Urbanisation and Physical Activity in Mexico

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July 2018

A dissertation submitted to the University of Bristol in accordance with the requirements of the degree of Doctor of Philosophy in the Faculty of Social Sciences and Law

Word count:44,359

Abstract

Low levels of physical activity are a global public health issue. Along with prolonged bouts of sitting, low physical activity is associated with an increase in the risk of noncommunicable diseases. Approximately 17.4% of adults and 39.5% of adolescents in Mexico do not meet the World Health Organization's recommended level of physical activity. Urbanisation is a potential correlate of physical activity that, at this moment, remains under-researched. The aim of this thesis was to study the association between physical activity in Mexico and two aspects of urbanisation: urbanicity and perception of safety.

In this thesis, the urbanicity was estimated using the measure developed by Novak et al. (2012). The first study used physical activity data from the Mexican 2012 National Health and Nutrition Survey and multivariable linear regression models to examine the association between physical activity and urbanicity. The characteristics of urbanicity that were negatively associated with physical activity were population size, economic activity, diversity and communication. The second and third studies, were based on a primary data collection from 4,079 Mexican adolescents. The second study investigated the associations between urbanicity and physical activity. Results showed negative associations between physical activity and communication-based urbanicity; and positive associations with overall urbanicity and population density. The third study investigated the association of physical activity with perception of safety; finding that lower perception of pedestrian safety was associated with lower physical activity amongst females.

Findings from this thesis demonstrated there is an association between urbanisation and physical activity in Mexico. Also, it gave an insight of the complexity of these associations, being different between adults and adolescents, between gender, state, and type of physical activity; highlighting the value of examining urbanicity as a multidimensional construct. The findings highlight that urbanisation should be considered in efforts to increase physical activity levels in developing countries.

Acknowledgements

My research would have been impossible without the support of the National Council of Science and Technology in Mexico (CONACyT) who funded my postgraduate study. I would also like to thank Daniel Avila Fernandez from the Secretariat of Public Education in Mexico for his help throughout the recruitment process, the head teachers from the schools in Mexico City and Oaxaca for their aid in coordinating the data collection, to Isaura A. Gonzalez Rodriguez who gave invaluable help with the questionnaires and Juan Carlos Sarmiento for receiving me at his house when I needed a place to stay during the data collection period in Oaxaca.

My sincere thanks to my supervisors, Prof. Russ Jago and Dr. Simon Sebire, for their guidance, support and words of encouragement.

Thank you to the ENHS crew for all the good laughs, companionship, and the continuous presence of cake. Zoi, Jez and George, you were the best office mates and I will miss you. A special thanks to Dani, Manos and Caitlin, who lifted my spirits when I was going through a hard time.

My friends in Mexico, Natalia, Hugo, Leslie, Dany, Claus, AnaSof, Lilia, Nadia, Panda, Jose, Arnoldo, your friendship means everything to me, thanks for being willing to listen to my half an hour voice notes.

Heartfelt thanks go to Dave, your good advice and laughter are a treasure!

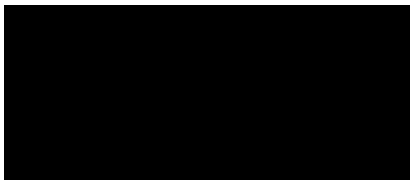
I am profoundly grateful to Mum and Dad for their unconditional support. Mum, gracias por ser ejemplo de valor y tenacidad. Dad, thanks for your guidance and for always believing in me.

To my brother Luis, thank you for your friendship and for teaching me so much about life even when you are the youngest of the two, I love you and admire you.

And my partner Phil, there are no words to explain how much your support means to me. Thanks for braving the sea of typos, withstanding my mess in the flat, staying optimistic when I wouldn’t and for the endless cups of tea ;) !!!

Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

SIGNED:  DATE: 20/11/2018

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Publications from this thesis

Two journal articles have been published from Chapter 4 and Chapter 6 of this thesis. A third article, as presented in Chapter 7, is planned.

Publications

Hermosillo-Gallardo ME, Jago R, Sebire SJ. The Associations Between Urbanicity and Physical Activity and Sitting Time in Mexico. J Phys Act Health. 2017;14(3):189-94. doi: 10.1123/jpah.2015-0654. PubMed PMID: WOS:000398342300004.

Hermosillo-Gallardo ME, Jago R, Sebire SJ. Association between urbanicity and physical activity in Mexican adolescents: The use of a composite urbanicity measure. Plos One. 2018;13(9):e0204739. Epub 2018/09/28. doi: 10.1371/journal.pone.0204739. PubMed PMID: 30261073.

Conferences

Association between Urbanicity and Physical Activity in Mexican Adolescents: The Use of a Composite Urbanicity Measure. 7th International Society for Physical Activity and Health Congress, London, England. Accepted oral presentation for October 2018.

Common Abbreviations Used in Thesis

AC	Active Commuting
AT	Active Travel
BAGA	Basic Geostatistical Area
BMI	Body Max Index
CFA	Confirmatory Factor Analysis
CI	Confidence Interval
CS	Crime Safety
ENSANUT	National Health and Nutrition Survey
FPAP	The Food and Physical Activity Programme
INEGI	National Institute of Geography and Statistics in Mexico
IPAQ	International Physical Activity Questionnaire
M	Mean
MET	Metabolic Equivalent of Task
MOPRADEF	Module of Sport Practice and Exercise
MPA	Moderate Physical Activity
MVPA	Moderate-to-Vigorous Physical Activity
NCDs	Noncommunicable Diseases
NEWS-Y	Neighbourhood Environment Walkability Scale-Youth
OR	Odds Ratio
PA	Physical Activity
PE	Physical Education
PS	Pedestrian Safety
RR	Risk Ratio
SD	Standard Deviation
SES	Socio-economic Status
VPA	Vigorous Physical Activity
WHO	World Health Organisation
YPAQ	Youth Physical Activity Questionnaire

Glossary

BAGA	Geographical unit
BMI	Measure for indicating nutritional status. A person's weight in kilograms divided by the square of the person's height in metres
MET	Unit for describing the energy expenditure of a specific activity. Ratio of the rate of energy expended during an activity to the rate of energy expended at rest
STATA	Statistical software package for data analysis

Chapter 1 Introduction

1.1 Mexico

The federal republic of the United Mexican States is the 13th largest nation state in the world by area (1,972,550 km^2). It is bordered on the north by the United States of America, the southeast by Guatemala and Belize, and it is surrounded by the Pacific Ocean on the south and west, the Caribbean Sean on the southeast and Gulf of Mexico on the east (Figure 1-1). Mexico is divided into 32 federated states, each of which are divided into municipalities. Its capital, Mexico City, has a land area of 1,485.49 km^2 and is the seat of the federal powers of the union.

Figure 1-1 Map of Mexico

According to the latest census, the total population of Mexico is of 119,938,473 individuals with an average growth of 1.4% per year from which 64.4% are between 15 and 54 years old[1]. Twenty-one percent of Mexicans identify themselves as indigenous. The most densely populated area in Mexico is the Metropolitan Area of the Mexican Valley (Valle de Mexico in Spanish) with a population density of 2,752 habitants per km^2 (21,650,668 habitants in an area of 7,866 km^2).

A metropolitan area is defined as "a set of two or more municipalities where a city of 50 thousand or more inhabitants is located, whose urban area, functions and activities overflow the boundary of the municipality that originally contained it, incorporating as part of itself neighbouring municipalities, predominantly urban, with which maintains a high degree of socioeconomic integration"[2]. The Metropolitan Area of the Mexican Valley, also known as "The Greater City", is the economic, financial, political and cultural centre of Mexico. It is the largest metropolitan area in North America and the third biggest in the world, after Tokyo in Japan and Seoul Incheon in South Korea[3]. The Metropolitan Area of the Mexican Valley includes the whole of Mexico City, 59 municipalities of Mexico State and one municipality of Hidalgo (Figure 1-2). The number of people living in urban areas in Mexico has been increasing over time. According to the latest census (2010) from the National Institute of Geography and Statistics in Mexico (INEGI, for its initials in Spanish) in 1950, 43% of the population lived in urban areas, in 1990 that percentage increased to 71% and in 2010 it reached 78%[1].

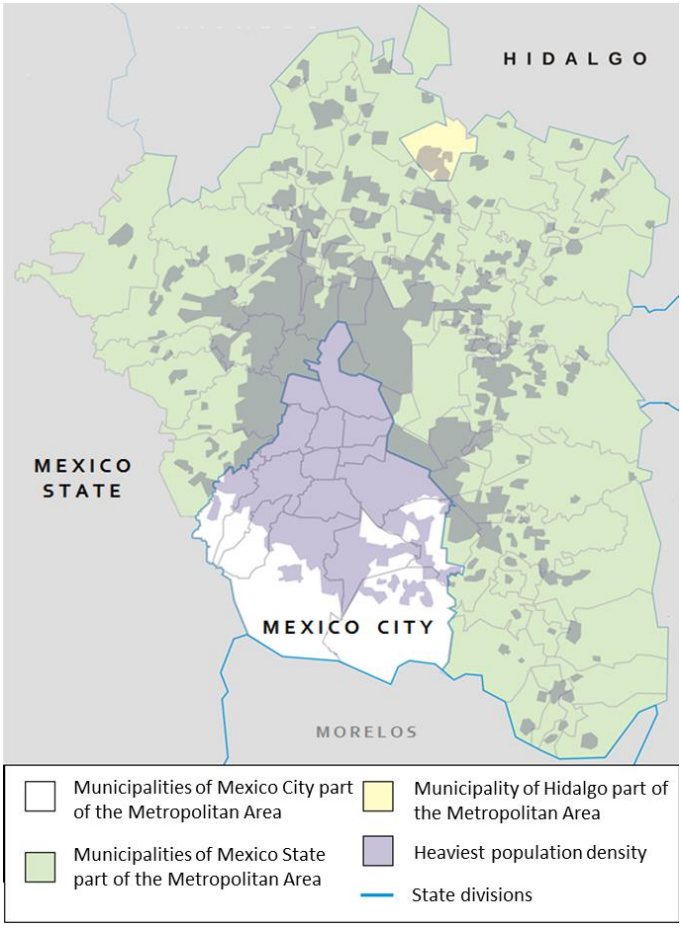


Figure 1-2 Metropolitan Area of the Mexican Valley

1.2 Physical Activity and Health

Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure"[4]. Exercise is "a subcategory of physical activity that is planned, repetitive, structured and purposive in the sense that improvement of maintenance of one or more components of physical fitness is an objective"[4]. While physical activity is positively correlated with physical fitness, exercise has physical fitness as an objective. Physical fitness is "the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits"[4]. Health related components of physical fitness are body composition, flexibility, cardiorespiratory endurance, muscular endurance and muscular strength.

According to the latest results from the Health and Nutrition National Survey (ENSANUT for its initials in Spanish), only 69.9% of male adolescents and 51.2% of female adolescents between 15 and 19 years old meet the World Health Organisation's physical activity guidelines of 420 minutes per week of moderate-to-vigorous physical activity (MVPA)[5]. Among adults, 86.2% of males and 84.9% of females meet the World Health Organisation's (WHO) guidelines of 150 minutes per week of moderate physical activity (MPA). Even though these values might not seem concerning, still 78.6% of adolescents and 55.5% of adults spend more than two hours per day in front of a screen. Thus, there is a need to increase physical activity in Mexican adults and adolescents and the overall aim of this thesis is to examine how urbanisation may be associated with physical activity in these groups and what that may mean for changing physical activity at a population level.

1.3 Urbanisation

More than half (55%) of the current world's population resides in urban areas and by 2050 it is likely that it will increase to 68%. North America (Canada, United States, Mexico) is the most urbanised region in the world with 82% of the population living in urban areas. In Mexico, the population size has tripled during the last 65 years, with 73% of the people living in urbanised areas. High urbanisation has been associated with an increase in NCDs' risk factors[6, 7], this is concerning because it is likely that population growth and therefore the expansion of urban areas will continue increasing with time.

Urbanisation has been quantified by different approaches. A systematic review[8] examining the ways urbanisation has been measured in relation to chronic diseases in developing countries found that half of the studies that met the inclusion criteria used demographic measures to assess urbanisation, this being a problem when trying to compare urbanisation between countries, due to different definitions and measurements of urbanisation, also failing to portray clearly the relationships between urbanisation and health. The other half of studies in the review, used a more complicated measure of urbanisation, including area level data for presence of markets, main economic activity of the population, land ownership etc... These measures start considering urbanisation as a process rather than a static concept, and if measured consistently across studies, could allow comparison between countries.

Urbanisation has many impacts on the work, residence and health of individuals. It therefore seems likely that the level of urbanisation and associated constructs such as safety and accessibility to physical activity infrastructure will affect physical activity in Mexican adolescents. There is, however, a lack of information on this topic.

1.4 Aim of the thesis

The main aim of this thesis is to investigate the association between urbanisation and physical activity in Mexico. In the next chapter there is an overview of the current literature in this area and the key research gaps that this thesis is designed to address. Detailed research questions and the structure of the remainder of the thesis are then presented in Chapter 3.

Chapter 2
Literature Review

In this chapter, the literature relevant to the thesis is reviewed. The chapter begins with a review of the health benefits of physical activity, the prevalence of NCDs', overweight and obesity in the Mexican population, the WHO's physical activity guidelines for adults and adolescents and a review of the health policy in Mexico. Following this, a summary of the main results, regarding physical activity in adults and adolescents in health surveys in Mexico is summarised. A review of the most common behaviour change theories in physical activity and an explanation on how the study of urbanisation fits into the Ecological Model is then presented. Finally, the topic of urbanisation is addressed, including its definition, measurement through urbanicity and the perception of safety and its associations with physical activity. Chapter 3 then presents the research questions and the structure of the thesis.

The literature discussed in this chapter was identified via systematic searches of several databases (PubMed, MEDLINE, EMBASE). A specific search was conducted for each section of the literature review using appropriate combinations. For example, for section 2.1, which focussed on physical activity and health, the following terms and combinations were used: ("physical activity" OR sports OR exercise OR walking OR cycling OR running) AND "non-communicable diseases" AND diabetes AND cancer AND "heart diseases" AND "respiratory diseases"). Only studies from the last 15 years, in English or Spanish and with full free text available through University of Bristol were included. Once the literature had been identified, the review was prioritised based on the Oxford Hierarchy of Evidence[9] such as where there was a recent systematic review or meta-analysis, it was considered the primary source of evidence, followed by adequately powered randomised controlled trials, prospective cohort studies, cross-sectional studies and qualitative methods, which was used to understand the context and support a deeper understanding of key constructs.

2.1 Physical Activity and Health

Physical activity is essential for the maintenance of good health. Physical activity is associated with lower rates of all cause-mortality, coronary heart disease, stroke, type 2 diabetes, high blood pressure, metabolic syndrome, colon cancer, breast cancer, and depression[10]. A burden of disease analysis[11] calculated the population attributable fractions associated with physical activity of the major NCD's by country to estimate how much disease could be prevented if physical inactivity were eliminated. Findings showed that physical inactivity was found to be responsible for 6% of the burden of coronary heart diseases, 7% of type 2 diabetes, 10% of breast cancer, 10% of colon cancer, and 9% of premature mortality (or 5.3 million of the 57 million deaths worldwide). In Mexico, the estimated population attributable fractions associated with physical inactivity were 6.2% of coronary heart disease, 7.7% of type 2 diabetes, 10% of breast cancer, 11.2% of colon cancer, 10.1% of all cause of mortality. If physical inactivity were eliminated in Mexico, the life expectancy in Mexico would increase by 0.76 years while in the world it would be 0.68 years. Apart from lowering the rates of NCDs, physical activity reduces the risk of hip fracture. A meta-analysis of 22 prospective cohort studies found that risk of hip fracture was 39% lower among individuals with high physical activity compared to the ones with lowest physical activity (95%, CI = 0.54 to 0.69)[12]. Moreover, physical activity increases the level of cardiorespiratory and muscular fitness and helps achieve a healthier body and mass composition[10]. Thus, increasing physical activity at a population level is important for health and disease burden globally and in Mexico.

2.1.1 Adult Physical Activity and Health

Non-communicable diseases (NCDs), also known as chronic diseases, are defined as long duration diseases with a combination of genetic, physiological, environmental and behavioural factors[13]. NCDs are responsible for 41 million deaths every year, from which 32 million occur in low-and-middle-income countries. Importantly, in low and middle-income countries, 15 million deaths occur in adults between 30 and 69 years old (premature deaths). The main types of NCDs are cardiovascular diseases (e.g. heart attack, stroke), cancers, chronic respiratory diseases (e.g. chronic obstructive pulmonary disease and asthma) and diabetes; together they account for over 80% of all premature NCDs deaths[13]. In Mexico, according to the latest health data available (ENSANUT 2016, medio camino), 9.4% of the

adult population have type 2 diabetes and its prevalence has been increasing throughout the years (from 7.2% in 2006 to 9.2% in 2012)[14]. The prevalence of diabetes is defined as "the percentage of the population of 20-year-old and older that has been diagnosed as diabetic through a doctor or that has glucose levels beyond 126 mg/dl or causal beyond 200 mg/dl. The prevalence of arterial hypertension is the percentage of the population of 20-year-old and older that has been diagnosed as hypertensive through a doctor or that presents a blood pressure considered a risk for health (systolic ≥ 140 mmHg o diastolic ≥ 90 mmHg)[14]. In Mexico the prevalence of hypertension was of 25.5% and the main risk factor of cardiovascular, cerebrovascular and kidney diseases. In terms of the causes of premature death in Mexico (deaths between 30 and 69 years old), 47% of males are expected to develop NCDs and 67% of females. The most common NCD are cardiovascular diseases, followed by diabetes, respiratory diseases and cancer (Figure 2-1)[15].

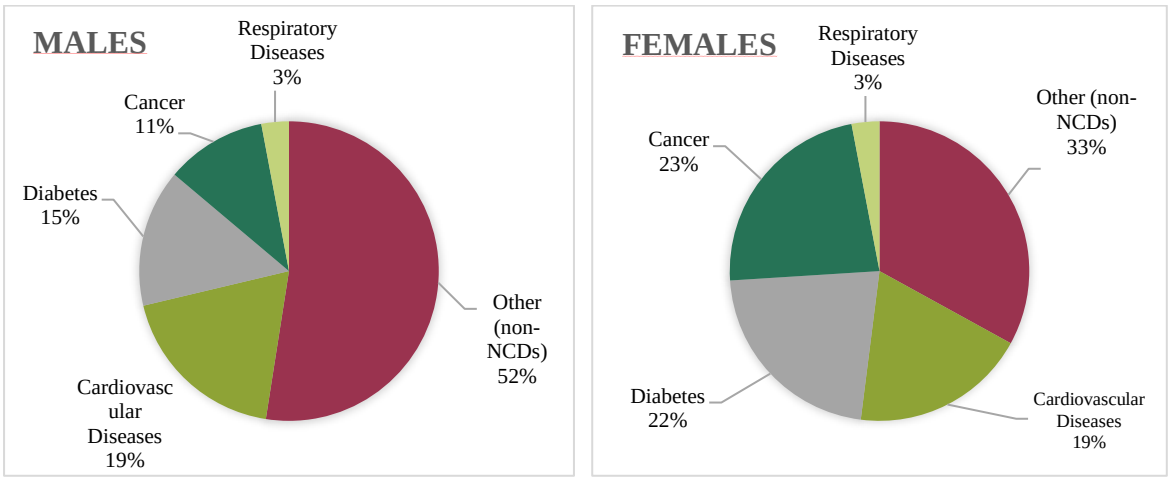


Figure 2-1 Main causes of premature death in Mexico (30-69 years old).

NCDs' risk factors (Figure 2-2) are divided into three: common risk factors, metabolic risk factors, and socio-economic, cultural, political and environmental determinants. The common risk factors are either modifiable (e.g. physical inactivity, unhealthy diet, excessive energy intake, harmful use of alcohol, tobacco use) or non-modifiable (e.g. age, race, heredity). Metabolic risk factors are raised blood pressure, raised blood glucose, abnormal blood lipids, overweight and obesity[13]. From these risk factors, raised blood pressure is the leading one with 19% of global deaths, followed by overweight and obesity, and raised blood glucose[13].

The socio-economic, cultural, political and environmental determinants are related to globalisation, urbanisation and population ageing.

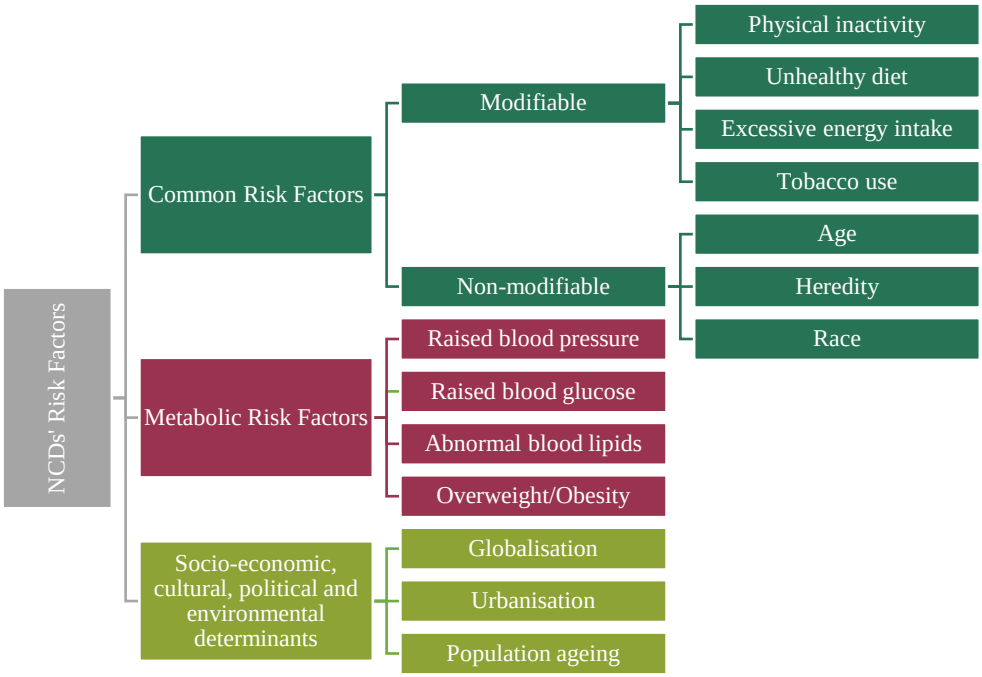


Figure 2-2 Noncommunicable Diseases' Risk Factors

According to the WHO, overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health[16]. Overweight and obesity are classified by using Body Mass Index (BMI), a measure of weight (kg) divided by the square of height (meters), with a BMI 25 and ≤ 30 classified as overweight and a BMI ≥30 classified as obese[16]. Overweight and obesity are caused by an energy imbalance between calories consumed and calories expended. All over the world, there has been an increase of consumption of high density caloric foods and a decrease of physical activity[16]. Reasons for this include changes in the dietary and physical activity patterns and environmental and social changes of the modern world, such as the appearance of sedentary employment and changes to passive transportation due to increasing urbanisation. Dietary changes such as the increased availability of energy dense food and the emergence of highly processed food have also been associated with the increase in obesity[16]. Globally, obesity has nearly tripled since 1975. In 2016, 39% of adults (39% men, 40% women) aged 18 years and over were overweight, and 13% (11% men, 15% women) were obese. According to the latest health and nutrition survey in Mexico (ENSANUT 2016), the combined prevalence of overweight and obesity has increased from 71.2% in 2012 to 72.5% in 2016[14]. The same survey reported an overweight prevalence of

41.7% in men and 37% in women, and an obesity prevalence of 27.7% in men and 38.6% in women.

