weight training, than walking, endurance recreation and sports (Dogra et al., 2010), therefore these activity should be targeted to increase overall patterns of activity. Health care practitioners, as well as newcomer service providers are therefore potential facilitators of physical activity participation that can raise awareness on community centres and gymnasiums within the local context.

Focus on Immigrant Health

At present, approximately two-thirds of visible minorities are born outside of Canada (Statistics Canada, 2011). Given a continued focus on increasing the proportion of new immigrants to Canada, health disparities amongst newcomer groups require further attention. At present, there are only very limited provincial health policies that address immigrants (Beiser, 2005), however, the health of Canadians cannot be addressed as one homogenous group. As both studies in this thesis confirm, there are differences in cardiometabolic health and physical activity in South Asians by time in country. As the health of established immigrants is worse than that of recent immigrations, specific attention should be paid to the newcomer group. Beyond the structural differences in health care access with this group – that includes a three month wait period for primary health care access upon arrival to Canada (Beiser, 2005) - there are opportunities to reinforce a healthier lifestyle through stakeholder groups such as Newcomer Services and Public Health Canada.

Study Limitations

Beyond the aforementioned self-report and objective differences in physical activity and cardiometabolic health, several additional findings warrant further discussion.

1. Despite the purposeful pooling of multiple survey cycles, the resulting sample size was insufficient to allow for analysis of *non-immigrants* in the CHMS. As demonstrated by the CCHS, there are differences in health between immigrants and non-immigrants, and this relationship warrants further investigation with objective measures of physical activity. However, as two-thirds of the visible minority population is born outside of Canada, several more cycles of data may be required before this research question can be investigated.

2. The finding that smoking was protective in all CCHS models and the CHMS steps model is unexpected, and contradicts the majority of published literature. One other study conducted on Turkish women found that smoking more than 11 cigarettes per day had a "protective effect" on MetS due to its effect on obesity (Onat et al., 2007). It was speculated that smoking leads to less obesity, which affects the relationship between insulin resistance and

lipoprotein lipase activity (Onat et al., 2007). However, these findings have not been established in other populations. As smoking is a known risk factor for cardiometabolic health, caution must be taken when interpreting the above findings, and further investigation is warranted.

3. The direct measure of waist circumference was changed between cycles 2 and 3 of the CHMS: Cycle 1 used the WHO waist circumference method, which measures the waist at the midpoint between the top of the iliac crest and the last rib, and Cycle 3 used the NIH method, which measures the waist just above the hipbone. Cycle 2 used both methods, which allows for comparison. Because the NIH protocol was deemed to be more accurate, the following equation was derived using CHMS cycle 2 data in order to convert the WHO waist circumference in cycle 1 to match the NIH waist circumference of cycles 2 and 3 for adults aged 20-79:

Men WC_NIH_predicted = 3.83072 + 0.98613*(WC_WHO) - 0.03609*(age)

Women WC_NIH_predicted = 3.53771 + 0.98479*(WC_WHO) + 0.21949*(x)