Insufficient physical activity is one of the 10 leading risk factors for global mortality, causing 3.2 million deaths each year[17]. In 2010, insufficient physical activity caused 69.3 million Disability-Adjusted Life Years (DALY), 2.8% of the global total[17]. Low levels of physical activity have been associated with cardiovascular diseases, diabetes, respiratory diseases and cancer. Regarding cardiovascular diseases, a meta-analysis of 23 prospective epidemiological studies found that moderate and high levels of leisure time physical activity are associated with a moderate reduced risk of cardiovascular diseases[18]. Even though, in the same study, moderate and high levels of occupational physical activity were found to increase the risk of cardiovascular diseases. The reason according the authors is that occupational physical activity might be detrimental of health because it continues for prolonged hours at work, it is repetitive (lifting, bending…) and usually under uncomfortable postures. Whereas leisure physical activity is of shorter duration, it involves numerous muscle groups and increases the whole-body metabolism and cardiac output. Regarding type 2 diabetes, systematic reviews and meta-analysis have found that physical activity reduces the risk of type 2 diabetes[19-21], either leisure physical activity or vigorous physical activity (VPA), identifying higher levels of physical activity as more beneficial in decreasing the incidence of type 2 diabetes than moderate levels. In the case of cancer, results from a meta-analysis suggest that regular physical activity might be associated with reduced risk of lung cancer[22, 23], colon cancer[24], breast cancer[25] and other types of cancer[26].

2.1.2 Adolescent Physical Activity and Health

According to the WHO, the prevalence of overweight and obesity among children and adolescents between 5 and 19 years old has risen from 4% in 1975 to 18% in 2016[16]. The latest data reports that 216 million children and adolescents are overweight and 124 million are obese globally. In this age group, overweight and obesity are measured using the WHO Growth Reference median tables; being 1 standard deviation above the median is considered overweight, and 2 standard deviations above obese[27]. In Mexico, the prevalence of overweight has slightly increased from 21.6% (19.6% males, 23.7% females) in 2012 to 23.3% (21% males, 25.4% females) in 2015, while obesity has slightly decreased from 13.3%

in 2012 to 12.8% in 2015[28]; still the combined prevalence of overweight and obesity in adolescents in greater than 30%, meaning that at least three from 10 adolescents are either overweight or obese and at risk of maintaining or increasing weight and their risk factor of suffering a NCD in their adult life. In terms of urban and rural areas, the prevalence of overweight and obesity is higher in urban areas (overweight: 23.5%, obesity: 14.6%) than in rural areas (overweight: 22.8%, obesity: 8.7%)[28].

In children and adolescents, physical activity provides significant health benefits by contributing to the development of healthy musculoskeletal tissues (i.e. bones, muscles, joints), healthy cardiovascular system, neuromuscular awareness, helps in the maintenance of a healthy body weight, helps in the prevention of anxiety and depression, builds self-confidence and social integration[29]. Physical activity is associated with the reduction of cardiovascular risk factors (i.e. systolic blood pressure, insulin, triglycerides) in children and adolescents[30], regardless of the time spend sedentary[31]. Moreover, evidence from a systematic review and a meta-analysis of 17 studies found aerobic exercise to be associated with reductions in fasting insulin levels and also prevent metabolic syndrome and type 2 diabetes[32]. Regarding asthma, a meta-analysis of cohort studies revealed that children and adolescents with low physical activity had and increased risk of new onset asthma[33]. Thus, ensuring that children and adolescents are physically active is important for the prevention of future disease.

Physical activity levels track moderately well from childhood and adolescence to adulthood. Previous longitudinal studies have found that the frequency of physical activity declines with age[34, 35] and that high levels of physical activity shown between 9 and 18 years old predict high levels of physical activity in adults[36]. Moreover, physical activity during childhood and adolescence may form the foundation for active habits in the future, carrying as well the health benefits associated with physical activity[37]. Therefore, adolescent physical activity is key for future disease prevention and adolescence will be the focus of this thesis.

2.1.3 Limitations on the Current Evidence on Physical Activity

As seen in the previous sections, there is extensive evidence of the positive effects of regular physical activity in health; the prevention of NCD's, reduced risk of premature death and even reversing the disease process in cardiovascular diseases. The evidence is built up on several types of observational studies (i.e. cross-sectional, longitudinal, cohort studies etc...), randomized controlled trials, meta-analysis and systematic reviews that coincide on the health benefits of regular physical activity. However, there are some unanswered questions that evidence has not agreed on. The first one is the ideal method of physical activity (resistance vs. aerobic training), resistance exercise (i.e. weight lifting) has been found to reduce average blood glucose levels[38] and preserve lean body weight and a decrease the resting metabolic rate[39], while aerobic training has been associated with a faster initial blood glucose decline[38]. The second one is the intensity level of physical activity, even though there are guidelines of physical activity, there is still a debate on which intensity of physical activity beneficiates the most to a particular health benefit[40-42]. And third, research still debating regarding the frequency of exercise to achieve health outcomes[43, 44].

2.1.4 Physical Activity Guidelines

According to the WHO, adults between 18 and 64 years old should engage in at least 150 minutes of moderate intensity aerobic physical activity throughout the week, or 75 minutes of VPA throughout the week, or an equivalent combination of moderate and vigorous intensity activity[29]. For additional health benefits, it is recommended to increase MPA to 300 minutes per week or increase VPA to 150, or a combination of both. Additionally, muscle-strengthening activities involving major muscle groups on 2 or more days a week[29].

For children and adolescents between 5 and 17 years old, to improve cardiorespiratory and muscular fitness and bone health, at least 60 minutes of MVPA every day should be accumulated. According to WHO, most of the daily physical activity should be aerobic and include at least 3 times per week activities that strengthen muscles and bones (e.g. gymnastics, football, martial arts...)[29]. According to ENSANUT 2012, 59% of the Mexican adolescents meet the WHO's guidelines, even though only 36.1% reported less than 2 hours per day of screening time[5]. The complete results from ENSANUT 2012 regarding physical

activity in adults and adolescents can be found in sections 2.2.1 and 2.2.2 of the current chapter.

In June 2018, the WHO launched the Global Action Plan on Physical Activity (2018-2030) "More active people for a healthier world"[45]. The programme shows how countries can reduce physical inactivity in adults and adolescents by 15% by 2030. To achieve this, it proposes a "systems-based approach" of four objectives that countries are encouraged to adopt to create active societies through the improvement of environments and the creation of opportunities for people of all ages to do more cycling, walking, sport, play and recreation. The first objective is to create active societies, focus on the promotion of health benefits related to physical activity, provide mass participation events and build a workforce capacity with health professionals. The second one is to create active environments, starting with integrating transport and urban planning policies, improving active commuting networks, strengthen road safety, improve accessibility of spaces and implement proactive building policies. The third objective is to create active people by investing in physical education at school, incorporate physical activity into social and health services, improve physical activity provision for adults and prioritize attention to people who are least active. And the fourth one it to create active systems by strengthening policies, building research, improve data systems and expand advocacy.

2.2 Physical Activity in Mexico

Physical activity data in Mexico is reported in two different surveys. The first one, the National Health and Nutrition Survey (ENSANUT)[5] is the national probabilistic survey conducted by the National Institute of Public Health that offers health related data (including physical activity) of the whole population from urban and rural areas of every entity of the country. Data for ENSANUT is officially taken every six years, being representative at national and state level. The latest complete ENSANUT survey was in 2012. In 2016, a "half way" survey was implemented to investigate the perception and knowledge of the latest health campaigns (Get Moving and Take Care of Yourself). The second survey that reports physical activity data of the population is the Module of Sport Practice and Exercise (MOPRADEF)[46]. This survey was initially done every three months by INEGI; now MOPRADEF is done every year. MOPRADEF offers statistical information of sport and

physical activity participation of males and females between 18 and 69 years old living in urban and rural areas. Both, ENSANUT and MOPRADEF offer a practical insight of the physical activity behaviour of the population. Their main objectives, methodology, sample size and population groups of both surveys are discussed in the following paragraphs.

ENSANUT offers information that constitutes an up-to-date description of the health conditions of Mexicans, as well as acting as the response of the health system to these conditions and the results achieved. The data provided by the survey also helps identify the challenges in health in the coming years and formulate the appropriate strategies to address them. The main objective of ENSANUT is "quantify the frequency, distribution and tendency of health and nutrition conditions apart from their determinants in the Mexican population; also, to make possible examining the answer from the Health Sector to the health and nutrition challenges from the population, including the quality and coverage of the services"[5]. Sampling was done through household selection through the national statistical framework generated by INEGI. Once households had been randomly selected, one-to-one interviews with one person per selected household representing different age groups (0 to 4 years old, 5 to 9, 10 to 19, 20 and older) were done. Later, a subsample of people were asked to provide weight and height measures, blood samples, hypertension measures and self-reported physical activity data. The sample sizes, representativeness, objectives and assessments of these surveys are presented in Table 2-1. ENSANUT 2012, holds information of 50,528 households distributed in the 32 states in Mexico and represents information for 29,429,252 households in the country, according to population projections; while ENSANUT 2016 holds information of 9,474 households. In terms of the physical activity subsample, ENSANUT 2012 offers information covering 16,934 individuals (representing 92,888,568 individuals) and ENSANUT 2016 reporting information for 10,549 individuals (representing 86,927,523 of individuals).

Table 2-1 Summary of surveys reporting physical activity data in Mexico

	ENSANUT 2012	ENSANUT 2016	MOPRADEF
Recurrence	Every six years	Middle survey between 2012 and 2018 (official ones)	Every 3 months until 2013, every year after then
Coverage	National Level	National Level	Urban areas
Age	0 to 4 years old; 5 to 9 years old; 10 to 19 years old, 20 to more		18 to 69
Sample	50,005 households 96,031 individuals	9,474 households 29,795 individuals	2,336 households
Represented at national level	29,429,252 households	117,029 individuals	n/a
Physical Activity subsample	13,009 individuals	10,549 individuals	n/a
Represented Physical Activity at national level	92,888,568 individuals	86,927,523 individuals	n/a
Objective	Frequency, distribution, tendency and determinants of health. Evaluate quality and coverage of the services.	Investigate the perception and knowledge of the latest health campaigns	Generate statistic information regarding sport participation and PA. Frequency, duration, intensity of activities, reasons and places for being active.
Assessment	Interviews and questionnaires. IPAQ short for PA assessment.		Interviews and questionnaires.

ENSANUT: Health and Nutrition Survey
MOPRADEF: Module of Sport Practice and Exercise
IPAQ: International Physical Activity Questionnaire
PA: Physical activity

The main objective of MOPRADEF is "to generate statistic information regarding the participation in sport and physical activity of males and females aged 18 years old and older". The survey identifies, frequency, duration, intensity of the activities, main reasons of people for being active, types of places where sport and physical activity are performed and other determinants of physical activity. The sample was done randomly but only in urban areas. Data collection entailed interviews and questionnaires but the use of a specific tool to collect physical activity data is not mentioned within their methodology. MOPRADEF was initially performed every three months but from 2013 onwards, it has been done every year in the month of November.

2.2.1 Adult Physical Activity

ENSANUT uses the WHO's guidelines of physical activity to catalogue physical activity of the population into three: "inactive" for those who does not meet the minimum physical activity recommended by the WHO of 150 minutes per week of MPA or 75 minutes per week of VPA, "moderately active" for those who meet the mentioned guidelines but don't exceed them, and "active" for those with equal or more than 300 minutes per week of VPA. In Figure 2-3, the percentage of inactive, moderately active and active people is shown at national level, in rural and urban locations. It shows that 82.6% of the population in the country reported meeting the WHO's physical activity guidelines, with people living in rural environments more active than in urban (84.6% vs. 82%). Even though more than 82.6% of adults were classified as active according to WHO, when evaluated per type of activity approximately 16 hours of the day were spent sedentary. ENSANUT recognizes that there is a possibility of data being overreported by 34%. The proportion of "inactive" adults was 17.4%, compared to ENSANUT 2016 which reported 14.4% of adults to be inactive. In ENSANUT 2016, 67.3% of adults considered themselves as active, 85.5% reported feeling "capable" or "very capable" to do at least 30 minutes of physical activity per day.

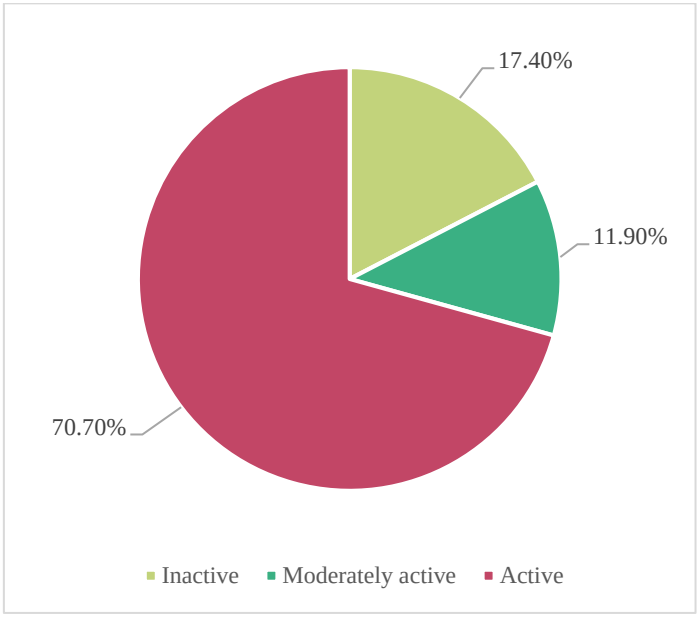


Figure 2-3 Percentage of Adults meeting WHO's physical activity guidelines according to ENSANUT 2012

In the survey conducted by MOPRADEF 2017[46], 49.1% of adults reported "enough" physical activity (meeting but not exceeding 150 minutes per week of MPA or 75 minutes per week of VPA) compared to past surveys, the percentage of people with "enough" physical activity has increased in an important way; in 2016 the percentage was of 46.1%, compared to 23.5% in 2015, 24.1% in 2014 and 21.5% in 2013. Regarding the most popular places where adults keep active, 62% mentioned public spaces while 33.5% mentioned private spaces. More than half of the adults keep active for health reasons, 19% do it for fun, 17.6% to look better and 3.7% for unknown reasons. Participants that reported to be physically "inactive", 26.5% had never done physical activity, 73.5% have been involved in physical activity in the past but stopped because of lack of time (47.3%), feeling tired after work (24.3%) and health problems (16.5%).

As seen in this section, even though the results of ENSANUT reflect "active persons" and MOPRADEF mentioned that nearly half of the adults in urban areas report enough physical activity, this does not mean that they are involved in less sedentary activities throughout the day. It is possible that, beyond overreporting physical activity, individuals show a display of physical activity in constricted periods of time during the day and spent most of the hours in sedentary activities, just like ENSANUT 2012 reported 82.6% of adults spending approximately 16 hours per day being sedentary. It is important for health strategies to promote physical activity, but it is also important to promote a reduction in sedentary activities by incorporating physical activity in more aspects of our daily lives (e.g. replacing sedentary leisure activities with active leisure activities, choosing active commuting over motorised vehicles, etc…).

2.2.2 Adolescent Physical Activity

As in the adults' survey, ENSANUT uses the WHO's physical activity guidelines to classify adolescents' physical activity into three categories: inactive (less than 30 minutes per day of MPA and VPA), moderately active (30 - 60 minutes per day of MPA and VPA) and active (at least 60 minutes of MPA or VPA per day). In ENSANUT 2012[5], at national level, 22.7% adolescents reported to be inactive, 18.3% moderately active and 59% to be active Figure 2-4. Similar to adults, adolescents from rural areas were more active than the ones living in urban areas (66.6% vs. 56.4%). According to this survey, more than 50% of adolescents meet

the WHO's physical activity guidelines but only 36.1% in 2012 and 27.1% in 2016 spend less than two hours on screen time per day. With the prevalence of sedentary activities increasing with age, health policies should come up with strategies to reduce the time spent in sedentary activities and promote physical activity, putting emphasis on young age where many habits are picked. This with the goal to prevent and control the incidence of chronic diseases.

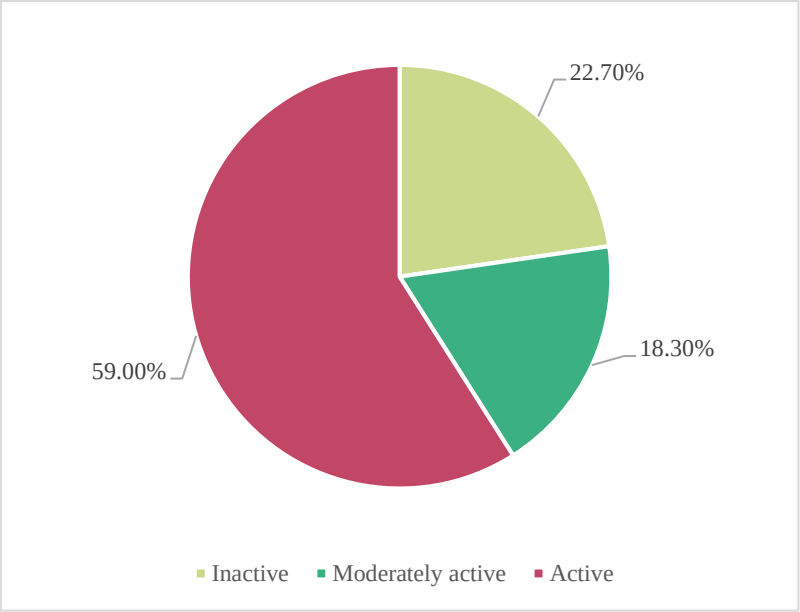


Figure 2-4 Percentage of Adolescents meeting WHO's physical activity guidelines according to ENSANUT 2012

ENSANUT 2012, finishes its report of physical activity in adolescents and adults recognising that among the several actions taken to prevent obesity and NCDs', apart from the ones directed to the individual there has to be changes to the physical environment to promote healthy lifestyles, for example by building cycling routes to increase active travel, improve the accessibility to sport centres, or by providing safe spaces for recreational activities.

Compared to ENSANUT 2012[5], ENSANUT 2016[14] reported a slight and non-significant increase of active adolescents (60.5%), while adolescents that only spent less than two hours per day on screening time reduced to 27.1%. According to ENSANUT, this slight increase in physical activity could be explained by the increase of massive leisure physical activity programs that were introduced in 2012 (e.g. night cycle rides, park yoga, Sunday cycling, etc..). Thus, there is a need to find ways to increase physical activity in Mexican adolescents,

and to achieve this aim we need to understand the key factors that are associated with physical activity.

2.2.2.1 Increasing adolescent physical activity in Mexico

The evidence presented above highlights a need to increase physical activity in Mexican adolescents. This creates a major public health challenge as most of interventions to increase adolescent physical activity have had limited effect or only worked in small sub-groups[47]. Moreover, the majority of the interventions have been focussed on individual behaviour change and have been delivered in developed nations as USA, Australia and European countries. Thus, the potential of these programs to have an impact in any country and particularly a middle-income country such as Mexico is very limited. As such, new strategies that take account of the country-specific issues in Mexico are needed. The Medical Research Council guidance for complex intervention development[48] states that a key phase in the intervention development is understanding the context of interventions and modelling potential intervention approaches. In order to achieve this, it is important to identify the potential determinants of behaviour and the variables that would need to be adapted or changed in order to facilitate increased physical activity[49, 50]. These variables will be context specific so the potential determinants of physical activity behaviour in Mexico will not be the same as in the UK. Thus, in order to identify strategies to increase physical activity in Mexican adolescents there is a need to identify the key potential determinants of behaviour change in this group.

2.2.3 Health Policy

The Sectorial Health Programme (Programa Sectorial de Salud, in Spanish) 2013 – 2018 refers to the Mexican national health strategy and key action points taken by the government to improve the health of the population, reduce health inequalities, provide access to health services, and the efficient administration of health resources[51]. One of the key action points of this programme is the prevention of NCDs through the promotion of healthy lifestyles. In Mexico, the main causes of death are cardiovascular diseases and diabetes mellitus, which risk can be reduced by engaging in regular physical activity[52]. In the following sections, the national and state health strategies for the promotion of physical activity are discussed.

2.2.3.1 National Level

The Food and Physical Activity Programme (FPAP) (Programa de Accion Especifico de Alimentacion y Actividad Fisica) 2013 – 2018[53] is part of the Sectorial Health Programme that seeks the prevention of NCDs' through the improvement of food and physical activity habits through the promotion of healthy lifestyles at all life stages. The action points of this programme are:

1. The promotion of an appropriate diet in different environments.
2. The promotion of physical activity between all age groups.
3. The implementation of campaigns that promote healthy lifestyles.
4. To encourage lactation among mothers as the main way to feed their child and the provision of adequate nutrition complementation.
5. The promotion and rescue of the traditional food culture.
6. Strengthening the skills of health personnel in terms of nutrition.
7. The supervision and evaluation of the mentioned actions.

As seen before, the second action point is related to the promotion of physical activity and the third one to the implementation of health campaigns, including the ones related to physical activity. The FPAP has identified three action plans for physical activity (Table 2-2). First, disseminate health campaigns with the help of mass media. In the past this kind of strategy has been very helpful to instate behaviour change in specific settings and in different age groups. For example: "Less diabetes more health" targeted to elderly adults or the annual heath strokes campaigns. Regarding physical activity, the government suggests targeting adults with desk jobs by recommending "physical activity breaks" during working hours, and children by promoting better Physical Education classes and encouraging them to play more outside during school breaks. The second strategy is to improve the physical environment at community level by improving the urban designs, street use and planned transport. The FPAP, with the help from the Secretariat of Agrarian, Land and Urban development, looks to provide adequate public spaces like parks, gyms, sports centres and courts, and swimming pools along with walking and cycling routes that connect these spaces generating a grid of places intended for physical activity. This new infrastructure should at least have appropriate

lighting, regular maintenance and vigilance, and be suited for people with disabilities, be signalised and most important, have universal free access. The third action is the use of technologies to prevent overweight and obesity in the population. The Secretariat of Public Health and the Mexico's Children Hospital *Federico Gomez* developed an overweight and obesity prevention programme with the use of the app PAIDOS[54]. This app registers the type of food ingested during the day and suggests personalised physical activity routines, it also helps identify users when the sense of hunger is originated by anxiety, anger, sadness and other feelings. During the implementation of this pilot trial, users had an adherence to the programme of 85% after three months of use and 70% after six months. Even though the use of technologies is just on early stages, its approach from the government to promote healthy lifestyles has triggered alliances between schools and private industry to develop apps to increase physical activity and healthy eating behaviour in the population.