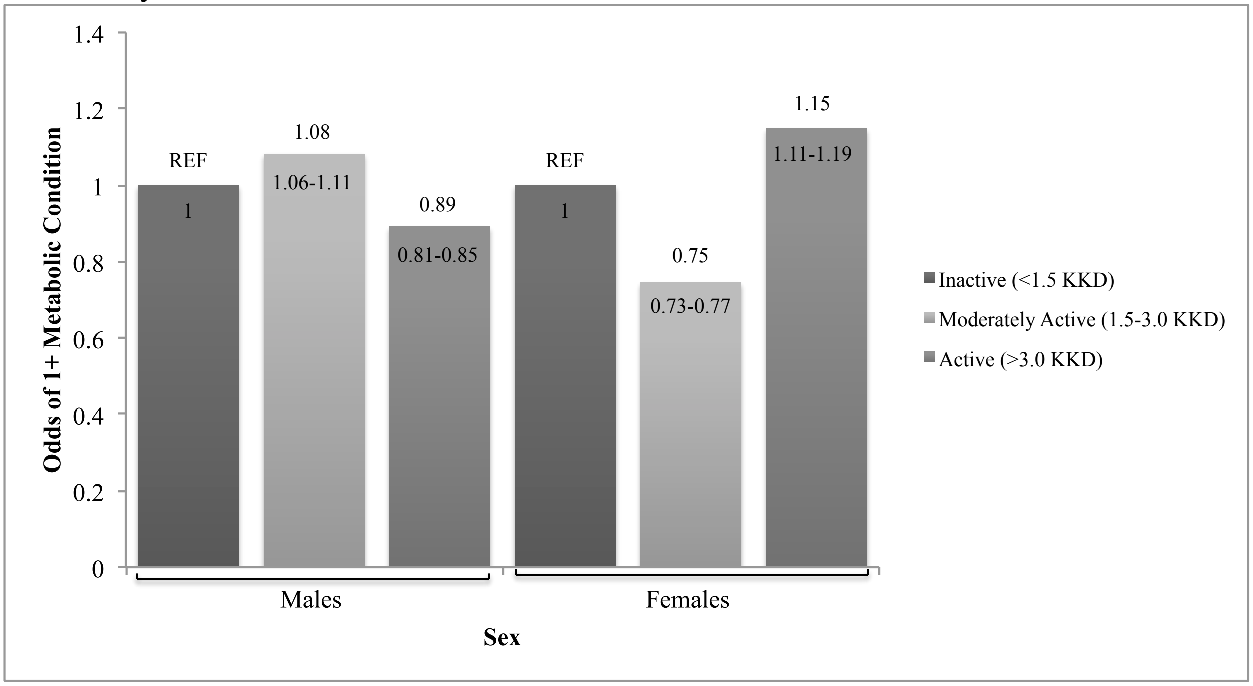
(where x is set to 1 if age is 20 to 39; otherwise x=0)

4. Cardiorespiratory fitness is also suggested to be lower in South Asians in comparison to European individuals (Gill et al., 2014), but due to exclusion criteria (and stringent screening procedures for fitness testing eligibility) in the CHMS, the resulting sample size was not sufficient for investigation. Future research should use fitness measures such as the Modified Aerobic Fitness Test (MCAFT) to elaborate further on the differences in fitness and physical activity among South Asians.

Future Research

As the South Asian diaspora increases, future research should focus on understanding the relationship between cardiometabolic health and physical activity in non-immigrant, as well as immigrant South Asians. Aerobic testing should also be used for a comprehensive understanding of fitness and physical activity in South Asians and how it may differ from highly researched ethnicities such as Europeans. Future research focusing on the aforementioned topics will allow for a holistic understanding of cardiometabolic health in South Asians, the effects of immigration, and the need for ethnic-specific physical activity guidelines.

Figure 1. Odds of 1+ metabolic condition by daily energy expenditure in leisure activity stratified by sex



*Adjusted for age, sex, marital status, education, income, alcohol, smoking, fruit and vegetable intake, and cycle

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Appendix A

Canadian Community Health Survey (CCHS) Protocol

To capture a national representative sample, the CCHS must sample 65 000 respondents on an annual basis. To capture this data, 110 health regions across Canada are used. The sample required from each province is in accordance with the population and number of health regions within that province. The sample of households is selected using an area frame (40.5%), list frame of telephones (58.5%), and Random Digit Dialling (RDD) (1%).

The area frames used in the CCHS are those designed for the Labour Force Survey (LFS). The LFS clusters are stratified into a sample of clusters and dwellings in each health region. List frame of telephone numbers is used in 105 health regions. The list frame is also stratified by health region. Telephone numbers are then selected through a random sampling process. RDD was used in 4 health regions using the working banks technique. This technique retains 100-number banks, which were randomly chosen in each stratum. Numbers between 0 and 99 are randomly chosen to generate 10-digit telephone numbers. Members of the household over the age of 12 are randomly chosen at the time of contact.