Table 2-2 Action plans for physical activity from the Food and Physical Activity Programme (FPAP)

	Action Plans	Objective	Specific Actions	Minimum required	Other public or private institutions involved
1	Dissemination of health campaigns through mass media	Instate behaviour change in different age groups – Be more active	TV and radio adverts about importance of active breaks during working hours (adults) and classes (children and adolescents)		Secretariat of Public Education
2	Improve the physical environment at community level	Improve urban design, street use, planned transport	Provide adequate public spaces for PA (parks, gyms, sports centres, courts, swimming pools)	1. Appropriate lighting 2. Regular maintenance 3. Vigilance 4. Universal Access	Secretariat of Agrarian, Land, and Urban Development
			Provide walking and cycling routes that connect to spaces intended for PA	1. Appropriate lighting 2. Suited for people with disabilities 3. Signalised	
3	Use of technologies	Prevention of overweight and obesity	Use Apps to give nutrition and health advice to individuals		Mexico's Children Hospital *Federico Gomez*
	Involve other public and private institutions in the promotion of PA	Receive support and contribution from other government agencies	Help in the organization, dissemination and logistics of PA promotion campaigns		SSA, IMSS, ISSSTE, SEP, DIF, CONADE, PEMEX, SEDENA, SEMAR, STPS, CONAGUA, PROFECO

PA: Physical activity,
For their initials in Spanish:
SSA: Health Secretariat
IMSS: Mexican Social Security Institute
ISSSTE: Institute for Social Security and Services for State Workers
SEP: Secretariat of Public Education
DIF: National System for Integral Family Development
CONADE: National Commission for Physical Culture and Sport
PEMEX: Mexican Petroleum
SEDENA: Mexican Secretariat of National Defence
SEMAR: Naval Secretariat
STPS: Secretariat of Labour and Social Welfare of Mexico
CONAGUA: National Water Commission
PROFECO: Office of the Federal Prosecutor for the Consumer

2.2.3.2 State Level

In response to the FPAP, each of the 32 states in Mexico have developed state programmes to promote and facilitate physical activity. The one that is best documented and publicly available is the one from Mexico City, and this section is mainly dedicated to describing the Mexico City campaign.

In Mexico City, the campaign "Get Moving and Take Care of Yourself" (*Checate, Midete, Muevete,* in Spanish) is an informed social movement that promotes healthy lifestyles through nutrition and physical activity. After three years since it started in 2008, it has impacted one million and a half of people through different areas of intervention. Its main objective, intervention groups, activities and material used are mentioned on Table 2-3.

Table 2-3 Mexico City Food and Physical Activity Programme. Summary of key points.

Objective: generate an informed and organised social movement to promote healthy lifestyles that achieve a deceleration in the prevalence of overweight and obesity in the population, through actions of nutritional orientation and promotion of physical activity.		
Intervention Groups	**Activities**	**Material and Training**
Move with the help of groups	Activities of nutrition and PA promotion in the 16 sanitary jurisdictions	Referral to health centres. Informing of PA, per age group.
Get moving in the Office	Ten-minute exercise routines in the workplace and diffusion of healthy eating messages through posters	Training of more than 600 "volunteer activators" Posters, flyers around the office
Get moving in the City (Eco-bike)	Sunday and evening bike rides.	Information Kiosks in Paseo de la Reforma every Sunday.
Get moving at School	Consultancy provision about the "healthy lunch-box", as the "Eat well plate", as the implementation of exercise routines.	Information Banners Personnel registering BMI and waist circumference
Get moving at the Park	Health Fairs at parks in which the promotion of healthy eating and physical activity is done through games and activities.	Informing adequate physical activities, exercises per age group.
Other	Information kiosks in subway exits about healthy lifestyles	

In the latest health and nutrition survey in Mexico (ENSANUT 2016), 8,458 adults were interviewed regarding the awareness of the Get Moving and Take Care of Yourself health campaign in their state. Fifty-seven percent of the interviewed adults mentioned knowing about the campaign, 64% of these adults live in an urban area and 43.7% in a rural area. Mexico City is the state in which the people are most aware of the health campaign, followed by the centre of the country, then the north and finally the south. Regarding differences between gender, more women knew about the campaign than men (61% vs. 53.3%), while people between 20 and 39 years old are the ones that identified the campaign the most (63.7%), followed by people between 40 and 59 year old (58.1%), and lastly the group of 60's and more (36%)[14]. Even though most of the population are aware of this programme, evidence suggests that changing awareness does not necessarily mean changing behaviour. Programme evaluations of mass media marketing campaigns showed that increasing awareness has very little impact on attitudes and behaviours[55], and that even though self-efficacy on physical activity can be increased through these campaigns, it is difficult to confirm their long-term effects[56, 57]. Therefore, it is important that the objectives and messages of the campaign reach more people, specially adolescents that will likely carry behaviours into adulthood and adults over 40 years old; but it is imperative to start adapting the built environment to suit the needs of the population in terms of physical activity and explore other strategies to change behaviour besides awareness.

2.3 Health and Behaviour Theories in Physical Activity

A theory is "a set of interrelated concepts, definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining or predicting phenomena"[58]. Theories are abstract by nature, and do not have a specific content, instead "they come alive when filled with practical topics, goals, problems"[59], as in the case of public health. Due to health behaviours being far too complex to be explained by one single theory, a collection of theories come together forming a model. Apart from models being informed by more than one theory, models are complemented with empirical findings. Models and theories explain behaviours and suggest ways to achieve behaviour change, and in social sciences, they specify the determinants influencing the phenomena of interest[59].

Even though several theories of behaviour change in physical activity have been used, the ones mentioned Table 2-4 have been more frequently applied to physical activity behaviour[60]. From cognitive theories that focus on behaviour change on the individual to the trans-theoretical model that studies behaviour change as a process, to ecological models that consider behaviour to have multiple levels of influence apart from the individual, the variety of focus on behaviour change is broad. Self-determination theory (SDT) is specifically a theory of motivation, which forwards concepts around the quality of motivation and the psychological needs to achieve autonomous motivation. SDT has been extensively applied in physical activity and health[61] but it does not specifically account for the physical environment. The Social Cognitive Theory (SCT) (evolved from the Social Learning Theory) explains the "why and how" people change individual health behaviours and the psychological and environmental determinants that influence them[60]. A strength of SCT is that it provides explanations for almost all human phenomena, even though the breadth of this makes it difficult to be tested comprehensively as a whole theory, compared to other theories[62]. Only the psychological construct of self-efficacy has been validated repeatedly[62]. The theories of Reasoned Action (TRA), Planned Behaviour (TPB) and the Integrated Behavioural Model (IBM) hypothesise relationships between attitudes, intentions and behaviours. TRA points out that the best predictor of a behaviour is behavioural intention, determined by attitude towards the behaviour and the social normative beliefs towards it. TPB adds to this theory the construct of "perceived control" which is composed by control

beliefs and perceived power; while IBM integrates constructs of TRA and TPB and concludes that the most important determinant of behaviour is intention to perform behaviour, composed by attitude, perceived norms and personal agency; followed by knowledge and skills to perform the behaviour, salience of the behaviour, environmental constraints and habit. These three theories provide a clear framework to decode individuals' actions and measure factors that affect behaviour and might be good for behaviours over which people have less volitional control[60]. However, targeting a few beliefs might not be effective if they represent a small proportion of the total set of beliefs affecting intentions. Moreover, literature has reported discrepancies regarding the strength of the intention-behaviour association[63, 64]. The theories discussed up to this point have focused on the individual, dealing with behaviour change through prediction and control but considering change as a sole event and not like a process.

Table 2-4 Strengths and Limitations of Health Behaviour Theories

Theory/Model	Description	Strengths	Limitations
Self-determination Theory	Motivation differs in its type based on if it is relatively autonomous or controlled. Autonomous motivation → predictive of behavioural, cognitive and affective outcomes[65]. Basic psychological needs: **Autonomy:** Being the perceived origin or source of own behaviours **Competence:** Feeling effective in ongoing interactions **Relatedness:** Feeling connected to others, belongingness.	A theory comprised of sub-theories that seek to explain human motivation and behaviour based on individual differences. Extensively applied and tested in physical activity and health.	Focuses on changing the behaviour of the individual and less on the environment. Not self-adherent to PA. Oversimplify the complexity of PA behaviour.	Does not specifically account for physical environment.
Social Cognitive Theory	Why and how people change individual health behaviours and the social and physical environments that influence them[60]. 1. Psychological determinants of behaviour: Outcome expectations and self-efficacy. 2. Observational learning: Learning to perform new behaviours by exposure to media or peer modelling. 3. Environmental determinants of behaviour: Incentive motivation (reward/punishment) and facilitation (provision of tools/resources) 4. Self-regulation: Self-monitoring, goal-setting, self-reward, self-instruction 5. Moral disengagement: Violation of moral that avoids violence to others.	Provides explanations for a range of human phenomena.		Not tested comprehensively, just self-efficacy has been validated within the PA domain[62].
Theory of Reasoned Action (TRA)	Best predictor of a behaviour is behavioural intention, determined by attitude and social beliefs.		Provides a clear framework that conceptualizes, measures, and identify factors that affect behaviour. Good for behaviour over which people have less volitional control.	Targeting a few beliefs may not be effective if they represent a small proportion of the total set of beliefs affecting intentions. Discrepancies regarding the strength of the intention-behaviour association: Does not decline over time[63]; declines over time[64].
Theory of Planned Behaviour (TPB)		Adds "perceived control", composed by: 1. Control beliefs 2. Perceived power		

Integrated Behavioural Model (IBM)		Integrates constructs from TRA and TPB. Most important determinant of behaviour is intention to perform the behaviour: 1. Attitude 2. Perceived Norm 3. Personal Agency *also:* 4. Knowledge and skills 5. Salience of the behaviour 6. Environmental constraints 7. Habit			Limited to single proximal determinant of behaviour - intention
The Transtheoretical Model/States of Change (TTM)	***Change*** not as an "event" but as a process that unfolds over time. 1. **Pre-contemplation:** No intention to take action in 6 months 2. **Contemplation:** Intents to take action within 6 months 3. **Preparation:** Take action in 30 days 4. **Action:** Change behaviour for less than 6 months 5. **Maintenance:** Change behaviour for more than 6 months 6. **Termination:** No temptation relapse, 100% confidence 7. **Processes of change:** Covert and overt activities people use to progress through stages 8. **Decisional Balance:** Weighing the pros and cons of changing. 9. **Self-efficacy:** Confidence that people can cope with high-risk situations without relapsing.		- Provides a framework to categorise individuals into a particular stage of change→how to encourage? - Interventions that meet individuals' requirements on their stage of change. - Enhance participation - Increase retention rates - Reduces the resistance of individuals to initiate difficult behaviours [66].		Depends of the culture in which is applied. More research needed to structure the stages of change in PA. TTM describes behavioural stages but not any psychological, social, environmental determinants of behaviour [59].
Ecological Models/Social Ecology	Behaviour has multiple levels of influence: 1. Intrapersonal 2. Interpersonal 3. Organizational 4. Community 5. Public Policy Behaviour is maximized when environment and policies support healthful choices, when social norms and social support are strong, and when individuals are motivated and educated to make those choices[59].		Focuses on individual influences as well as social, environmental factors and policy. Multiple levels of influence broaden options for interventions. Policy → affects population (≠ from individual based theories). Acknowledges that influence of determinants may change over time → influence upon behaviour.	Unspecific about the mechanisms of important hypothesized influences→ methodological and conceptual challenges. Hard to identity critical factors because of the lack of information about how the broader levels of influence operate or how variable interact across levels. Fail to provide applicable measures to be implemented across numerous domains and settings.	

To overcome the limitations of the social cognitive models, The Transtheoretical Model (TTM), also known as "Model of Change", treats behaviour change as a process that unfolds over time. TTM uses stage-based approaches which are characterised by a particular set of psychological and behavioural changes. The stages of TTM start with precontemplation, contemplation and preparation, in which the individual does not take immediate action in a set of time but ponders the change to make; followed by action of changing the behaviour for less than six months; and then maintaining that behaviour for more than 6 months (maintenance), and finally adopting that behaviour completely with a 100% confidence (termination). TTM also borrows constructs from other theories by incorporating individuals' weighing of "pros and cons" of the behaviour and self-efficacy as part of the model of change. A strength of this model is that designing interventions that are tailored to the requirements of individuals based on their stage of change is considered to enhance participation and retention rates of individuals, but most importantly to reduce the resistance of individuals to initiate difficult behaviours[66]. Moreover, it provides a framework to categorise individuals into the stage they are at, and also encourages them to change behaviour and progress through the stages. Limitations of the model would be its dependence on the culture in which it is applied; also, failing to recognise, as the case of cognitive individual theories, that apart from the individual complexities there are external and social factors such as age, socio-economic status, gender, social and built environment and policy environment that help to explain multifaceted and complex phenomenon such as the engagement in physical activity[59, 67, 68].

2.3.1 Multi-layered models of understanding behaviour

As noted above, the majority of the current intervention approaches have employed the individual level behaviour change approaches that have been based on the theories identified above. These approaches have not yielded the hypothesized effects at individual level nor the potential to scale these approaches for population level behaviour change, and as such, alternative designs need to be considered. In the last 20 years, researchers have become aware that changing health behaviour is a complex phenomenon that has multiple levels of influences[67, 69]. In an attempt to, not only focus on the individual but also in social, environmental and policy factors that may facilitate or inhibit individual behaviour, the use of ecological approaches has become popular. The Ecological Model introduces the idea of behaviour having multiple levels of influence: intrapersonal, interpersonal, organizational,

community and public policy. According to this model, behaviour is maximized when individuals are motivated and educated to make those choices, but, differently from individualistic theories and TTM, also when environment and policies support healthful choices and when social norms and social support for healthful choices are strong. Individualistic theories might be more specific about the most important hypothesized influences, but they are unlikely to drive population change. Ecological models, due to their multiple levels of influence, broadens options for interventions that are more likely to reach entire populations and chance policy. In the following sub-section, the main concept, core principles and limitations of the Ecological Model are described, as well as why it was the chosen health and behaviour theory for this thesis.

2.3.1.1 Ecological Model

The term ***"ecology"*** refers to the interrelations between organisms and their environments[59]. The Ecological Model, aside from studying the individual, recognises the influence of the organizational elements and the polices implemented, on health behaviour of the broader community. In other words, the ecological model emphasizes the environmental and policy contexts of behaviour, while incorporating social and psychological influences. Ecological models guide the development of more comprehensive population approaches to changing behaviours that will reduce the prevalence of health problems. The main concept of the ecological model is to consider "behaviour" as a construct of multiple levels of influence. Behaviour is maximised when it is supported by environments and policies, strong social support, and when individuals are motivated and educated to make those choices.

The four core principles of ecological models of health behaviour are: 1) there are multiple levels of influence on specific health behaviours: intrapersonal (biological, psychological), interpersonal (social, cultural), organizational, community, physical environment, and policy, 2) the different influences on these health behaviours interact across different levels, 3) ecological models should be behaviour specific, 4) multi-level interventions are most effective in changing behaviour. The Ecological Model of Active Living[70] proposes the following ecological approach to creating more physically active communities: intrapersonal (i.e. demographics, biological, psychological, family situation), perceived environment (i.e. safety, comfort, accessibility, convenience), access and characteristics of the neighbourhood,

recreation environment, home environment, workplace and school environment; and the final ring deals with policy environment (i.e. health care incentives, transport and public recreation investments, park policies, school policies…) (Figure 2-5). These rings are soft divided by active recreation, household activities, occupational activities and active transport; and hard divided into information environment (i.e. mass-media, media regulations), social cultural environment (i.e. social support, social climate, advocacy by individuals and organizations) and natural environment (i.e. weather, air quality, open space, land use policies). This onion-like division with cross-level divisions gives an extremely complete panorama of all the factors at different levels affecting the change of behaviour in physical activity.

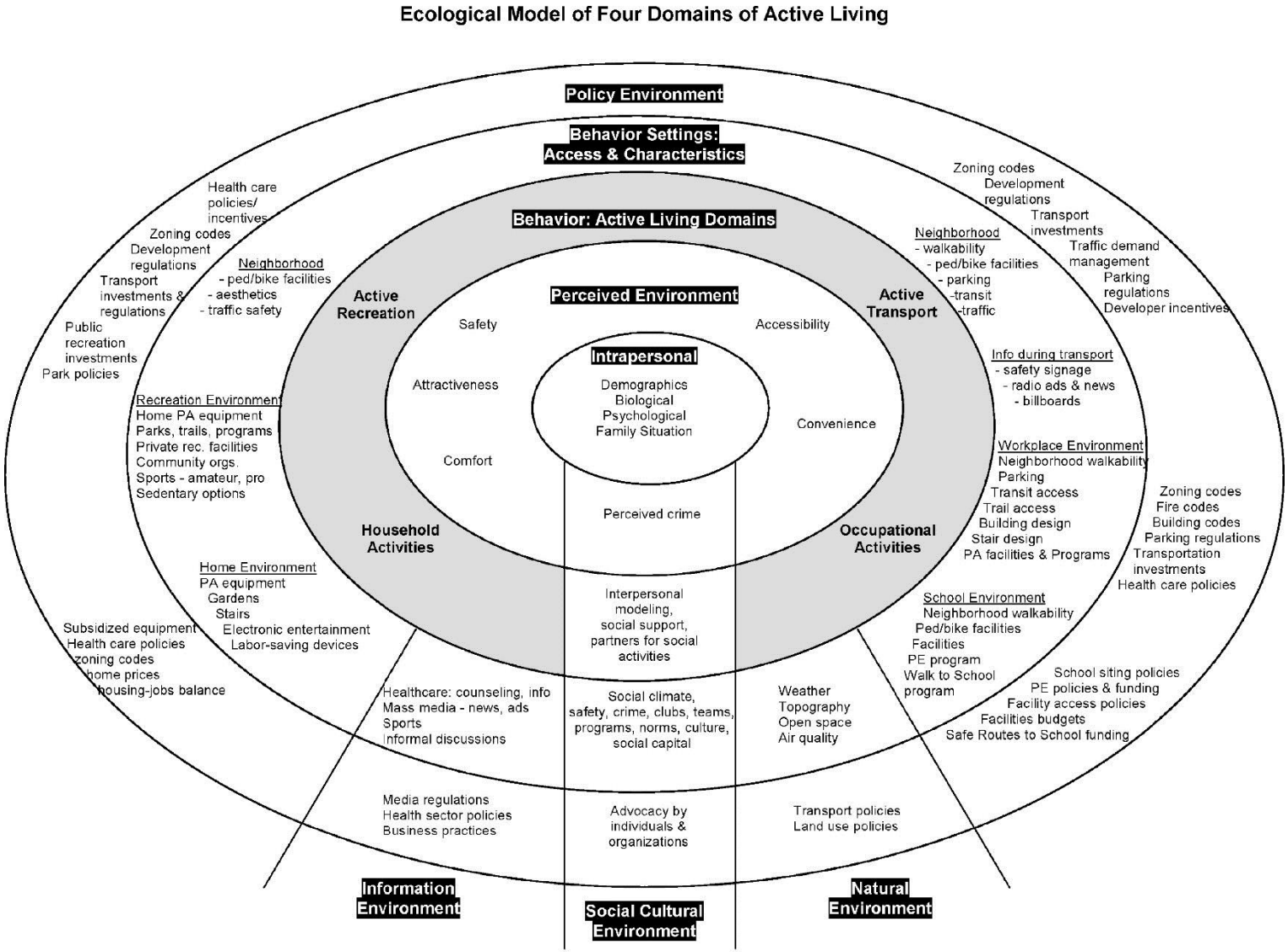


Figure 2-5 Ecological Model of Active Living by Sallis, et al. 2006[70]

The main strength of the ecological model is that it includes multiple levels of influence, thereby broadening the options for interventions. This multi-level influence increases the possibility of influencing the entire population, in contrast with interventions based on the individual. A limitation of this model is the lack of specificity about the hypothesized influence; also it is difficult to identify critical factors due to lack of information regarding how the broader levels of influence operate and how the variables interact across levels. On the other hand, individual-level psychosocial theories of health behaviour are more likely to specify the mechanisms of interaction and the variables expected to influence behaviours. In a country such as Mexico, where physical activity research is in its early stages, the socio-ecological model provides a broad framework for understanding physical activity. Even though the model does not specifically mention urbanisation nor many factors that underpin it, some are scattered at different levels (e.g. perceived crime, traffic safety, presence of trails/paths, availability of electronic entertainment, demographics). Thus, the socio-ecological model provides an appropriate framework for promoting physical activity in middle income countries such as Mexico, which have a limited evidence base.

2.4 Urbanisation

The study of urbanisation is complex, it involves the study of many elements, not only environmental and therefore it is a key candidate to be considered within an ecological framework of physical activity. For example, the population density of a place and the primary source of activity of the region (i.e., farming, services, business) are socio-cultural elements that impact the individual; the perception of crime and traffic safety are part of the perceived environment; the elements of the number of paved roads, sewage services, education related buildings and health buildings are part of the neighbourhood environment, and the availability of television, internet, technological devices could be part of the information and school environment of an adolescent.

Urbanisation refers to the rate of increase in the proportion of people living in urban areas and the expansion of built-up areas (i.e. buildings, infrastructure). The ***proportion*** of people living in urban areas is increased by urban growth. Urban growth is the increase in the ***number*** of people living in urban areas through settlement transition, which is when an existing village meets administrative criteria of a town, through a re-adjustment of boundaries

during settlement expansion or by rural-urban migration or by natural increase, where births exceed amount of deaths (Figure 2-6).

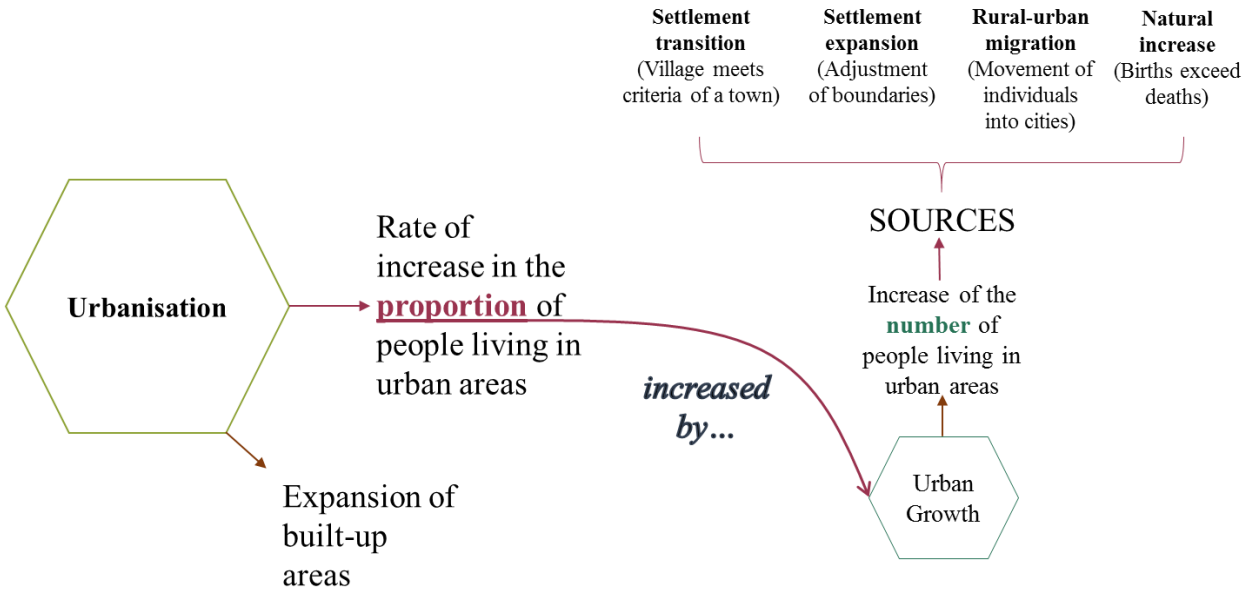


Figure 2-6 Definition of urbanisation and urban growth

According to the 2018 revision of World Urbanisation Prospects from United Nations[3], 55% of the current world's population resides in urban areas and by 2050 this percentage is projected to increase to 68%. The most urbanised regions include North America where 82% of the population live in urban areas, followed by Latin America and the Caribbean with 81%, then Europe (74%), Oceania (68%), Asia (50%) and Africa (43%). Urban populations have rapidly increased in the world, rising from 751 million in 1950 to 4.2 billion in 2018, from which Asia holds 54% of the world's urban population, followed by Africa (13%) and Europe (13%)[3]. In Mexico, the population size has tripled in the last 65 years, 73% of the population live in metropolitan areas, urban centres and megacities (cities with 10 million inhabitants or more)[71]. Mexico City, with a population 22 million habitants, is approximately the fourth largest city along with Sao Paulo; after Tokyo, New Delhi and Shanghai[3].

Urbanisation is conceptualised as a process, a non-static concept that is hard to measure because of its constant change. Consequently, urbanicity is used to provide an idea of the level of urbanisation of a location. Urbanicity is the presence of conditions that are specific to

urban areas or are present to a much greater extent than in non-urban areas[72]. Some authors consider urbanicity as a complementary aspect of urbanisation[72], which is understandable when both refer to different features of the urban environment. For example, while urbanisation would focus on industrialization as one of many elements of the physical environment, urbanicity would focus on number of industries and factories or pollution; industrialization refers to a social and economic change which is hard to measure because of unclear markers and continuous change, while it is easier to count the number of factories within a municipality. Due to the above, it is understandable why urbanicity is seen by some authors as a complementary aspect of urbanisation, but in practice urbanicity is a static concept that gives us an idea of how urbanised an area is at a given point in time.

2.4.1 Urbanicity

As mentioned above, urbanicity is used to estimate how urbanised an area is, as it refers to the elements and circumstances that are present to a greater extent in urban versus rural places. According to Vlahov, Galea [72], urbanicity refers to the "impact of living in urban areas at a given point in time, the presence of conditions that are particular to urban areas or are present to a much greater extent than in non-urban areas". Urbanicity can be practically assessed by measuring physical elements, for example the number of paved roads, availability of televisions, number of health centres and number of schools. But urbanicity could also be the presence of other non-physical elements, such as substantial industrial pollution, pedestrian-motor-vehicle injuries, homicide rates, substance abuse, availability of public transport and perception of safety.

To measure urbanicity, several authors have created urbanicity scales. These scales give a value (between 0 and 10) to a range of features of a location depending on their presence in the environment, and then they are aggregated into one urbanicity score. A number of different scales have been created and the most widely used scales are summarised in Table 2-5. Mendez, Du, Popkin [73] (2004) created the multicomponent measure for urbanicity basing their work on an unpublished manuscript from Mendez, Stookey, Adair, Popkin [74] (2003). Mendez et al. (2004) studied the association between urbanicity and food availability and included 10 items to calculate urbanicity. Later, Dahly, Adair [75] (2008) refined the urbanicity score and applied it to communities in the Philippines. Following this, Jones-Smith, Popkin [76]

(2010) identified, common definitions for distinguished features of the urban environment and developed a list of characteristics to measure urbanicity.

The scale by Jones-Smith and Popkin (2010) used the scoring system from Dahly and Adair (2008) for some of the urbanicity items but included the sub-scales of "social services", referring to the availability of preschool and social services, and "diversity", referring to the variance in housing quality and years of education among mothers, and differentiated between "traditional markets" and "modern markets". This scale showed very good internal consistency (α= 0.85 to 0.89), good item scale correlations (>0.4) and good test-retest reliability (r=0.90 to 0.94). Moreover, it showed "fair-to-good" inter-scale agreement (Spearman correlation = 0.75 to 0.78) when compared to the official government rural-urban classification of communities. A limitation of this measure was that the 12 elements included make assessment impractical when conducting studies on larger scales such as state level, national or even large localities due to the availability of public data.

Parallel to Jones-Smith and Popkin's scale, Allender and other authors [6, 7] (2010 & 2011) developed a scale, based partially on the scoring system from Dahly and Adair but adapted to fit the Indian and Sri Lankan context. Then they used the urbanicity scale to study the association between urbanicity and NCDs' risk factors. The authors also suggested that urbanicity might need to be targeted to the culture of the country and also to the availability of data needed to calculate scores. In 2012, Novak, Allender, Scarborough, West [77] developed the urbanicity scale further and assessed its feasibility in other countries (Ethiopia, India, Peru). The scale was tested for criterion validity, in which the composite urbanicity scale score was compared with a dichotomised version of urbanicity (urban-rural), resulting in good agreement (Kappa=0.76; Spearman's rank-correlation coefficient=0.84, $p<0.0001$). Construct validity was assessed through factor analysis which tested if the scale accurately measured the latent construct (urbanicity) and scale correlations for each domain of the urbanicity score were calculated. The scores demonstrated good item-factor correlations ($r\geq0.40$); meaning that each domain of the scale is associated with the concept of urbanicity and contributes to its measurement. Moreover, construct validity was supported by evaluating the relationship between the urbanicity scale and other factors that are known to vary with urbanicity, such as housing quality and socio-economic status. In all three countries, both

variables showed a positive correlation with urbanicity ($p<0.05$). As previously mentioned, there are several scales to measure urbanicity, most of them share similar items and they are often based on the same score from Dahly and Adair (2008). On these grounds, there is not an obvious choice regarding which scale to use to assess urbanicity in Mexico. In this thesis, the scale by Novak et al. (2012) was selected for the following reasons (1) it has been tested for validity in three different countries with a cultural and political situation similar to Mexico, (2) there is a published clear methodology for the assessment of each of the urbanicity sub-scores and (3), the information required to calculate the seven proposed sub-scores is publicly available in Mexico.

Table 2-5 Composite measures of urbanicity

	Mendez, Du, Popkin [73] (2004)	*Dahly, Adair* [75] (2008)	*Jones-Smith, Popkin* [76] (2010)	Allender, Lacey, Webster, Rayner, Deepa, Scarborough, Arambepola, Datta, Mohan [7] (2010)	Allender, Wickramasinghe, Goldacre, Matthews, Katulanda [6] (2011)	*Novak, Allender, Scarborough, West* [77] (2012)
	China	Philippines	China	India	Sri Lanka	Ethiopia, India, Peru
Population size *Number of people in a place*	X	X		X	X	X
Population density *Number of people per km²*	X	X	X	X	X	
Communications or Media *Presence of phone services, internet, cable TV, mobile phones newspaper*	X	X	X	X	X	X
Education *Amount of primary schools, secondary schools, colleges, vocational schools*	X	X	X	X	X	X
Health infrastructure or health services *Presence of health services/centres, amount of doctor/nurses per person*	X	X	X	X	X	X
Economic Activity *Amount of people involved in agriculture/farming*	X		X		X	X
Built environment or Sanitation *Amount of paved roads, light posts, sewage services…*	X		X		X	X
Transportation *Availability of public transport**	X	X	X	X	X	
Housing Quality *Structural integrity of the place, structural hazards*	X		X		X	
Access to markets Number of retail shops, drug stores, grocery stores	X	X	X		X	
Diversity *Variance in housing quality plus variance in years of education among mothers*			X	X		X
Social Services *Availability of preschool and social services*			X			

* Depending on the scale, density of paved roads could also be measured.

2.4.2 Safety

As mentioned in 2.4.1 Urbanicity, apart from the built environment, communication media, transportation, health services etc... there are other elements that are present to a greater extent in urban areas than rural and that are not taken into account in the several urbanicity scales; two of them being crime safety and pedestrian safety. It is of note that these are included (perceived environment) in the Socio-ecological model (Figure 2-5). According to the National Survey of Urban Public Safety (ENSU, for their initials in Spanish)(March, 2018)[78], the perception of unsafe environments in Mexico has increased in the last three years from 69.4% in females and 66% in males, to 81% in females and 71.8% in males. According to ENSU, the most common places where the Mexican population feel unsafe and at risk of crime, are ATMs in public roads (81.3%), public transport (74.3%) and walking along the streets they use daily (68.7%) (Figure 2-7)[79]. Also, 56.8% of the adults interviewed mentioned feeling unsafe at leisure centres and parks. As a result of unsafe environments, 70.5% of adults wouldn't let their children go out alone and 33.5% wouldn't go out for a walk[80].

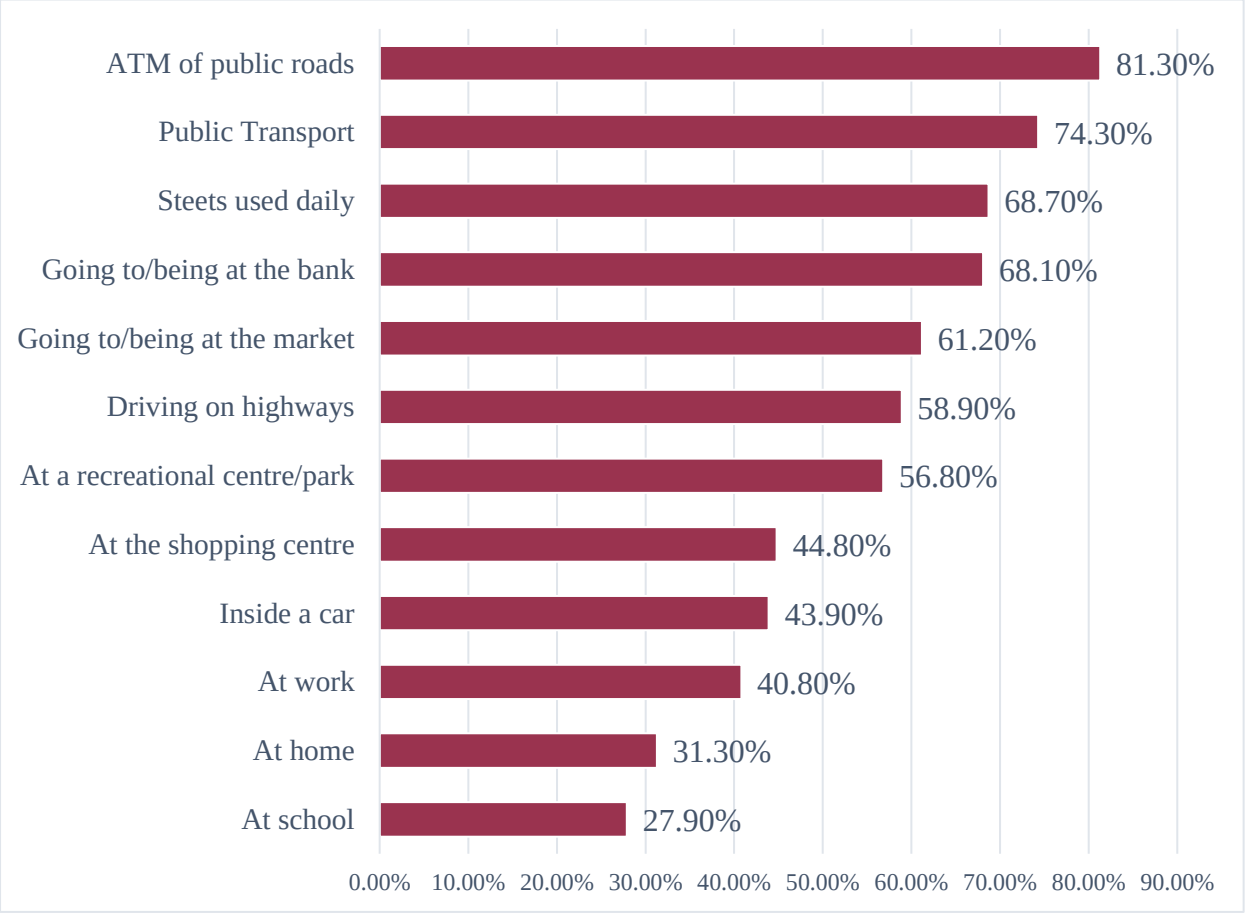


Figure 2-7Percentage of the population (>18 years old) that feel unsafe per location, ENSU (2018)

The most common problems identified by the population with the place they live in are shown on Figure 2-8. Crime is the second most common problem, mentioned by 68% of the population, followed by insufficient public lighting (63.3%), heavy traffic in streets and avenues (47.6%), inefficient public transport (41.4%), neglected parks (34.9%) and inefficient litter collection (28.8%)[79]. Considering the environmental influences on physical activity (Figure 2-5), these elements potentially influence the population's physical activity. This is corroborated into the findings of the ENSANUT 2016 survey which found that after a lack of time (56.8%), the second most common barrier of performing physical activity was lack of adequate and safe spaces (37.7%)[14].

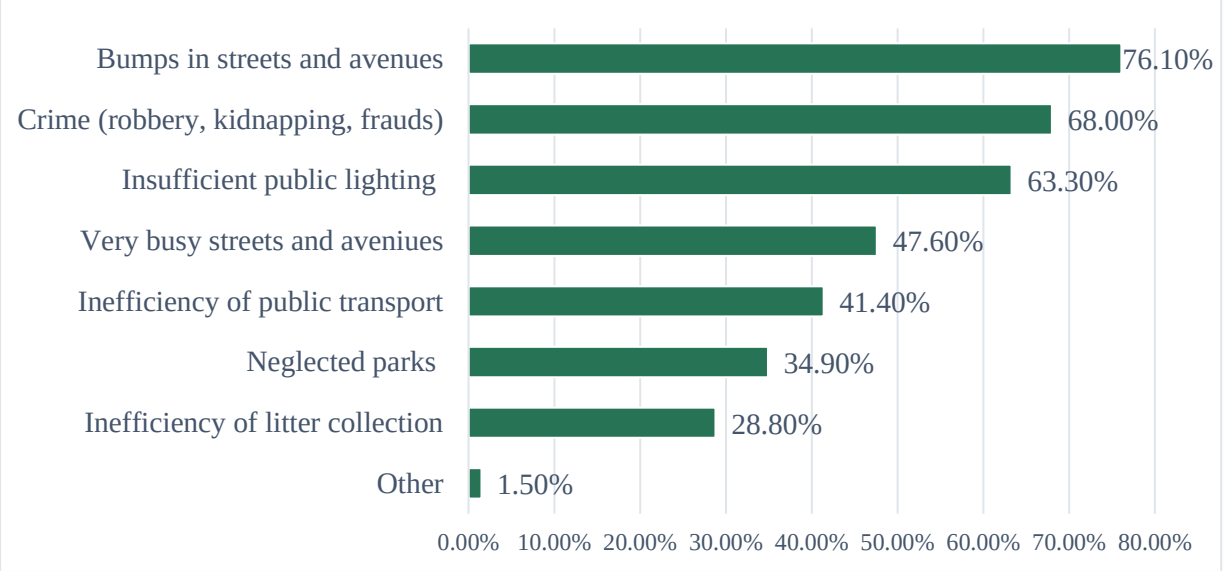


Figure 2-8 Most common problems in the city identified by the population.

The measurement of people's perception of safety is mainly done using; (1) single-item questions with dichotomized answers (i.e. agree/disagree)[81, 82], (2) unvalidated published questions[83], or (3) by using environmental scales that explore multiple aspects such as walkability, road and personal safety and general aesthetics. Examples of these environment scales are the Children's Perceptions of the Physical Environment[84] and the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y)[85]. The Children's Perceptions of the Physical Environment assesses children's perceptions of the physical and social environment at home and in their neighbourhood; it has moderate internal reliability and fair test-retest reliability[84]. The NEWS-Y mainly assesses walkability through several aspects of the

environment (i.e. mix-land use, street connectivity, neighbourhood aesthetics etc...) that make an area "walkable or not", pedestrian automobile traffic safety and crime safety being two of them. The pedestrian automobile traffic safety sub-scale has been used in previous literature to assess perception of safety in a sample of Brazilian adolescents[86], and in many other research papers cited in Table 2-7. Previous work has reported acceptable test-retest reliability in adolescents[85]. The traffic safety and crime safety questions can be found in Appendix H.

2.4.3 Urbanicity, Safety and associations with Physical Activity

2.4.3.1 Urbanicity

Previous literature has used composite measures to assess urbanicity and examine associations with physical activity (Table 2-6). A study in India[7] investigated the association between a composite measure of urbanicity and NCD risk factors in a sample of adolescents and adults (n=3,705); findings reported that urbanicity was positively associated with physical inactivity in males (OR=3.26, 95% CI=2.5 to 4.3) and females (OR=4.13, 95% CI=3.0 to 5.7). Similarly, in a study in Sri Lanka, using the same urbanicity measure, a positive association with physical inactivity was found in males (OR=3.22, 95% CI=2.27 to 4.57) and females (OR=2.29, 95% CI=1.64 to 3.23)[6]. Moreover, a study in 7,340 adolescents and adults in Uganda found that increases of urbanicity in communities defined by the government as "rural" were positively associated with an increased risk of physical inactivity (RR=1.19, 95% CI=1.14 to 1.24)[87]. Even though physical activity is lower in areas with high urbanicity, larger declines of physical activity are seen in areas with low urbanicity. A study examining the differences in physical activity over time according to urbanicity and income in Chinese adults (n=20,083) found that the weekly physical activity in places with low urbanicity declined from 500 MET-hours per week in 1991 to 300 MET-hours per week in 2009, whereas in areas with high urbanicity the decline was less, from 200 MET-hours per week in 1991 to 125 MET-hours per week in 2009[88]; even though it can be argued that the physical activity decline was proportional in both cases. Together the data from a number of studies suggests that urbanicity is associated with physical activity in low and middle-income countries but there is a lack of information about the association between urbanicity and physical activity in Mexico using composite measures.

There have been a number of studies that have investigated associations between urbanisation and physical activity through non-composite measures. A study in Papua New Guinea examined the influence of urbanisation on physical activity and dietary changes, urbanisation was measured as per government definitions for "urban settlement" and "village". Findings showed that females living in urban settlements reported less physical activity than females from villages (urban: PAL=1.63±0.19 vs. rural: PAL=1.88±0.26; $p<0.01$)[89]. Similarly, adults (n=552) living in urban areas in Cameroon reported lower physical activity energy expenditure (PAEE) than those living in rural areas (PAEE kJ/kg/day=44.2±21 vs. PAEE kJ/kg/day=59.6±23.7; $p<0.001$)[90]. Regarding adolescents, a study in Kenya compared objective physical activity data from rural and urban areas and found that MVPA was higher among adolescents living in rural areas (males: 68±22; females:62±20) than in adolescents living in urban areas (males: 50±17; females:37±20) ($p<0.001$)[91]. Physical activity among adolescents not only seems to be higher in places with low urbanicity, but also children living in rural areas spend more time in outdoor activities (185.2 minutes per day) and less time in structured physical activity than children living in suburban (132.0 minutes per day) or urban places (129.4 minutes per day)[92]. Thus, again there is growing evidence of a link between urbanicity and physical activity but a lack of data on comparable associations in Mexico or other Latin American Countries.

Table 2-6 Associations between urbanicity, urbanisation and physical activity. Summary of key studies.

Author	Population Sample	Objective	Urbanicity Measure	Findings
Allender, Lacey, Webster, Rayner, Deepa, Scarborough, Arambepola, Datta, Mohan [7] (2010) *India*	Adults (15-64y) n=3,705	Find an association between urbanicity an NCDs' Risk Factors	Multicomposite measure 1 to 10 (refer to Table 2-5)	Urbanicity had a positive association with physical inactivity **Males:** OR=3.26, 95% CI=2.5 to 4.3 **Females:** OR=4.13, 95% CI=3.0 to 5.7
Allender, Wickramasinghe, Goldacre, Matthews, Katulanda [6] (2011) *Sri Lanka*	Adults n=4,485	Find an association between urbanicity an NCDs' Risk Factors	Multicomposite (refer to Table 2-5)	Urbanicity had a positive association with physical inactivity **Males:** OR=3.22, 95% CI=2.27 to 4.57 **Females:** OR=2.29, 95% CI=1.64 to 3.23
Attard, Howard, Herring, Zhang, Du, Aiello, Popkin, Gordon-Larsen [93] (2015) *China*	Adults (18-75y) n=20,083	Examine the differences in PA over time according to urbanicity and income.	Multicomposite scale by Jones-Smith	PA is lower in individual living in urban areas than in less urban areas, larger declines of PA are seen in low urban areas than in urban areas. **Low urban areas:** 1991: 500 MET-hr/wk 2009: 300 MET-hr/wk **High urban areas:** 1991: 200 MET-hr/wk 2009: 125 MET-hr/wk In low urban areas the association between income and total PA went from negative in 1991 ($p<0.05$) to positive in 2000 ($p<0.05$); in high urban areas the association remain positive.
Riha, Karabarinde, Ssenyomo, Allender, Asiki, Kamali, Young, Sandhu, Seeley [87] (2014) *Uganda*	Adolescents and adults (13- y) n=7,340	Examine the distribution of urban characteristics across rural communities in Uganda and their associations with NCDs' risk factors.	Multicomposite scale by Novak et al	Urbanicity positively associated with an increase in risk of physical inactivity RR=1.19, 95% CI=1.14 to 1.24
Fleischer, Diez Roux, Alazraqui, Spinelli, De Maio [94] (2011) *Argentina*	Adults (18-97y) n=40,849	Investigate the associations between SES and NCDS' risk factors by urbanicity level	Indicators from the national census	Greater levels of urbanicity were associated with higher odds of low physical activity **Males:** OR=1.19, 95% CI=1.09 to 1.38 **Females:** More education was associated with greater probability of low physical activity in more urban areas (p=0.002).