Household members from the area frames answered the questionnaire through Computer-Assisted Personal Interviewing (CAPI) method, whereas household members from the list frame and RDD answered through Computer-Assisted Telephone Interviewing (CATI) method. Starting in 2013, certain cases from the area frames were selected to answer the questionnaire through the CATI method. Computer assisted interviewing (CAI) customizes questions according to age and sex of respondent, date of interview and previous questions answers. It also skips questions that are not applicable and provides feedback to the respondent and the interviewer when there are inconsistencies in the answers (Statistics Canada, 2016).

Canadian Health Measures Survey (CHMS) Protocol

For each survey cycle, 11 age-gender groups were created with 500 to 600 sample units (household members) per group to produce national estimates (Statistics Canada, 2012). Each site area was limited to a 50 kilometers (km) radius (100 km for rural areas) in order to ensure close proximity of mobile examination centers (MEC). Collection sites are defined as "geographic area with a population of at least 10 000 and a maximum respondent travel distance of 50 km in urban areas and 100 km in rural areas" (page 16). A total of 257 sites are created across Canada stratified into 5 regions: Atlantic, Quebec, Ontario, Prairies and British Columbia. Each site is sorted according to population size and census metropolitan areas (CMA). Then, these sites are randomly selected through a systematic sampling method resulting in a total of 18 collection sites. Within the collection sites, dwellings are used as a frame. The Census and other administrative sources are used to collect the date of birth and other demographics of each household member in order to stratify dwellings into 6 age groups: ages 3-5, 6-11, 12-19, 20-39, 40-59 and 60-79.

Letters are sent through the mail before collection began to inform participants that an interviewer would visit to collect information. Household members are then contacted for a member list at the time of survey. One to two members of each household are randomly selected to participate. Two members of the household are chosen if there is a child between the ages of 3-11. One child is chosen along with a member between the ages of 12-79. If a child does not live in that household, only one member between the ages of 12-79 is selected for the interview. A personal interview with the selected members was collected separately via computer-assisted interviewing method at the household. After the interview, which could last up to one hour, each respondent is made an appointment at a MEC. The interviewer informs the respondent whether they have a morning or afternoon/evening interview. For the morning interview, the respondent is required to fast for 12 hours for measurements on tests such as fasting glucose and blood lipids.

The MEC is located within the collection site for 5-8 weeks. Each MEC collects direct measures from approximately 350 respondents. This portion of the interview lasts up to 2 hours. At the end of this interview, activity monitors are given to each respondent to wear for 7 days and mailed back (Statistics Canada, 2011a)

Appendix B

Daily Energy Expenditure in Leisure Physical Activity

Variable name: PACDEE

Based on: PAC_1V, PAC_2A, PAC_2B, PAC_2C, PAC_2D, PAC_2E, PAC_2F, PAC_2G, PAC_2H, PAC_2I, PAC_2J, PAC_2K, PAC_2L, PAC_2M, PAC_2N, PAC_2O, PAC_2P, PAC_2Q, PAC_2R, PAC_2S, PAC_2T, PAC_2U, PAC_2W, PAC_2X, PAC_2Z, PAC_3A, PAC_3B, PAC_3C, PAC_3D, PAC_3E, PAC_3F, PAC_3G, PAC_3H, PAC_3I, PAC_3J, PAC_3K, PAC_3L, PAC_3M, PAC_3N, PAC_3O, PAC_3P, PAC_3Q, PAC_3R, PAC_3S, PAC_3T, PAC_3U, PAC_3W, PAC_3X, PAC_3Z

Description: This variable is a measure of the average daily energy expended during leisure time activities by the respondent in the past three months.