Yamauchi, Umezaki, Ohtsuka [89] (2001) *Papua New Guinea*	Adults (20-69y) n=56	Examine the influence of urbanisation on physical activity and dietary changes	Urban settlements vs. villages	**Males:** Urban PAL: 1.71±0.21 Rural PAL=1.84±0.22 **Females**: Urban PAL: 1.63±0.19 Rural PAL=1.88±0.26 (p<0.01)
Donatiello, Dello Russo, Formisano, Lauria, Nappo, Reineke, Sparano, Barba, Russo, Siani [92] (2013) *Italy*	Children (2-10y) n=1,673	Investigate the distribution of adiposity indices according to urbanisation level and patterns of physical activity among children	Rural, suburban, urban	Children in rural areas spent more time in outdoor activities but less time in structured physical activity than suburban and urban children. Outdoor activity (min/day): rural=185.2, suburban=132, urban=129.4 (p<0.001) Structured PA (%): rural=28.8, suburban=43.2, urban=47.2 (p<0.001)
Ojiambo, Easton, Casajus, Konstabel, Reilly, Pitsiladis [91] (2012) *Kenya*	Adolescents (13-16y) n=200	Compare objective physical activity from rural and urban areas.	Rural, urban	**Males:** Urban MVPA (min) =50±17 Rural MVPA (min) = 68±22 (p<0.001) **Females:** Urban MVPA (min) =37±20 Rural MVPA (min) = 62±20 (p<0.001)
Assah, Ekelund, Brage, Mbanya, Wareham [90] (2011) *Cameroon*	Adults (25-55y) n=552	Examine the associations between objectively measured free-living PAEE and the metabolic syndrome		Participants living in urban areas had lower PAEE than rural participants **Urban** PAEE KJ/Kg/day=44.2±21 **Rural** PAEE KJ/Kg/day=59.6±23.7 (p<0.001)
Reis, Bowles, Ainsworth, Dubose, Smith, Laditka [95] (2004) *USA*	Adults (18-75) n=137,359	Estimate levels of non-occupational leisure-time PA by degree of urbanization and region.	Rural-urban continuum codes (metro, large urban, small urban, rural)	Participants from South, greatest likelihood of physically inactivity compared to the rest of the Country. Participants in rural areas from Midwest and South, greatest likelihood of being physically inactive compared to their large urban and small urban counterparts. Rural Midwest: OR=2.59, 95% CI= 1.35 to 4.97 Rural South: OR=5.49, 95% CI= 2.82 to 10.68 Small Urban Midwest: OR=1.99, 95% CI= 1.65 to 2.40 Small Urban South: OR=2.32, 95% CI= 2.02 to 2.67 Large Urban Midwest: OR=1.83, 95% CI= 1.51 to 2.23 Large Urban South: OR=2.04, 95% CI= 1.72 to 2.41

PAL: Physical Activity Level
PAEE: Physical Activity Energy Expenditure

2.4.3.2 Perception of Safety

The main studies related to perception of pedestrian and traffic safety, and crime safety are shown in Table 2-7 and Table 2-8. The elements they have in common have been grouped into columns for an easier visualisation.

In terms of road safety, a study in Australia found that road unsafety was negatively associated with MVPA (min per day) during the evening (ß=-0.714, p=0.044) and outside school hours (ß=-1.5, p=0.047)[96]; similarly, a study in Belgium found that feeling safer around traffic was associated with more leisure-time sports (ß=0.104 (0.036); p<0.001)[97]. Regarding specific elements of roads, a study of 346 adolescents in Australia found that female adolescents in neighbourhoods with traffic lights were more likely to walk and cycle than females in neighbourhoods with scarce traffic lights (OR=2.7, 95% CI=1.2 to 6.2). In the same study, the presence of speed humps were positively associated with males' MVPA during the evenings (OR=0.38, 95% CI=0.15-0.97)[98]. Another element of roads that is important in the perception of pedestrian and traffic safety is the presence of "cul-de-sacs" (i.e. streets closed at one end). There is evidence that suggests that the presence of cul-de-sacs might be more important for males' physical activity than females. A study found that male adolescents living on cul-de-sacs recorded increases of 9 to 22 minutes of MVPA per day, compared to males living by "through roads"[98]. Cul-de-sacs likely present a safer environment for young people to play in, facilitated by lower volume and speed of traffic, close presence of children from other households and use of the closed end of the street for sport/games (i.e. football matches, baseball, etc...). Thus, there is emerging evidence that road safety is associated with physical activity but there is a lack of data from Mexico.

In terms of distance and accessibility to destinations, apart from contradictory findings regarding mixed-use land, findings from the literature seem to be consistent. A prospective study in Belgian adolescents found that a shorter distance to school (ß=0.164 (0.024), 95% CI=0.117 to 0.211) and the perception of connected streets (ß=0.116 (0.057), 95% CI=0.004 to 0.228) were associated with more minutes per day of active travel to and from school [99]. Contrarily, a study in United Kingdom found that children living in highly connected, short and direct routes were less likely to active commute[100]. A reason for this disparity might be

the cultural differences but also disparities in deprivation and traffic flow in the areas. A study in Belgium and studies in Nigeria and China have found that difficult access to recreational facilities is negatively associated with physical activity[97, 101, 102]. The presence of mixed-use land means that different types of buildings are present in a space (i.e. single buildings, residential houses, commercial, cultural, industrial places, etc.). The findings in the literature regarding mixed-use land are contradictory. A prospective study in Belgium found that mixed-use land was negatively associated with active travel to and from school in adolescents (ß=-0.112 (0.049), 95% CI=-0.208 to 0.016)[99], while another Belgian study found that high mixed-use land was associated with more active travel (ß=0.020 (0.011); $p<0.05$)[97]. Both studies used NEWS-Y for the assessment of mixed-use land so, perhaps the difference in the direction of the association lies in the purpose of active travel, the first study found a negative association with active travel to school; and the second study a positive association with active travel as a means of transportation. A possible reason for this might be that mix-land areas are more likely to have traffic during rush hours compared to residential areas, and traffic might discourage adolescents from active commuting to school. Moreover, residential density was found to be positively associated with leisure time MVPA[101]. Regarding walking infrastructure, the literature reports contradictory findings. Less infrastructure for walking was associated with more minutes per day of active travel to school (ß=-0.091 (0.045), 95% CI=-0.179 to -0.003)[99], while the opposite was found in Nigeria, where availability of walking infrastructure was positively associated with leisure-time MVPA (ß=0.14, 95% CI=0.49 to 2.68)[101]; in Portugal, adolescents with a positive perception of infrastructure for active travel were 44.2% more likely to be active (OR=1.44, 95% CI=1.05 to 1.98)[103], and in China were adolescents living in neighbourhoods without sidewalks were 1.3 times more likely to be inactive (95% CI:1.0 to 1.6)[102]. The authors contend that the negative association between infrastructure for walking and active travel to school might be because adolescents prefer to take routes that go through parks, back streets and recreation areas that in essence are not paved, in order to avoid busy city centres[99]. Thus, there is emerging evidence on the importance of accessibility to destinations being associated with physical activity in adolescents but again there is a lack of data from Mexico or other comparable Latin American countries.

Table 2-7 Perception of Pedestrian and Traffic Safety in Adolescents

Author	Sample	Objective	Assessment of Perception of Safety	Road Safety	Road Elements	Distance/Access to destinations	Mix Land Use	Walking infrastructure
Carver, Timperio, Crawford [96], (2008) **Australia**	13-15y n=346	Examine the associations between perceptions of neighbourhood safety and PA.	Questionnaire (agree – disagree)	**Females:** Perception of unsafety negatively associated with MVPA during the evening (-0.714, p=0.04) and outside school hours (-1.5, p=0.047)				
Carver, Timperio, Crawford [98] (2008) **Australia**	13-15y n=346	Examine the associations between objective measures of the local road environment and physical activity	Objective measure of road environment (Arcview GIS 3.3)		**Females** in neighbourhoods with traffic lights more likely to AC than females in neighbourhoods with fewer traffic lights (OR=2.7, 95% CI=1.2 to 6.2). **Males** living on a cul-de-sac more MVPA than males living in a "through road". Speed-humps, positively associated with MVPA. (OR=0.38, 95% CI=0.15-0.97)			
De Meester, Van Dyck, De Bourdeaudhuij, Deforche, Cardon [99] (2013) **Belgium**	13-15y n=637	Prospective study Investigate relationship between the perception of neighbourhood attributes and adolescents AT	NEWS-Y			Shorter distance to school, more AT to and from school (ß=0.164 (0.024), 95% CI=0.117 to 0.211). Connected streets, more AT to and from school (ß=0.116 (0.057), 95% CI=0.004 to 0.228)	Lower degree of land use mix diversity, more AT to and from school. (ß=-0.112 (0.049), 95% CI=-0.208 to 0.016)	Less walking infrastructure, more AT to and from school. (ß=-0.091 (0.045), 95% CI=-0.179 to -0.003)

Oliveira, Mota, Moreira, Vale, Abreu, Moreira, Santos [103] (2014) **Portugal**	15-18y n=948	Verify if PA behaviour is associated with environmental features.	Environmental Questionnaire developed by Evenson *et al*. [104]					Positive perception of transportation infrastructure, more likely to be classified as active. (OR=1.44, 95% CI=1.05 to 1.98).
Oyeyemi, Ishaku, Deforche, Oyeyemi, De Bourdeaudhuij, Van Dyck [101] (2014) **Nigeria**	12-19y n=1006	Assess the associations between perceived built environment and adolescents' PA.	PANES			**Males:** Access to destinations was positively associated with AT to school (ß=0.18, 95% CI=0.67 to 2.24)	Residential density positively associated with leisure-time MVPA (ß=0.10, 95% CI=0.01 to 1.74)	Availability of infrastructure (ß=0.14, 95% CI=0.49 to 2.68) positively associated with leisure-time MVPA
Deforche, Van Dyck, Verloigne, De Bourdeaudhuij [97] (2010) **Belgium**	n=1445	Determine if perceptions of the environment are associated with AT and leisure-time sports	NEWS	Higher perceived safety from traffic, more active transport (ß=0.104 (0.036); p<0.001)		Higher street connectivity (ß=0.023 (0.014); p<0.05) and difficult access to recreational facilities (ß=-0.020 (0.010); p<0.01) associated with more AT. Difficult access to recreational facilities (ß=-0.043 (0.026); p<0.05), were associated with more leisure-time sports.	Higher land use mix diversity associated with more AT (ß=0.020 (0.011); p<0.05).	
Li, Dibley, Sibbritt, Yan [102] (2004) **China**	13-18y n=1804	Cross-sectional	MICS from UNICEF			Difficult access to community recreational facilities (moderate OR=1.4, 95% CI=1.0 to 1.9; difficult OR=1.7, 95% CI:1.2-2.4) were associated to inactivity.		Adolescents living in neighbourhoods without sidewalks were 1.3 times more likely to be inactive (95% CI:1.0-1.6).

MICS: Multiple Indicator Cluster Surveys
UNICEF: United Nations Children's Fund
PANES: Physical Activity Neighbourhood Environment Survey

AC: Active Commuting
AT: Active Travel
PA: Physical activity

Regarding crime safety, there is not extensive literature available in adolescents and the one available is for the most part qualitative studies. The summary of the studies is in Table 2-8. Two quantitative studies in the United States found a positive association between neighbourhood safety and physical activity. The first study found that adolescents with low perception of neighbourhood safety had 21% reduced odds of being physically active, on five or more days, compared to adolescents who felt safe (OR=0.79, CI=0.56 to 0.89)[105]. The second study found that lower neighbourhood safety was positively associated with less physical activity (OR=0.5, 95% CI=0.3 to 0.8)[106]. The qualitative studies support these findings. Interviews with 25 Latino adolescents from the United States, who expressed greater fear of crime were the ones with less physical activity and outdoor recreation. Additionally, the perception of anti-social behaviour kept them from engaging in outdoor activities[107]. Furthermore, interviews with 22 Malaysian adolescents revealed that adolescents who felt unsafe also felt demotivated to be physically active[108]. On the other hand, four focus groups (n=8 per focus group) in Ecuador found that, more than adolescents expressing crime safety concerns, they referred more to their parents' safety concerns and how that influenced in them not being active in outdoor areas[109]. The role of parents in determining adolescents' exposure to favourable or unfavourable aspects has been reported before in quantitative studies[110, 111]. Adolescents are more physically active outdoors when parents perceive higher levels of safety[112].

Table 2-8 Perception of Crime Safety and Physical Activity in Adolescents.

Author	Sample	Objective	Assessment of Perception of Crime	Findings
Lenhart, Wiemken, Hanlon, Perkett, Patterson [105] (2017) USA	Adolescents	The association between perceived neighbourhood safety and levels of physical activity	YRBS	Low perception of neighbourhood safety has 21% reduced odds of being physically active on 5 or more days, compared to those who felt safe (OR = 0.79, CI = 0.56-0.89, p=0.04).
Molnar, Gortmaker, Bull, Buka [106] (2004) USA	Adolescents (11-16y) n=1,378	Associations between activity levels of urban adolescents and limited access to safe recreation areas in their neighbourhoods.	Own measure Five items, safe/unsafe answers	Lower neighbourhood safety was associated with less activity (OR=0.5, 95% CI=0.3 to 0.8).
Shinew, Stodolska, Roman, Yahner [107] (2013) USA	Adolescents (Latino) n=25	Examine how fear of crime, crime victimization and incivilities are related to physical activity participation.	Interview	-Greater fear of crime, less PA and outdoor recreation. -Perceived incivilities engaged in less outdoor recreation.
Saimon, Choo, Bulgiba [108] (2015) Malaysia	Adolescents n=22	Understand factors influencing physical activity	Interview	-Feeling unsafe outdoors demotivates for being physically active.
Van Royen[109] (2015) Ecuador	Adolescents n=32 in 4 focus groups	Develop a conceptual framework through identifying context-specific factors.	Focus groups	-Some mentions of crime safety concerns but referred more to their parents' concerns.

2.5 Summary of Literature

The most recent health survey in Mexico has shown that most adults and adolescents (82.6 and 77.3%, respectively) meet the WHO's physical activity guidelines, although the survey's authors recognise the possibility of the data being overreported by 34% due to its self-reported nature, as the data also shows that 8 in 10 adults and 7 in 10 adolescents spend more than 16 hours per week on leisure screen time. As a number of studies have shown that adolescents who are active are more likely to be active as adults, and adolescents who are inactive are at an increased risk of obesity, which is also very high in Mexico, there is an urgent need to increase physical activity and reduce sedentary time among Mexican adolescents. Although a number of different strategies to promote physical activity are

currently underway in Mexico, the evidence base to inform these approaches is limited. In order to develop new, scalable, population level interventions to change behaviour we need to understand the key factors that are associated with physical activity. Current literature in this area is dominated by individual level studies (which have reported limited effects) and have not taken Mexican context into account. A key issue in Mexico is the current levels of urbanisation and how it is associated with adolescent physical activity. International evidence suggests that urbanisation is likely to be important but there is a lack of Mexican data nor any study that has assessed broader aspects of the ecological model such as perception of safety. Urbanicity scales exist to account for elements of the urban environment and give a sense of the urbanisation of a place. Research in other countries has shown that urbanicity as a whole is negatively associated with non-communicable risk factors, but its association with physical activity has not been explored in depth in Mexico. Moreover, the association of the elements of urbanicity with physical activity have never been addressed before. Perception of safety is an element of urbanisation that is not currently considered within the urbanicity scale and has not been studied in Mexico notwithstanding the high rates of crime and traffic unsafety. Several studies have found a positive association between elements related to pedestrian and traffic safety and physical activity but research regarding crime safety is not as broad and still needs to be explored. Thus, the main aim of this thesis is to examine how urbanisation and safety are associated with adult and adolescent physical activity in Mexico as a mean of filling key gaps in current knowledge. The next chapter outlines how the current thesis will address these issues, the research questions and structure of the thesis.

Chapter 3
Research Questions and Structure of the Thesis

The aim of this thesis is to investigate the association between urbanisation and physical activity in Mexico. The overall aim has been broken down into three quantitative studies which address the following research questions:

1. Is there an association between physical activity, sitting time and urbanicity in an adult population in Mexico?
    a. Is it possible to use a validated score to measure urbanicity in Mexico?
2. What are the associations between different types of physical activity and urbanicity among adolescents in Mexico?
    a. Is it possible to use a composite urbanicity score with local-level data in Mexico?
    b. Is there a difference on associations between males and females?
3. Is there an association between perception of safety and adolescents' physical activity?
    a. Do existing questionnaires, translated to Spanish assessing perceptions of safety demonstrate construct validity amongst Mexican adolescents?
    b. Is the perception of pedestrian and traffic safety associated with physical activity in adolescents?
    c. Is the perception of crime safety associated with physical activity in adolescents?
    d. Is there any difference of perception of safety between males and females?

3.1 Structure of the Thesis

This section provides an overview of the structure of the thesis and the implications of the studies and corresponding chapters used to address the research questions. Figure 3-1 shows how Chapters 4, 6 and 7 correspond to individual quantitative studies, in which their background, results, discussion and implication for the thesis are discussed in each chapter. Chapter 5 is a fully detailed Methods section for Chapters 6 and 7. Chapter 8 is the Discussion in which the findings from the results and discussions in Chapters 4, 6 and 7 are synthesised and the strengths and limitations of the overall thesis and conclusions are

considered. To facilitate the understanding of the structure of the thesis, an overview and implications for the thesis sections are explained as follows.

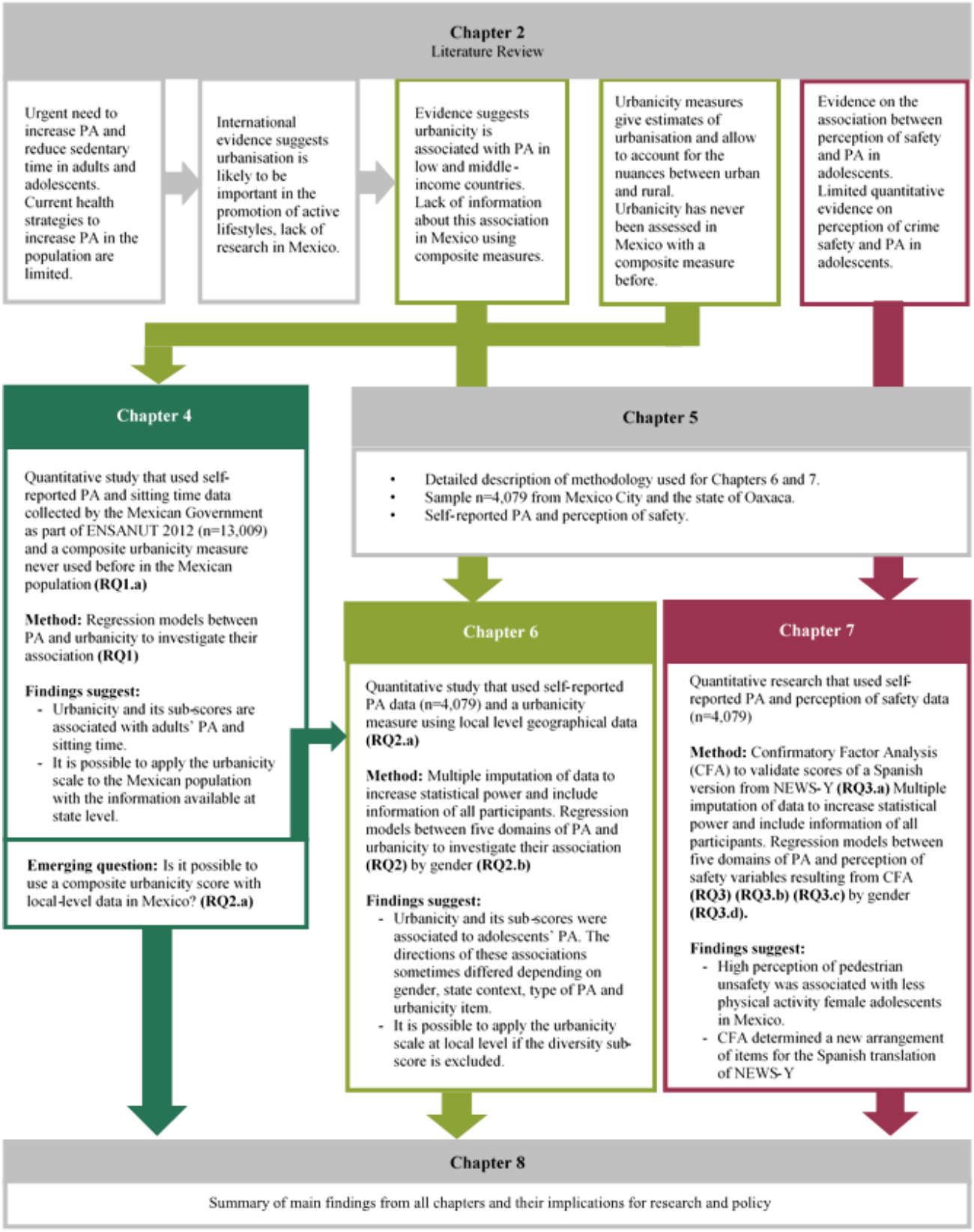


Figure 3-1 Structure of the Thesis

3.2 Overview of Chapter 4

This chapter addresses the first key research question of the thesis: Is there an association between physical activity, sitting time and urbanicity in an adult population in Mexico? A quantitative study was conducted using self-reported physical activity and sitting time data collected by the Mexican Government in 2012, as part of the National Health and Nutrition Survey (ENSANUT, for its initials in Spanish), and a composite measure of urbanicity based on the scale developed by Novak, Allender, Scarborough, West [77].

The content of this chapter was published as a peer reviewed article ***(Hermosillo-Gallardo ME, Jago R, Sebire SJ. The Associations Between Urbanicity and Physical Activity and Sitting Time in Mexico. Journal of Physical Activity & Health. Mar 2017;14(3):189-194.)*** in the Journal of Physical Activity and Health in 2017 and is presented in this format after a brief introductory section. The chapter outlines previous research within this area and the rationale of conducting this study, followed by the methods used and analysis process. The results are presented along three tables that present the descriptive statistics of the study and all the studied associations. The results are then discussed in relation to the existing literature, followed by a section of the study implications to the overall thesis.

The findings of this chapter show that urbanicity and its sub-scores are associated with adults' physical activity and sitting time. Even though the associations were generally small between physical activity and state-level urbanicity, it is important to recognize that in sedentary adults these associations might be important at population level. A detailed summary of findings is found in Chapter 4, section 4.4. In addition, the findings reported in this chapter raise the question of a possible inadequacy of the urbanicity score at state level when having individual measures of physical activity. Having this disparity in measurement might fail to account for individual-level detail in terms of immediate urbanicity (environment) in which participants live.

3.3 Overview of Chapter 5

This chapter describes in detail the methodology used for studies in Chapters 6 and 7 which address research questions 2 and 3. It starts with the study design of both studies, describing the recruitment of schools and participants, the questionnaire used and gives a rationale for using the Youth and Physical Activity Questionnaire over other self-reported measures of physical activity and some items of the Neighbourhood and Environmental Walkability Scale for measuring the perception of safety. Moreover, Confirmatory Factor Analysis to test the construct validity assessment of the Spanish translation of specific sections of the Neighbourhood and Environmental Walkability Scale in a sample of Mexican adolescents is reported. The chapter also addresses the handling of missing data in Chapters 6 & 7.

3.4 Overview of Chapter 6

This chapter addresses the second research question: What are the associations between different types of physical activity and urbanicity among adolescents in Mexico? The quantitative research designed to answer this question involved data collection in Mexico (Mexico City & Oaxaca) due to insufficient public information of physical activity on adolescents. Also, unlike the study in Chapter 4, urbanicity was computed using local-level data, making it possible to give each participant a unique urbanicity score depending on their household location.

The content of this chapter is under second revision at PLOS One and is presented as such, after a brief introductory section and with an abbreviated version of the methods which have been fully explained in Chapter 5. Chapter 6 reviews previous research in urbanicity and adolescents and the rationale of the study, followed by an abbreviated version of the methodology, results and discussion. It includes tables for the descriptive statistics of the participants by gender and state (Mexico City, Oaxaca) and tables of the linear regression models are included within the results. The chapter finalises with a section of study implications to the overall thesis.

The findings from Chapter 6 show that the items composing urbanicity were differently associated with physical activity. In some cases, the direction of the association depended on participants' gender or the state context, and in other cases on the type of physical activity and the urbanicity item. These more nuanced associations highlight the value of examining urbanicity as a multidimensional construct. Moreover, the associations found in this chapter are different from the associations found in Chapter 4 with adults, suggesting that adults and adolescents may be influenced differently by their urban environment.

3.5 Overview of Chapter 7

This chapter addresses the third research question: Is there an association between perception of safety and adolescents' physical activity? The quantitative research designed to answer these questions used the same sample of adolescents from Chapter 6. Perception of safety was measured through the subscales of perception of pedestrian and traffic safety, and perception of crime safety from the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y). The chapter summarizes previous research within the area and provides rationale for the study, followed by an abbreviated methods section and continues to outline the results, including tables for the CFA factor loadings, descriptive statistics of participants and the regression models; finishing with a discussion section and implications for the thesis.

A summary of the results of this chapter can be found in Chapter 7, section 7.4. Briefly, pedestrian safety was negatively associated with physical activity in female adolescents, this coincides with the belief that environments with better lighting, appropriate crosswalk and walking and cycling trails might increase physical activity in adolescents. In addition, the study provides evidence for the validity of perception of safety in Mexican adolescents, based on the subscales of NEWS-Y. The findings of this chapter contribute to improve the understanding of adolescents' perception of safety, its measurement and how this might be affecting their physical activity.

3.6 Role of the PhD candidate

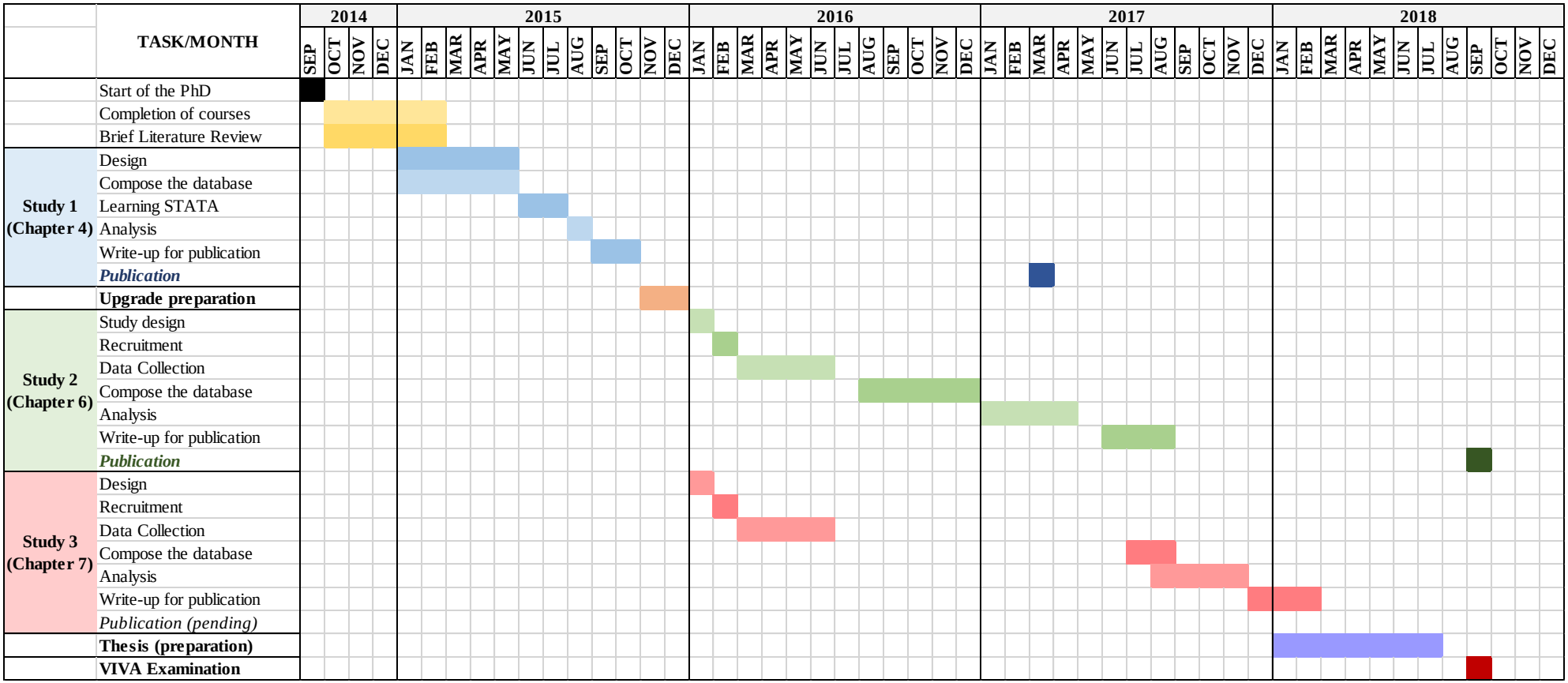
This section summarises the activities carried out during the PhD and reviews the work of the PhD candidate throughout each study. Table 3-1 shows the role of the PhD candidate on studies corresponding to Chapters 4, 6 and 7 on this thesis. In the first study (Chapter 4), the student was responsible for the study design, selection of methods, ethics application, analysis of data and writing the original draft. The student was not involved in the recruitment of participants, data collection or project administration, as the data was obtained from different government databases. In the second and third studies (Chapters 6 and 7), the student was responsible for all the roles described in Table 3-1.

Table 3-1 Role of the PhD candidate across each study

Role/Study	Study 1 (Chapter 4)	Study 2 (Chapter 6)	Study 3 (Chapter 3)
Study design	✓	✓	✓
Methodology	✓	✓	✓
Ethics application	✓	✓	✓
Recruitment of schools and participants		✓	✓
Data Collection		✓	✓
Project administration		✓	✓
Analysis and Software	✓	✓	✓
Writing original draft	✓	✓	✓

The timeline of activities during the PhD is shown in Table 3-2. The initial task and completion of courses, description of activities within each study and duration of tasks and the month of publication of each are displayed. Please note that the publication of the third study is pending.

Table 3-2 Timeline of activities and studies across the PhD



Chapter 4
The Associations between Urbanicity and Physical Activity and Sitting Time in Mexico

4.1 Overview

The work presented in this chapter has been published in the Journal of Physical activity and Health, and, except from this overview and the implications sections at the end, it is as per the published article. ***"The Associations between Urbanicity and Physical Activity and Sitting Time in Mexico"*** answers the Research Question 1 of this thesis: Is there an association between physical activity, sitting time and urbanicity in an adult population in Mexico? Findings from this study provide an insight of the association between urbanicity and its components and physical activity in adults. The rationale, methods, results, discussion are presented below, concluding with a brief section of implications of the findings for this thesis.

4.2 Rationale

Low levels of physical activity are a current global public health issue[113]. Along with prolonged bouts of sitting, low physical activity is associated with an increase in the risk of noncommunicable diseases such as overweight and obesity[114]. In the National Survey of Health and Nutrition in Mexico, 17.4% of people self-reported physical activity levels below the WHO's guidelines (150 minutes of moderate-intensity physical activity (MPA) or 75 minutes of vigorous-intensity physical activity (VPA) per week)[10] and 82.6% spent an average of 260 minutes of MPA or 118 minutes of VPA per week and 3.5 hours per day sitting in front of a screen[5]. In the quarterly survey from the Module of Sport and Physical Activity (MOPRADEF by its initials in Spanish) in Mexico, 54.6% of people reported low levels of physical activity, 27.5% reported having never been involved in any regular physical activity and 43.8% of people who consider themselves as "active" did not meet the WHO's guidelines[46]. Several attempts have been made by the Mexican government to increase physical activity[53], but there is lack of information about the key factors that are

associated with physical activity in Mexico. Previous research has studied the association between physical activity and different aspects of urbanization (e.g., urbanicity, built environment, urban sprawl). Urbanicity in defined as "the impact of living in urban areas at a given point in time... the presence of conditions that are particular to urban areas or present to a much greater extent than in non-urban areas"[72]. Urbanicity has been estimated in a variety of ways including rural-urban dichotomy, population size and population density[75]. More recently, tools have been developed to provide a more comprehensive measurement of urbanicity, incorporating variables such as economic activity, communications, education, infrastructure and social services [7, 76, 77]. Features of the built environment such as the perceived proximity to shops and recreational facilities, street connectivity, and aesthetic qualities of a place are positively associated with physical activity[115, 116]. A number of studies have also suggested that areas in which buildings are within close proximity to one another, and that facilitate walking between locations, are associated with greater physical activity[117].

Existing evidence suggests that the association between urbanicity and physical activity may differ in developing and non-developing countries. In developed countries, a positive association between physical activity and urbanicity has been found. For example, a cross-sectional study in Belgium found a positive relationship between adults' physical activity and environmental variables (quality of sidewalks, accessibility to public spaces, public transport, activity facilities outside home)[118], while a study in United States found that adolescents living in urban areas reported more minutes of moderate-to-vigorous physical activity per day than adolescents living in rural areas[119]. In contrast, cross-sectional studies in Sri Lanka, India and Uganda have found a negative association between urbanicity and physical activity[6, 7, 87]. Another example of the association between physical activity an urbanicity in China, in which the rapid urbanization from the last 6 years has been associated with 68% greater odds in men and 51% greater odds in women of having light (less active) versus heavy (more active) occupational activity[120]. Mexico is a developing country with extensive variation in urbanicity, from rural communities in Chiapas and Guerrero to urban cities such as Mexico City and Monterrey. Even though to the best of our knowledge no previous research has examined the association between urbanicity and physical activity in Mexico. Evidence in Mexico suggest that high residential density and street connectivity (measured as intersection density or few cul-de-sacs) represent a barrier[121, 122] for physical activity and that the combination of mixed land use with residential density is negatively associated with all

physical activities[123]. The aims of this study is to measure urbanicity in Mexico and assess its associations with physical activity (walking time, MPA and VPA) and sitting time.

4.3 Methods

The data for this paper were obtained in 2014 from multiple datasets to provide a national picture of physical activity and urbanicity in Mexico. Data from the National Institute of Statistics and Geography (INEGI)[1], the Public Education Department (SEP)[124], and the National Council of Politics and Social Development (CONEVAL)[125] were used to calculate state-level (n = 32 states) urbanicity scores based on previous work by Novak et al (2012) and were then merged by locality with physical activity data from the National Health and Nutrition Survey 2012 (ENSANUT)[5]. The anonymised data sets are publicly available from the webpage http://ensanut.isnp.mx/basesdoctos.php. Participants provided informed consent. To verify data quality, random checks of scanned questionnaires from ENSANUT with the corresponding cases in the database were performed to see if the information captured in the excel file was the same as the printed version questionnaires. Also, for computing the urbanicity measure, methods and procedures were documented.

4.3.1 Study Population

The study population was determined by those individuals with physical activity and sitting time variables in the ENSANUT (2012) survey. The ENSANUT survey was collected between October 2011 and May 2012, it is representative at state and national level. Fifty thousand and five households were selected from all the states in Mexico using data from the CENSUS 2010, resulting in 96,031 participants, from which a subsample (n = 13,009) of 5459 men and 7550 women aged 20 to 69 self-reported their physical activity. Participants had complete data for MPA, VPA, walking and sitting time. Other variables such as self-reported weight (Kg), height (m), calculated BMI (Kg/m^2), educational level and socioeconomic status were also reported.

4.3.2 Assessment of Physical Activity

The variables of MPA (minutes per week), VPA (minutes per week), walking time (minutes per week) and sitting time (minutes per week) were derived from the short form of the International Physical Activity Questionnaire (IPAQ)[126]. The outcome variables were analysed as continuous and were processed according to the Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ)-Short Form[127]. The short form of the IPAQ has a moderate reliability ($r = .55$, $P<.001$) and weak validity ($r = .26$, $r = .31$, $P<.01$) for assessing moderate and vigorous physical activity among Mexican adults[128].

4.3.3 Assessment of Urbanicity Level

Urbanicity scores were estimated for the 32 Mexican states using the measure developed by Novak et al. (2012) and data from the CENSUS 2010, the Public Education Department, and the National Council of Politics and Social Development in Mexico. The overall scores comprised seven categories: (1) demographic (either based on population size or on population density), (2) economic activity (percentage of people involved in agriculture as a primary source of income), (3) built environment (amount of blocks with paved roads, households with sewage services and flush toilet), (4) communication (percentage of households with television, mobile phone, internet and blocks with pay phones in all their roads), (5) education (amount of preschools, elementary schools, secondary schools, universities and average of women's education), (6) diversity (households with floor made of ground and inhabitants per room), and (7) health (number of doctors per inhabitant, amount of medical units and access to health services)[77]. For each participant, an urbanicity score was given according to their state. Two overall urbanicity indices were computed by summing the seven sub-scores where the Demographic sub-score was measured as population size (Overall urbanicity 1) and as population density (Overall urbanicity 2). The rationale for doing this is that in Mexico there are large rural areas that would have a similar population size compared to small urban cities, suggesting that for Mexico, population density might be a better indicator of urbanicity. More detailed information on how the sub-scores were computed can be found as Appendix A.

4.3.4 Statistical Analysis

Statistical analyses were performed using STATA, Version 13 (Statacorp, College Station, TX). Datasets of physical activity and urbanicity were merged according to locality of each participant. Descriptive statistics were calculated for all variables. Linear regression models were used to examine the association between physical activity (outcome) and urbanicity (exposure). Sixteen models were run with MPA, VPA, walking time, and sitting time as outcomes. For each of the 4 outcomes there were 4 separate models. In the first group (Group I) there were simple and multi-variable models where demographic was measured as population size. In the second group (Group II) 2 further models were run (simple and multivariable) where demographic was measured as population density. All models were adjusted for participant sex, education level, socioeconomic status and BMI and were checked for multicollinearity using the variance inflation factor. Although there was some evidence that the outcome variables were skewed, further analysis indicated that the residuals from all models were normal and as such all analyses presented include the original variables without transformation.

In the current analysis, the different levels of data were state level urbanicity and individual physical activity and, as mentioned before, they were analysed using linear regression models. A different approach for the analysis of the data would have been through multilevel analysis. Multilevel analysis allows for different regression coefficients for each predictor in each location. For example, if a categorical variable to account for state (1 to 32) on top of state level urbanicity and individual physical activity is added, a multilevel approach would assume that the effect of urbanicity is not the same everywhere because of differences of other factors (i.e. local laws, culture, economy) between states. This means that people from a given state would have physical activity data generated by a single set of urbanicity sub-scores, whereas people from another state would have physical activity data generated by a different set of urbanicity sub-scores. This analysis would be useful in future research to account for interactions between the different levels and the individual, but for the aim of this study, a linear regression works better to initially understand the unstudied association between urbanicity and physical activity in Mexico.

4.4 Results

Descriptive statistics are presented in Table 4-1 and Table 4-2. The mean age (±SD) of participants in 2012 was 41.26 ± 13.53 years, with a mean BMI of 28.79 ± 5.71 (Kg/m^2), an educational level in which 23.88% of the participants (n = 7091) had elementary studies or lower, 50.30% lower secondary studies and 34.23% upper secondary studies; and a socioeconomic status in which 30.40% of participants reported low socioeconomic status, 35.37% medium and 34.23% high. Participants reported an average of 255.21 ± 316.78 minutes per week of MPA, 117.55 ± 260.98 minutes per week of VPA, 214.20 ± 257.22 minutes per week of walking and 1470 ± 1132.98 minutes per week of sitting time. The mean variance inflation factor for the multivariable regressions was 1.74 for the regressions from Group I and 2.05 for the regressions from Group II, and the tolerance greater than 0.1, meaning that the urbanicity sub-scores are moderately correlated.

Table 4-1 Descriptive Statistics of Participant Physical Activity and Sitting Time

Education level	**n = 7,091**			**%**	
Elementary studies or lower	1552			21.89	
Lower secondary studies	3425			48.30	
Upper secondary studies	2114			29.81	
Socio-economic status	**n = 7,091**			**%**	
Low	2156			30.40	
Medium	2508			35.37	
High	2427			34.23	
BMI (Kg/m^2)	**n = 6,837**			**%**	
Underweight	123			1.80	
Normal weight	3596			52.60	
Overweight	2427			35.50	
Obesity	691			10.10	
Physical Activity	**Mean**	**SD**	**Range**	**Median**	**IQR**
Moderate physical activity (n = 6946) *minutes per week*	255.21	316.78	(0-1155)	198.32	142.12-288.36
Vigorous physical activity (n = 6948) *minutes per week*	117.55	260.98	(0-1200)	96.11	88.36-134.72
Walking time (n = 6945) *minutes per week*	214.20	257.22	(0-1155)	132.12	99.24-314.61
Sitting time (n = 6904) *minutes per week*	1470.00	1132.98	(0-6720)	934.71	651.57-1636.15

Table 4-2 Descriptive statistics of urbanicity variables in Mexican states (n = 32)

	Mean	SD	Range	Median	IQR
Demographic 1[a d]	9.89	0.50	(5-10)	9.02	8.93-9.92
Demographic 2[b d]	6.42	2.99	(1-10)	6.13	6.05-6.56
Economic Activity[d]	9.53	1.11	(2-10)	9.32	9.12-9.63
Built Environment[d]	8.91	0.87	(3.36-9.98)	8.82	8.77-9.01
Communication[d]	4.41	1.03	(0.64-8.77)	4.22	4.01-4.56
Education[d]	5.54	1.39	(3.42-9.53)	5.32	5.14-5.69
Diversity[d]	8.95	1.04	(4-10)	8.72	8.55-9.10
Health[d]	4.84	0.60	(2.08-7.93)	4.80	4.75-4.86
Overall 1[a c]	52.10	4.58	(33.22-65.29)	51.95	51.87-52.19
Overall 2[b c]	48.63	6.54	(25.22-65.29)	48.52	48.47-48.79

[a] Based on population size.
[b] Based on population density.
[c] Overall scores can range from 0 to 70.
[d] Sub-scores can range from 1 to 10.

Models in Group I are shown in Table 4-3. In the simple linear regression models, for every unit increase of overall urbanicity (when measured as population size) there was a mean decrease of 2.08 minutes per week of MPA (95% CI = -3.90 to -0.27), a decrease of 3.60 minutes per week of VPA (95% CI = -5.03 to -2.17), and an increase of 14.38 minutes per week of sitting time (95% CI = 8.18 to 20.58). In the multivariable linear regressions, a negative association was found between the demographic and communication sub-scores and MPA; meaning that a 1 unit increase in demographic urbanicity was associated with 17.10 (95% CI = -32.57 to -1.63) and 12.61 minutes less MPA per week (95% CI = -25.30 to -0.07). VPA was negatively associated with the economic (coef = -10.58, 95% CI = -17.07 to -4.09) and communication (coef = -11.43, 95% CI = -21.43 to -1.44) sub-scores; and positively associated with the built environment sub-score (coef = 12.35, 95% CI = 2.93 to 21.77), meaning that for every unit increase in the built environment sub-score there is an increase of 12.35 minutes of VPA per week. For walking, a unit increase in the demographic sub-score was associated with 14.48 fewer minutes of walking per week (95% CI = -26.99 to -1.97) and a similar result was found for the diversity sub-score where a unit increase was associated with 11.95 minutes less waling per week (95% CI = -20.31 to -3.59). In contrast, education had a positive association with walking where for each unit increase of the education there was an increase of 6.91 minutes per week of walking (95% CI = 1.48 to 12.33). Regarding sitting time, per every unit increase of the health sub-score there was an increase of 48.52 minutes per week of sitting time.

Table 4-3 Group I of linear regression models: Associations between urbanicity, physical activity and sitting time where demographic is measured as population size.

Linear regression [a]	**Score/sub-score**	**MPA**[b] **(n=6946)**				**VPA**[b] **(n=6948)**				**WALKING TIME (n=6945)**				**SITTING TIME (n=6904)**			
		min per week				min per week				min per week				minutes per week			
		Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|
Simple	Overall urbanicity 1	-2.08	-3.90	-0.27	0.02	-3.60	-5.03	-2.17	0.00	-0.04	-1.51	1.42	0.95	14.38	8.18	20.58	0.00
Multivariable	Demographic	-17.10	-32.57	-1.63	0.03	-11.09	-23.28	1.09	0.07	-14.48	-26.99	-1.97	0.02	24.69	-28.00	77.4	0.35
	Economic Activity	3.37	-4.86	11.60	0.42	-10.58	-17.07	-4.09	0.00	-5.86	-12.52	0.79	0.08	26.77	-1.36	54.92	0.06
	Built Environment	5.48	-6.47	17.43	0.36	12.35	2.93	21.77	0.01	4.89	-4.77	14.56	0.32	36.16	-4.67	77.01	0.08
	Education	3.14	-3.56	9.85	0.35	-2.21	-7.50	3.06	0.41	6.91	1.48	12.33	0.01	16.34	-6.54	39.22	0.16
	Health	8.97	-4.87	22.82	0.20	6.57	-4.32	17.48	0.23	10.50	-0.70	21.70	0.06	48.52	1.34	95.71	0.04
	Diversity	-9.22	-19.55	1.11	0.08	-4.87	-13.02	3.27	0.24	-11.95	-20.31	-3.59	0.00	26.31	-8.96	61.58	0.14
	Communication	-12.61	-25.30	0.07	0.05	-11.43	-21.43	-1.44	0.02	3.4	-6.86	13.68	0.51	-38.61	-81.93	4.71	0.08

[a] Simple linear regression models: Overall urbanicity, demographic score measured as population size. Multivariable linear regression models: Seven-urbanicity sub-scores (demographic score measured as population size).
[b] MPA: Moderate physical activity, VPA: Vigorous physical activity.
[c] All associations adjusted for socioeconomic status, education level and BMI.

In the multiple linear regression in Group II (Table 4-4), for every unit increase of overall of urbanicity (measured as population density) there was a mean decrease of 1.44 minutes per week of MPA (95% CI = -2.71 to -0.17), a mean decrease of 2.31 minutes per week of VPA (95% CI = -3.31 to -1.32) and a mean increase of 10.42 minutes per week of sitting time. In the multivariable linear regressions from the same group, communication was negatively associated with MPA, meaning that a unit increase of the communication urbanicity was associated with 14.10 (95% CI = -26.66 to -1.53) minutes less of MPA per week. Regarding VPA, the economic and communication sub-scores were associated with 10.60 (95% CI = -17.10 to -4.11) and 12.40 (95% CI = -22.29 to -2.51) minutes less per week respectively. The built environment sub-score was positively related to VPA (coef = 14.57, 95% CI = 4.70 to 24.80). Walking was negatively associated with the diversity sub-score, meaning that a unit increase of diversity was associated with 11.20 minutes less walking time per week (95% CI = -19.60 to -2.81). Sitting time was positively associated with demographic urbanicity (coef = 17.23, 95% CI = 4.18 to 30.28) and health related urbanicity (coef = 69.32, 95% CI = 19.95 to 118.70).