Note: Energy Expenditure (EE) is calculated using the frequency and duration per session of the physical activity as well as the MET value of the activity. The MET is a value of metabolic energy cost expressed as a multiple of the resting metabolic rate. For example, an activity of 4 METS requires four times the amount of energy as compared to when the body is at rest.

EE (Energy Expenditure for each activity) = (N X D X METvalue) / 365
Where:
N = the number of times a respondent engaged in an activity over a 12 month period
D = the average duration in hours of the activity
MET value = the energy cost of the activity expressed as kilocalories expended per kilogram of body weight per hour of activity (kcal/kg per hour)/365 (to convert yearly data into daily data)

MET values tend to be expressed in three intensity levels (i.e. low, medium, high). The CCHS questions did not ask the respondent to specify the intensity level of their activities. Therefore the MET values adopted correspond to the low intensity value of each activity. This approach is adopted from the Canadian Fitness and Lifestyle Research Institute because individuals tend to overestimate the intensity, frequency and duration of their activities.

Variable Name	Activity	**MET Value** (kcal/kg/hr)
PACDEEA	WALKING FOR EXERCISE	3
PACDEEB	GARDENING OR YARD WORK	3
PACDEEC	SWIMMING	3

PACDEED	BICYCLING	4
PACDEEE	POPULAR OR SOCIAL DANCE	3
PACDEEF	HOME EXERCISES	3
PACDEEG	ICE HOCKEY	6
PACDEEH	ICE SKATING	4
PACDEEI	IN-LINE SKATING OR ROLLERBLADING	5
PACDEEJ	JOGGING OR RUNNING*	9.5
PACDEEK	GOLFING	4
PACDEEL	EXERCISE CLASS OR AEROBICS	4
PACDEEM	DOWNHILL SKIING OR SNOWBOARDING	4
PACDEEN	BOWLING	2
PACDEEO	BASEBALL OR SOFTBALL	3
PACDEEP	TENNIS	4
PACDEEQ	WEIGHT-TRAINING	3
PACDEER	FISHING	3
PACDEES	VOLLEYBALL	5
PACDEET	BASKETBALL	6
PACDEEZ	SOCCER	5
PACDEEU	OTHER (U)*	4
PACDEEW	OTHER (W)*	4
PACDEEX	OTHER (X)*	4

* Jogging (MET value 7) and running (MET value 12) fall under one category. Therefore, the MET value for the combined activity is the average of their MET values (9.5). Since it is difficult to assign a MET value to the category "Other Activities", the MET value used is the average of the listed activities except for the average value of jogging and running. Here, the average value of jogging and running is replaced by the value for jogging only. Some activities have MET values lower than the average, however, this approach is consistent with other studies, such as the Campbell‟s Survey and the Ontario Health Survey (OHS).