Table 4-4 Group II of linear regression models: Associations between urbanicity, physical activity and sitting time where demographic is measured as population density.

Linear regression [a]	**Score/sub-score**	**MPA[b] (n=6946)**				**VPA[b] (n=6948)**				**WALKING TIME (n=6945)**				**SITTING TIME (n=6904)**			
		min per week				min per week				min per week				minutes per week			
		Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|	Coef.	[95% Conf. Interval]		P>|t|
Simple	Overall urbanicity 2	-1.44	-2.71	-0.17	0.02	-2.31	-3.31	-1.32	0.00	0.53	-0.49	1.56	0.30	10.42	6.10	14.74	0.00
Multivariable	Demographic	-3.29	-7.13	0.53	0.09	-2.09	-5.11	0.92	0.17	1.60	-1.49	4.69	0.31	17.23	4.18	30.28	0.01
	Economic Activity	3.34	-4.89	11.58	0.42	-10.6	-17.10	-4.11	0.00	-5.54	-12.20	1.12	0.10	27.95	-0.19	56.10	0.05
	Built Environment	9.27	-3.48	22.03	0.15	14.75	4.70	24.80	0.00	3.01	-7.30	13.33	0.56	16.18	-27.37	59.74	0.46
	Education	6.38	-1.63	14.40	0.11	-0.17	-6.49	6.14	0.95	4.58	-1.90	11.06	0.16	-2.73	-30.06	24.60	0.84
	Health	4.40	-10.10	18.90	0.55	3.67	-7.74	15.08	0.52	11.61	-0.11	23.35	0.05	69.32	19.95	118.70	0.00
	Diversity	-9.67	-20.04	0.70	0.06	-5.15	-13.33	3.02	0.21	-11.20	-19.60	-2.81	0.00	30.07	-5.31	65.46	0.09
	Communication	-14.10	-26.66	-1.53	0.02	-12.40	-22.29	-2.51	0.01	1.18	-8.99	11.35	0.82	-39.20	-82.06	3.65	0.07

[a] Simple linear regression models: Overall urbanicity, demographic score measured as population density. Multivariable linear regression models: Seven-urbanicity sub-scores (demographic score measured as population density).
[b] MPA: Moderate physical activity, VPA: Vigorous physical activity.
[c] All associations adjusted for socioeconomic status, education level and BMI.

4.5 Discussion

The data presented in this paper show evidence of associations between some components of urbanicity and physical activity in Mexico but the magnitude of the majority of associations is relatively small. It is important to recognize, however, that in sedentary adults these small differences may be important at the population level. Existing literature has reported an association between physical activity and urbanicity[115-117] but inconsistency in the measurement of urbanicity in these studies makes direct comparison of these findings difficult. The reason for studying disaggregated urbanicity indicators is that a composite urbanicity score might be masking associations between components of urbanicity and physical activity variables and sitting time.

Previous research suggests a positive association between certain features of the built environment (eg, presence of sidewalks, availability of recreational infrastructure, walking/cycling routes) and physical activity. A literature review of the influence of physical environment in children's physical activity found a positive relationship between the presence of sidewalks and controlled intersections with children's physical activity[129]. A literature review in adults found positive associations between several environmental features (eg, enjoyable sceneries, presence of sidewalks, adequate roads for cycling/walking, and public lighting among others) and physical activity[130]. In the current study, the build environment sub-score refers to the amount of paved roads per block, sewage services and availability of electricity in public areas, and as such, its positive association with VPA supports previous literature. The education sub-score was only positively related to 6.91 minutes of walking per week and not related to any other physical activity outcomes, unlike previous research that has found that access to recreational facilities and schools enhances physical activity[129]. This might be because the measurement of education is slightly related to the built environment features (amount of preschools, elementary schools, secondary schools, universities) which should be responsible of the positive associations with walking but not enough to be associated with the other physical activity values.

There was evidence of small negative associations between the physical activity variables and demographic, economic, diversity and communication-based urbanicity. A high score in the economic activity sub-score refers to a higher proportion of people not involved in agriculture, therefore the findings may indicate lower physical activity among people living in more urbanized areas who do not work in agriculture, therefore the findings may indicate lower physical activity among people living in more urbanized areas who do not work in agriculture, farming, or fishing for example. This is consistent with previous studies in developing countries in which people living in rural areas had higher levels of physical activity than those living in urban areas[131-133]. Diversity and communication sub-scores are closely related to household quality and availability of electricity and internet connection, characteristics that are more frequent in urbanized environments.

Regarding sitting time, its positive association with the overall urbanicity and the demographic sub-score is consistent with previous research. Sitting time spent in TV viewing, in the workplace and in transport are among the main determinants of adults' sedentary behaviour and are more closely related to urban lifestyles[134]. Moreover, people in jobs requiring manual labour are more likely to spend less time sitting that people enrolled in office jobs[135]. The biggest association with sitting time was health based urbanicity. The health sub-score measures the amount of doctors, medical units and access to health services which are more likely to be in urban areas than in rural communities. In the results, the mean health score was 4.8, meaning that there are still a lot of opportunities for it increase as development continues. This could mean that health access is a key urbanicity indicator as it is so fundamental to communities. Supporting this idea, the correlation between the health sub-score and the overall urbanicity is 0.47, which indicates a medium correlation between the variables.

4.5.1 Strengths and Limitations

Strengths of the study include the use of a large sample that is representative at state level in Mexico, the combination of different databases from the Government and a comprehensive measure of urbanicity. The identification of both positive and negative associations between the different components of urbanicity and physical activity suggest that there is merit in studying these disaggregated components to prevent the potential masking of associations

that may occur if only overall urbanicity is considered. Limitations include the possibility of over-estimates of self-reported physical activity and some research has questioned the reliability of the IPAQ in measuring physical activity in developing countries[136]. Moreover, studying state-level measures of urbanicity and individual measures of physical activity may fail to account for individual-level detail in terms of the immediate environment in which participants live. For example, the measure of urbanicity used could not capture more fine-grained features of the immediate environment that could be associated with people's physical activity in Mexico (e.g., street lighting, perception of safety, proximity to parks)[137, 138].

4.6 Conclusions

We identified generally small associations between physical activity and state-level urbanicity. The demographic, economic and communication features of urbanicity had a negative association with physical activity while the built environment and the presence of educational facilities had a positive relationship. Overall urbanicity was positively associated with sitting time and this is consistent with previous literature. The other urbanicity variables were no associated with physical activity or sitting, this may be due to limitations in measurement or reflective of a null association between these variables. Future research could focus on studying these associations using individual-level data on physical activity and local data on urbanicity.

4.6.1 Acknowledgments

Main author is funded by The National Council on Science and Technology of Mexico (CONACyT), fellow no. 218160.

4.7 Implications for the Thesis

Results of this study provide a better understanding of the role of urbanisation in the Ecological Model of Active Living[70]. The opposite direction of associations between components of urbanicity and physical activity (positive association: built environment, educational facilities; negative association: size/density, economic activity, availability of

communication services) give an insight on how complex urbanicity can be and highlight the need for composite urbanicity measures instead of dual ones (urban vs. rural). Moreover, this chapter confirmed that is possible to compute the urbanicity measure at state level with the information publicly available from government sources, this being critical for the methodology of the study in Chapter 6. Finally, this chapter highlights that an urbanicity score calculated using state level data may not be accurate enough for portraying the immediate environment of a person. As such more local-level data is likely to be needed to provide a better understanding of the individual's environment and this will be discussed and developed in Chapter 6.

Chapter 5
Detailed Methods for studies reported in Chapters 6 & 7

5.1 Study Design

From the little research concerning urbanisation and physical activity in the world, the great majority is on adults. In Mexico no information exists about the association of urbanisation and physical activity on adolescents. The study of this association is essential to broaden the understanding of the correlates of adolescents' physical activity and improve the health strategies targeted to them. Due to all of the above, Chapters 6 and 7 focus on the adolescent population in Mexico and in this chapter, more detailed methods for the studies corresponding to these chapters are presented, adding greater detail to the methods reported in the peer-reviewed publications. Figure 5-1 shows the steps in sampling and recruitment, data collection and analysis. The figure also links with the sub-sections from this chapter that explain the assessment of the variables and the analysis performed.

Studies in Chapters 6 & 7 used data from a cross-sectional study which was collected in Mexico City and Oaxaca between February and June 2016. In Chapter 6, a study of the associations between different types of physical activity and urbanicity amongst adolescents in Mexico is reported, and in Chapter 7, the associations between adolescents' perception of safety and physical activity in Mexico is reported. In both chapters, adolescents' physical activity (outcome) was self-reported using the Youth Physical Activity Questionnaire (Y-PAQ). In Chapter 6, urbanicity (exposure) was objectively assessed using the urbanicity scale developed by Novak, Allender, Scarborough, West [77] applied to data from the National Population and Housing Census (2010)[139], the Council for the Evaluation of the Social Development Policy (CONEVAL)[125] and the Education Department[124]. In Chapter 7, Perception of Safety (exposure) was self-reported using the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y). Ethical approval was obtained by the University of Bristol's School for Policy Studies Research Ethics committee (Ref: SPSREC14-15.A55) (Appendix B) and written informed consent was obtained for all participants.

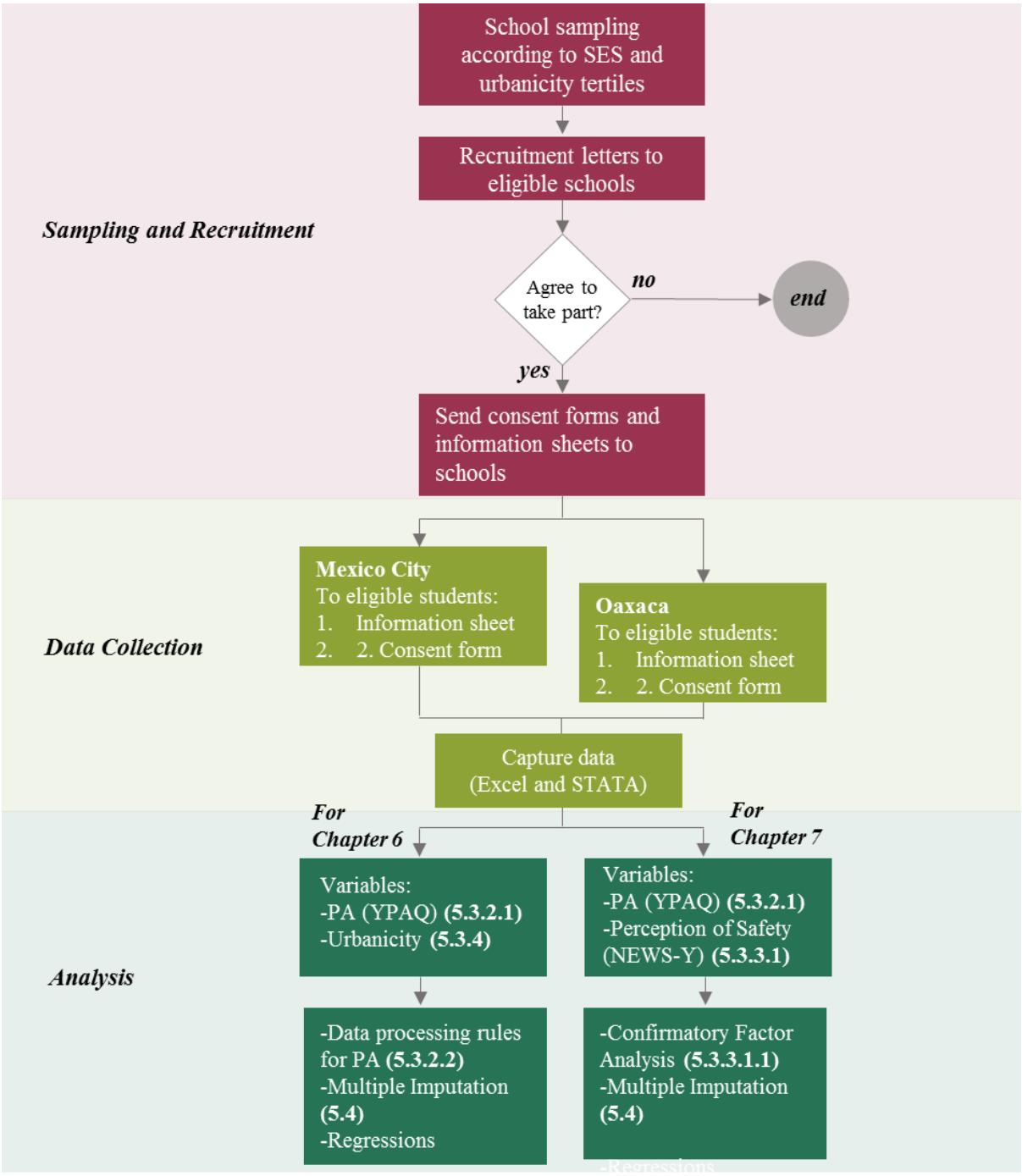


Figure 5-1 Flow diagram of methods for Chapter 6 and 7.

5.2 Recruitment of Schools & Participants

Mexico City and Oaxaca were chosen as the two sites for data collection as they provide variation in urbanicity (Mexico City: 58.16 vs Oaxaca: 39.70, on a zero to 70 scale using the urbanicity scale developed by Novak, Allender, Scarborough, West [77]). The map with the urbanicity scores for all the states in Mexico can be found in Appendix M. A list of state

schools in both states was provided by the Department of Education in Mexico and school sampling was stratified by socio-economic status (SES) and urbanicity level. Each municipality from both states was allocated to a SES tertile (low, medium or high) according to the National INEGI[1] and then each municipality in the SES categories was given an urbanicity level (low, medium, high) based on results from Chapter 4. Schools in municipalities were identified and fifteen schools from each SES-urbanicity combination were sampled, giving 1,440 potential schools for each state. From that list, 1,319 schools were eligible (with students between 15 and 18 years old), 517 were excluded for being in areas deemed unsafe for data collection, 637 for not having publicly available contact details, and 69 were not approached having met the recruitment stratification quota (Figure 5-2). An example of the recruitment letter sent to schools, the information sheet provided and the consent form can be found on Appendices C, D and E. Ninety-six schools were contacted; 79 did not reply, seven refused and 10 schools agreed to participate. Schools that refused to participate showed lack of interest in the study from their headmasters or were lacking personnel at that time due to teachers being on strike, or they lacked on sport facilities, gyms or recreational areas and they thought they were going to be "judged badly". Figure 5-3 shows the location of the schools which agreed to participate and the percentage of participants that contributed to the final total sample.

Data were collected from six schools from Mexico City (n participants = 1,918) and four schools from Oaxaca (n participants = 2,530). Participants were recruited within schools where the researcher gave all eligible (students between 15 and 18 years old) and present pupils an information sheet (Appendix F) and a consent form (Appendix G). From 4,448 eligible students, 4,079 completed the questionnaire on the day of data collection (recruitment rate: 91.70%). Students that did not want to participate were either feeling ill, were not allowed to take part due to bad behaviour or were falling behind with their studies and preferred to use that time to catch up with work.

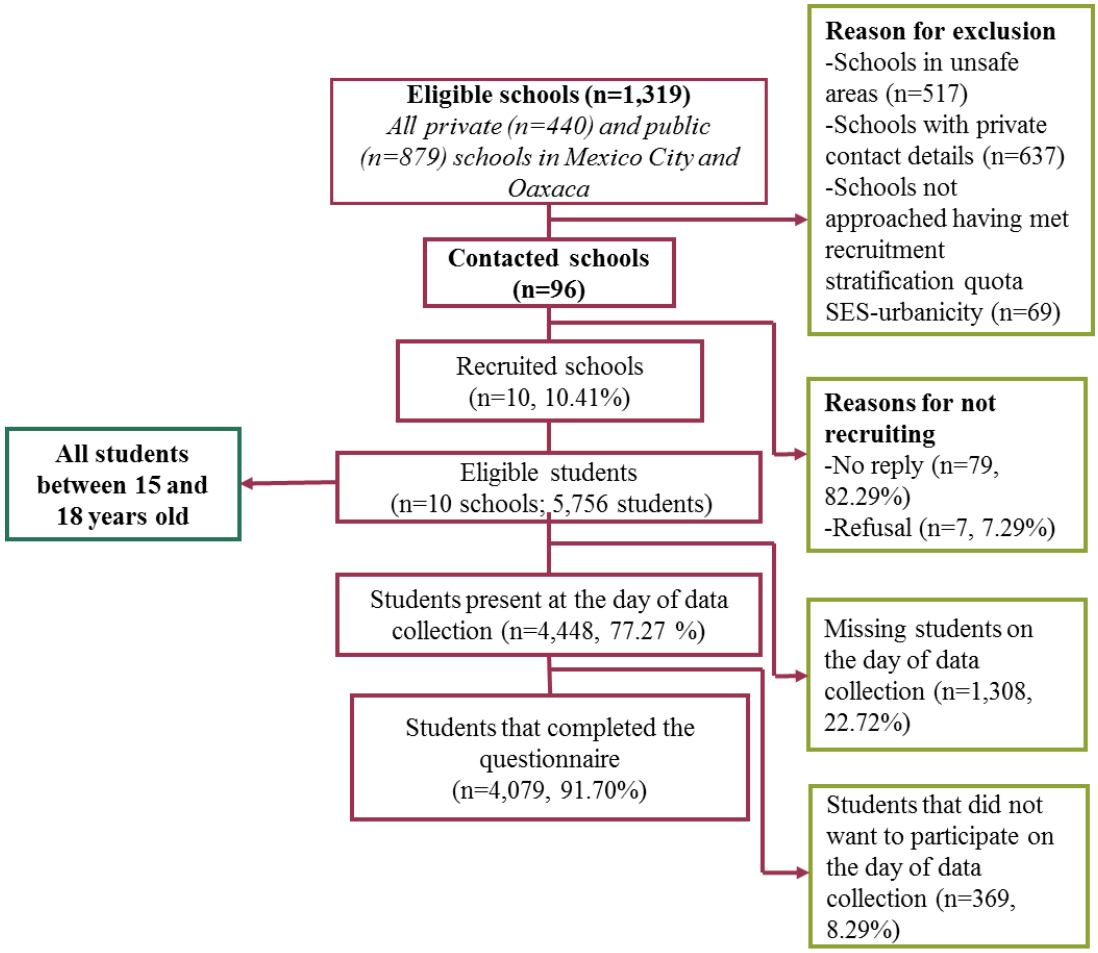


Figure 5-2 Eligibility Criteria

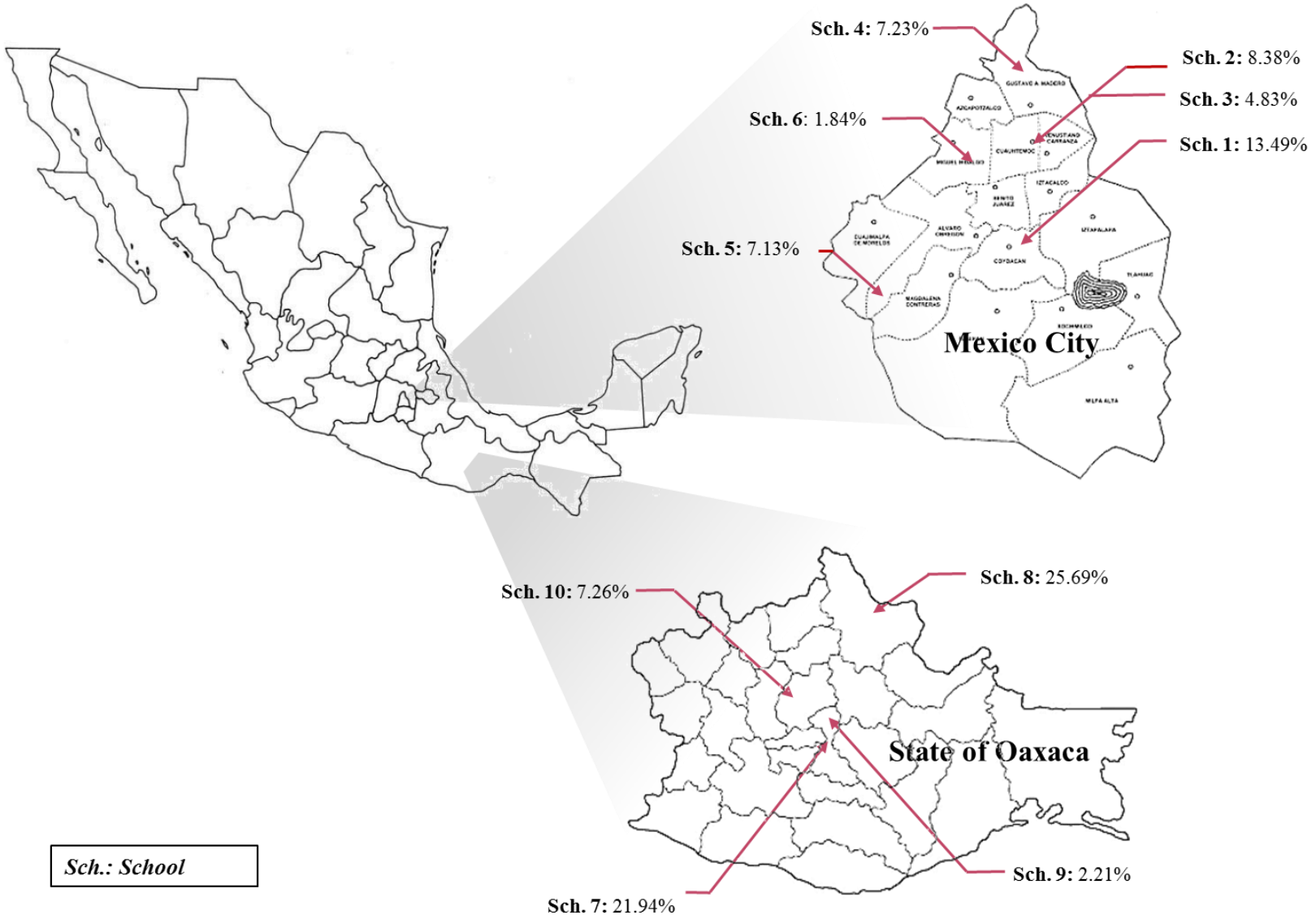


Figure 5-3 School sampling and percentage of participants per school (n=4,079)

5.3 Description of the questionnaire

Consenting participants were asked to complete the questionnaire which was in Spanish (English version in Appendix H) and comprised of eight sections: 1) Descriptive Information, 2) Getting Around in Your Neighbourhood, 3) Barriers to Walking and Cycling to School, 4) Places for Physical Activity Near Your Home, 5) Other Places for Physical Activity, 6) Proximity to Parks and Green Areas, 7) Your Physical Activity, 8) Your Free Time. Details of each section are outlined below.