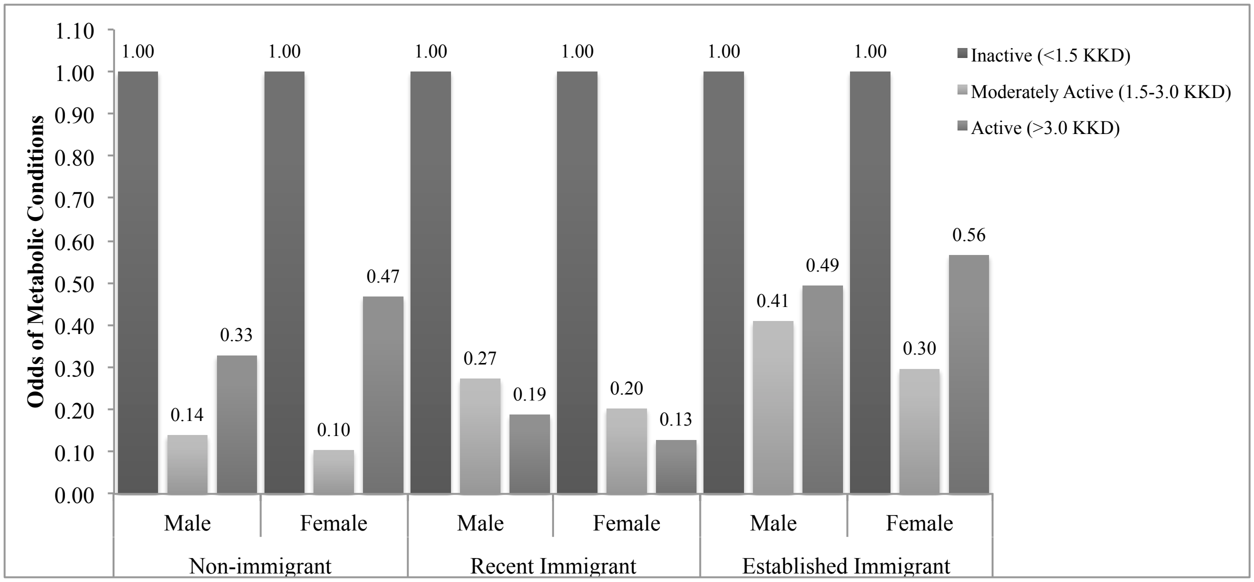
* Times were assigned an average duration value for the calculation, as with NPHS:
(13 minutes or .2167 hour, 23 minutes or .3833 hour, 45 minutes or .75 hour, 60 minutes or 1 hour)

Beginning in CCHS cycle 2.1, the list of activities (PAC_1n) changed slightly from previous CCHS cycles: The activity "Soccer" was asked explicitly in Cycle 2.1. For Cycle 1.1, this activity was part of the "Other" activities.

(Statistics Canada, 2011)

Appendix C

Odds of 1+ metabolic condition by daily energy expenditure in leisure activity in South Asians in Canada



*Non-immigrant and recent immigrant models: adjusted for age, sex, marital status, education, income, alcohol, smoking, fruit and vegetable intake, and cycle. Established immigrant model: adjusted for age, sex, marital status, education, income, alcohol, smoking, and cycle.

Appendix D

Activity Monitor

At the end of the Mobile Examination Centre (MEC) visit, each respondent is provided with an Actical physical activity monitor (Statistics Canada, 2012). Each activity monitor is provided with an adjustable belt, an XPRESSPOST envelope to mail back the activity monitor after 7 days, and an information sheet. Respondents are to wear the activity monitor for 7 days excluding when they are sleeping. This includes swimming and bathing.

The activity monitors are set to collect data in 60-second epochs. Respondents with non-valid/ bad data are excluded. This referred to those respondents who had initialization errors or unreliable data. Then, respondents without 1 day of 10 hours of data (for ages 6-79) are excluded.

After exclusions of those respondents who do not return their activity monitors and those who do not have at least four days of valid data (10 hours/day), the common response rate is 42.4% (Statistics Canada, 2011a).

Conclusion

The CCHS study examined the relationship between metabolic conditions and physical activity in South Asians living in Canada. The CHMS allowed for further investigation of this relationship through objective measures of physical activity, blood pressure, waist circumference, and blood measures such as glucose, HDL and triglycerides. According to the CCHS and CHMS, approximately one quarter of the South Asian population in Canada has 1+ metabolic conditions and metabolic syndrome, respectively. In the CCHS, active (>3.0 KKD) recent immigrants and moderately active (1.5-3.0 KKD) established immigrants and non-immigrants had lower odds of metabolic conditions in comparison to inactive South Asians. However, the CHMS data shows that high step counts (≥10 000 steps) and long duration of MVPA (≥ 232 minutes) resulted in lower odds of metabolic syndrome. This thesis provides evidence for the need of ethnic-specific physical activity guidelines, and those specifically for immigrants according to length of time in Canada. However, further investigation for the optimal amount of physical activity required for recent immigrant, established immigrant and non-immigrant South Asians is warranted.