5.3.1 Descriptive Information

This section measured descriptive information of the participants: gender (male/female), age, weight (kg) and height (cm); location information of participants' household (delegation, street name and post code), duration of residence (less than a year/between 1 and 3 years/between 4 and 10 years/between 10 and 15 years/all my life); and educational level of parents or guardians (primary school/secondary school/college/higher education [undergraduate]/postgraduate degree/none). Household information was later used to calculate urbanicity scores for Chapter 6.

5.3.2 Physical Activity Measurement

There are several possible self-reported measures for assessing adolescents' physical activity. These include the Oxford Physical Activity Questionnaire (OPAQ), the Quantification de l'activité physique en altitude chez les enfants (QAPACE), the Previous Day Physical Activity Recall (PDPAR), the Self-administration Physical Activity Checklist (SAPAC), the International Physical Activity Questionnaire (IPAQ) and the Youth Physical Activity Questionnaire (YPAQ). A summary of each measure, its strengths/limitations, and evidence for the validity and reliability of its scores are shown in Table 5-1.

Two recent systematic reviews[140, 141] suggested that the "Previous Day Physical Activity Recall" (PDPAR) and the "Quantification de l'activité physique en altitude chez les enfants" (QAPACE) showed higher construct validity than the YPAQ (Table 5-1). However, both questionnaires were unsuitable for use in the studies reported in Chapters 6 and 7 due to the

recall period. Specifically, the period of measurement of the PDPAR, which measures physical activity on the previous day only, was deemed too short to provide a robust measure of young people's habitual physical activity[142], while QAPACE is one year recall period too long for the objectives of this PhD and only measures daily energy expenditure. Other measures, such as the Oxford Physical Activity Questionnaire (OPAQ)[143] and the International Physical Questionnaire for Adolescents (IPAQ-a), have a one week recall period but have not shown a construct validity as high as the YPAQ. In terms of test re-test reliability, Y-PAQ showed acceptable reliability (Intra Class Correlation Coefficient [ICC]=0.73) for MVPA, and even though the OPAQ scores showed stronger reliability (>0.90), its validity was weaker than the Y-PAQ (r=0.32, accelerometer [Caltrac]) and does not include questions to assess "walking" outside from active commuting to school, an activity that contributes to overall MVPA[144] (e.g. walk for exercise/hike, MET = 6.0) or leisure physical activity (e.g. walk the dog, MET = 3.0)[145].

The validity and reliability of the YPAQ scores have been reported previously[140, 141, 146, 147]. One study reported Spearman correlations of r=0.11 with accelerometer estimates and r=0.46 with estimates of energy expenditure from doubly labelled water[140]; while another study reported a Spearman correlation of r=0.39 and a Pearson correlation of r=0.47 with accelerometer assessed[146]. These correlation coefficients showed acceptable construct validity, apart from one which was insufficient (r=0.11). Moreover, YPAQ was found to elicit over-reported MVPA by 25.6±50.2 minutes per day (95%, CI=10.4 to 40.9)[146] and because of this, and according to McCrorie, Perez, Ellaway [146], YPAQ should not be used interchangeably with accelerometers as it tends to over report higher levels of physical activity and underreport lower levels. With regards to reliability, YPAQ scores showed an acceptable (>0.70) ICC of 0.73 for MVPA and a ICC of 0.79 for Physical Activity Energy Expenditure (PAEE)[147].

Even though construct validity is not as strong as other self-report questionnaires, the YPAQ still presents a moderate correlation and poses advantages above other measures. Firstly, participants can choose from 47 listed activities according to their physical activity and having the activities listed might favour the recall process. Secondly, at present there is no Spanish version for most self-reported measures of physical activity and the format and

number of questions in the YPAQ is sufficiently simple to translate so that the loss of information or risk of mistranslation was minimised. YPAQ also differentiates between activities considered as sport, leisure and sedentary on weekdays and weekends, and allows the calculation of MVPA, VPA, MPA and PAEE, giving the opportunity to explore associations between these different intensities of physical activity.

As there is no official Spanish translation of the YPAQ and also no evidence of the scale being implemented amongst Mexican adolescents, future research could focus in validating a Spanish version of the YPAQ that could be used in Latin America.

Table 5-1 Comparison chart of some self-reported measures of physical activity in youth.

	Oxford Physical Activity Questionnaire ***(OPAQ)***	*Quantification de l'activité physique en altitude chez les enfants* ***(QAPACE)***	*Previous Day PA Recall* ***(PDPAR)***	*Self-admin PA checklist* ***(SAPAC)***	*International Physical Activity Questionnaire* ***(IPAQ)***	*Youth Physical Activity Questionnaire* ***(YPAQ)***
Age group	Mean = 13.1	8-16	7 - 12	11-15	13-18	12-17
Recall period	1 week	1 year	Previous day	3 days	1 week	1 week
Number of items	Time table format	18 questions	35 activities to be filled in 30 min blocks	50 activities	**IPAQ:** 27 questions **IPAQ-s:** 7 questions	47 activities
Validity	**MVPA** Spearman r=0.32 (against accelerometer [Caltrac])	**DEE** ICC=0.56 (against indirect maximum oxygen uptake) ICC:0.69 (against direct maximum oxygen uptake)	**TEE** r=0.77 (against accelerometer [Caltrac]) r=0.88 (against pedometer)	Time spent in PA r=0.51(against MET) Sedentary minutes Pearson r=0.18 *(95% CI=0.07-0.28) (against Actigraph)* [141] Spearman r=0.14*(95% CI=0.05-0.23) (against Actigraph)* [141]	**IPAQ-A** Spearman r=0.20 *(p<0.01)* [141]	**MVPA** Spearman r=0.11 (against accelerometer) Spearman r=0.46 *(against DLW)* **MVPA** Pearson r=0.47 Spearman r=0.39 (against accelerometer)[146] **PAEE** Spearman r=0.46 *(p=0.03) (against DLW)* [141]
Reliability	**MPA** ICC=0.76 **VPA** ICC=0.80 **MVPA** ICC=0.91	**DEE** ICC=0.96	**METmin** ICC = 0.98[141] **TEE** Pearson r=0.98 *(p<0.01)* [141]	**MVPA** r=0.67 **VPA** r=0.63	**MPA:** ICC=0.37[141] **LPA**: ICC=0.28[141] **MPA**: ICC=0.15[141] **VPA:** ICC=0.40[141] **MPA:** ICC=0.55[141] **VPA**: ICC=0.54[141] **WALKING:** ICC=0.62[141] IPAQ-s (used in youth) ICC= 0.10 to 0.30[141]	**MVPA** ICC=0.73[147] **PAEE** ICC=0.79 *(p<0.001)* [141]
Strengths	-Provides an example on how to report PA data. -Differentiates PA during PE class from PA inside school facilities.	-Used in a Latin-American country (Colombia) -Covers PA during Holidays	-Highest validity	-Used on a population of mixed ethnicity	-Spanish version available -Used internationally in different populations	-Differentiates from activities considered as sports, leisure PA & sedentary apart from recording MVPA and PAEE -Weekend and week recall
Limitations	-Does not allow participants to report "walking" outside of AC to school.	-Does not measure MPA/VPA/MVPA -Minimum 1 year of assessment	-Only measures previous day PA, specifically after school hours. (3 pm to 11:30 pm)[148] -Used on a younger age	-Used on a younger 11-15	**IPAQ-A**: Mainly used in European ethnicity	-Used in mainly white ethnicity

Note: Information obtained from *Chinapaw, Mokkink, van Poppel, van Mechelen, Terwee* [140], unless cited differently in the table. **PA:** Physical activity, **PE:** Physical education, **MVPA:** Moderate-to-vigorous physical activity, **MPA:** Moderate Physical Activity, **VPA:** Vigorous Physical Activity, **DEE:** Daily Energy Expenditure, **TEE:** Total Energy Expenditure **DLW:** Doubly Labelled Water, **PAEE:** Physical Activity Energy Expenditure. **IPAQ-s:** International Physical Activity Questionnaire. Short Version, **IPAQ-A:** International Physical Activity Questionnaire Adolescents, **AC:** Active Commuting

Based on the evidence above, the Y-PAQ[149] was used as a 7-day self-reported questionnaire that assesses the duration and frequency of 47 activities. The following five variables were derived:

a) ***Sport Activities (15 activities):*** Duration (hours/minutes) and frequency (how many times) from Monday to Sunday, distinguishing between weekdays and weekends. These activities included team sports as well as individual sports no matter if they were performed during or outside school time. For example: baseball, gymnastics, swimming (lessons or for fun), martial arts, tennis etc...
b) ***Leisure time activities (13 activities):*** Duration and frequency from Monday to Sunday, distinguishing between weekdays and weekends. Example of these activities are: walking for exercise and cycling for fun, trampolining, bowling, household chores, scooter, etc...
c) ***Activities at school (3 activities):*** Duration and frequency from Monday to Friday. These activities were commuting to school by bike (to and from school), commuting to school walking (to and from school) and physical activity performed during Physical Education (PE) class.
d) ***Activities during free time (12 activities):*** Duration from Monday to Sunday, distinguishing weekdays from weekends. The listed activities were sedentary activities such as watching television, playing indoors with toys, reading, etc... Commuting by car or bus to school was also noted in this section.
e) ***Other (2 activities):*** Y-PAQ allows participants to list duration and frequency on weekdays or weekends of any non-listed activity.

Different measures of physical activity are obtained from the Y-PAQ: total minutes of physical activity, MET-minutes and Physical Activity Energy Expenditure (PAEE). Total minutes of physical activity are calculated by multiplying duration (number of minutes/hours) by frequency (number of times the activity was done) to derive the total amount per weekday, weekend or week. MET-minutes are calculated as follows:

$$MET\ min = duration \times frequency \times MET\ intensity$$[150]

PAEE is calculated by the assumption that one MET is equivalent to an oxygen consumption rate of 4.54 mL*kg^{-1}*min^{-1} for adolescents between 12 and 13 years old and 4.00 mL*kg^{-1}*min^{-1} for adolescents between 16 and 17 years old[151]. The formula to estimate daily PAEE from the Y-PAQ is:

$$PAEE = (Reported\ time)(OEE \times MET\ equivalent)\left(\frac{Total\ METmin}{Total\ time\ frame}\right)$$

Where:

MET equivalent = 4.54 mL*kg^{-1}*min^{-1} or 4.00 mL*kg^{-1}*min^{-1} depending on age

OEE (Oxygen Energy Equivalent) = 0.0209 kJ*mL^{-1}

Reported time = 1440 (minutes in one day)

The data collected on activities during free time was not included in the analyses of Chapters 6 and 7 because these studies are a continuation of findings from Chapter 4, and because this chapter was mainly based on physical activity data (the only sedentary behaviour variable was sitting time), a decision to mainly focus on physical activity data was taken. Sedentary behaviour data was still collected in hope that its analysis could be done within the duration of this PhD, but this was not the case.

5.3.2.1 Assessment of Physical Activity

Physical activity was measured using the Y-PAQ. Minutes per week of physical activity were calculated by multiplying duration (minutes) and frequency (times per week) of the activities previously mentioned. These activities were then grouped, as shown in Appendix I, into five domains of physical activity:

1) ***Moderate-to-vigorous physical activity:*** Any activity with a metabolic equivalent ≥ 4 kcal·kg^{-1}·h^{-1}) according to the compendium of physical activity[150], regardless of their type (sport activities, leisure activities, activities commuting to school...). Total MVPA was the sum of minutes per week of all these activities.
2) ***Sport activities:*** Any activity listed under this questionnaire subheading (e.g., baseball, football, gymnastics, swimming). Total time spent in sport activities was the sum of minutes per week of these activities.
3) ***Leisure time activities:*** Any activity listed in this part of the questionnaire (e.g., bowling, roller-skating, and playing with pets). Total leisure activity was the sum of minutes per week of these activities.
4) ***Physical Education (PE) class at school:*** Minutes per week reported under this section on weekdays.
5) ***Active commuting to school:*** Sum of minutes per weekday walking or cycling to and/or from school.

5.3.2.2 Data Processing Rules for Physical Activity

There are many different ways to analyse physical activity data, yet at present there is no consensus on a "correct" method for defining levels of physical activity based on self-report population surveys. Because there are no data truncation rules specifically for the Y-PAQ, the guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ) Long Form[127] were adapted as follows for data processing rules:

1. Data Cleaning: Any responses to duration (time) provided in hours were converted into minutes.
2. Exclusion of outliers: All cases in which the sum of total physical activity was greater than 960 minutes per day (16 hours) were excluded from the analysis, this is considering an average sleeping time of eight hours.
3. Minimum values for duration of physical activity: Values less than 10 minutes of duration were re-coded as 'zero' for the calculation of MVPA, sport activities and leisure physical activity. The reason for this is that, in order to achieve health benefits, a minimum of 10 minutes of physical activity should be performed[31].

4. Truncation of data: In an attempt to normalise the distribution of physical activity, which is usually skewed in large population datasets, any total of MVPA, sport activity, leisure physical activity was truncated to 8 hours per day. Physical activity during PE class was truncated to a maximum of 3 hours per day and active commuting to 4 hours per day.

5.3.3 Perception of Safety

The questionnaire items related to perception of safety were utilised in the study reported in Chapter 7. There are scarce validated and reliable self-reported tools to assess the perception of safety in one's surrounding environment. Several studies measure perception of safety through unvalidated questions designed for each study[83], or the perception of neighbourhood safety is measured through single item (e.g. *I feel safe to engage in physical activity in my neighbourhood*) with dichotomised answers (e.g., agree & disagree)[81, 82]. Other measures like the Children's Perceptions of the Physical Environment explore multiple aspects of children's environment like home, neighbourhood, aesthetics & incivilities, general safety (e.g. *it is easy to walk/cycle around*), traffic/road safety (e.g. *I feel safe crossing the road*) and personal safety (e.g. *I am worried about strangers*). The safety scales from this questionnaire have shown moderate internal reliability ($\alpha = 0.65$) and fair test and retest reliability (ICC = 0.88, CI = 0.76 – 0.94)[84]. A limitation of this tool is the dichotomised response format ("no" and "yes") that does not allow for a more graded indication of individuals' perception of safety.

On the other hand, the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y) self-report measure, adapted from the adults' NEWS questionnaire which was developed to provide a more concise and empirically-derived measure of several features of the built environment related to walking in young people. Nevertheless, subscales from the NEWS-Y have been used for different purposes apart from the assessment of walkability, including assessment of the perception of neighbourhood safety amongst Brazilian adolescents[86]. Another study examined the relationship between children's physical activity and the subscales from the NEWS-Y[152]. For the purpose of the study reported in Chapter 7, the "Pedestrian automobile traffic safety" and "Crime safety" subscales from NEWS-Y were used to assess perception of safety.

NEWS-Y subscales had acceptable test-retest reliability (pedestrian and automobile traffic safety ICC=0.67, crime safety ICC=0.73) in a sample of 171 adolescents between 12 and 18 years old[85]. In terms of validity, in the same sample, the pedestrian and automobile traffic safety subscale has been associated with walking to a park (p=0.003) and crime safety has been associated to walking to shops (p=0.027)[85]. In a study with adults, NEWS used self-reported walking as validity criterion and reported a positive association between traffic and crime safety and walking for transport[153]. No further research has studied the criterion validity of the NEWS, NEWS-Y, NEWS-A as a tool to measure the environment. Even though NEWS-Y can be used to examine neighbourhood environment correlates of physical activity, no study has measured the validity of the pedestrian and automobile traffic safety and crime safety subscales.

NEWS-Y has been translated to Maltese and Traditional Chinese, but there is no official Spanish translation. Future research should not only develop a Spanish translation of the NEWS-Y but a cultural adaptation that enhances the environment features that are unique to a country or group of countries that share similarities in society values, government and lifestyle. India, Korea and some sub-Saharan African countries (Cameroon, Ghana, Mozambique, Nigeria, South Africa, Uganda) have adapted the NEWS scale to their own culture[154 155 156].

5.3.3.1 Assessment of Perception of Safety

The "Pedestrian and automobile traffic safety" and "Crime safety" sub-scales from the NEWS-Y comprise the following items:

a) **Pedestrian and automobile traffic safety:** was measured using six items scored on a four-point scale: 1. Strongly disagree, 2. Somewhat disagree, 3. Somewhat agree, 4. Strongly agree. The items were:
    1. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood.
    2. The speed of traffic on most nearby streets is usually slow. (*)
    3. Most drivers exceed the posted limits while driving in my neighbourhood.

4. Our neighbourhood streets have good lighting at night. (*)
5. Walkers and bikers on the streets in our neighbourhood can be easily seen by people in their homes. (*)
6. There are crosswalks and signals to help walkers cross busy streets in our neighbourhood. (*)

b) ***Crime safety:*** Five items were used to assess crime safety using the same response options as above. The items were:
    1. There is a high crime rate in our neighbourhood.
    2. I am worried about being taken or hurt by a known bad person in my neighbourhood.
    3. I am worried about being taken or hurt by a stranger in my yard, driveway or apartment common area.
    4. I am worried of being taken or hurt by a stranger on local streets.
    5. I am worried of being taken or hurt by a stranger in a local park.

Following reverse scoring of the items indicated with a "*", subscales' scores were derived by averaging the items within each subscale. Higher scores in both subscales denote lower walkability, thus lower perception of pedestrian and automobile traffic safety and lower perception of crime safety.

5.3.3.1.1 Confirmatory Factor Analysis

In view of the lack of existing evidence for the construct validity of pedestrian and automobile traffic safety and crime safety subscales of the NEWS-Y in Mexican adolescents, a Confirmatory Factor Analysis (CFA) was performed to examine the construct validity of the hypothesised structure and relationship between the subscales.

CFA is a specific instance of structural equation modelling. It is a multivariate technique used to test hypotheses of the relations among a set of observed variables (i.e., indicators) and the construct they were designed to measure (i.e., factor/latent variable)[157]. Each observed variable has its own unique variance and develops a scale score that represents the shared meaning of the set of observed variables on a single dimension[158].

A measurement model was specified in which the 11 observed variables loaded onto their hypothesised latent variables: Pedestrian and automobile traffic safety (PAS) and Crime Safety (CS) (Figure 5-4). The number next to each item corresponds to their order in the questionnaire, as it was not sequential. It is important to note that in the final CFA model the latent variable of PAS changed for Pedestrian Safety (PS), to best represent the content of the retained items.

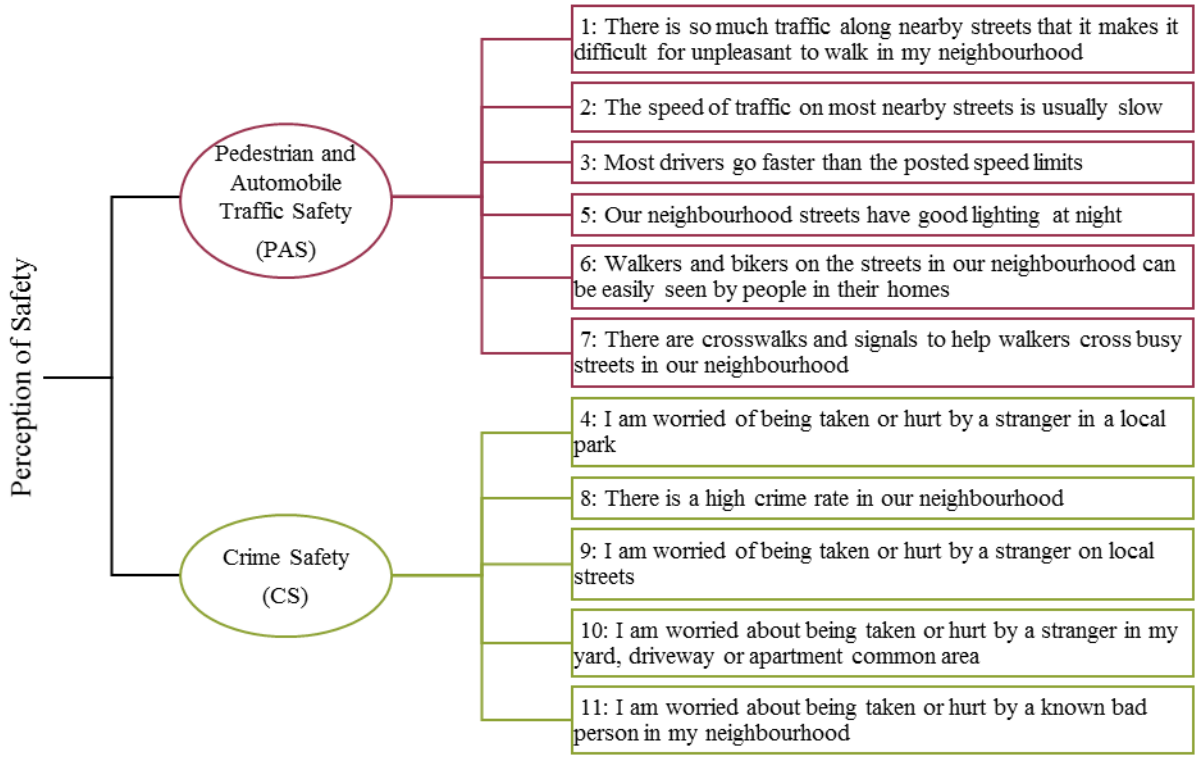


Figure 5-4 Latent variables and observed variables for Perception of Safety prior to CFA.

Following the recommendations of Acock [158], the CFA model was built in STATA (Version 13), College Station, TX, and the *"sem"* command was used. Model fit was assessed using the following Goodness of Fit Indicators:

a) **Chi^2 (χ^2):** Compares the model to a saturated model that has no degrees of freedom. The number of degrees of freedom is based on the number of parameters that are being estimated and the amount of information that is available. Structural equation modelling tries to reproduce the covariance matrix for the eleven items and picks the combination of parameters estimates that best reproduces the covariance matrix[158]. Even though non-significant values of chi^2 indicate good fit,

it is sensitive to sample size and it should be considered alongside other goodness of fit indices[158].

b) **Comparative fix index (CFI):** Compares the model with a baseline model that assumes there is no relationship between the six observed indicator variables of PAT and the five variables of CS. Values of 0.90 or 0.95 indicate good fit[158].

$$CFI = \frac{\max(our\ chi\ squared\ df, 0)}{\max(our\ chi\ squared\ df, baseline\ chi\ suared\ df}$$

Where:

df **=** degrees of freedom for the corresponding model

c) **Standardised root mean squared residual (SRMR):** Indicates proximity to reproduce each correlation on average. Values <0.08 indicate good fit[158].

d) **Root mean squared error of approximation (RMSEA):** Considers how much error there is for each degree of freedom. RMSEA penalises the model for unnecessary added complexity (i.e. adding more paths). A complex model benefits from chance and might fit better, but RMSEA adjusts for this. Values ≤0.05 indicate good fit and values between 0.05 and 0.08 indicate a reasonably close fit[158].

$$RMSEA = \sqrt{\frac{T}{(N-1)}/df}$$

Where:

T **=** max (model chi-squared – df, 0)

df **=** degrees of freedom

N **=** sample size

Besides goodness-of-fit indicators, item-factor loadings and modification indices were considered to derive and fit the final model. The value of item-factor loadings indicates

whether an observed variable can be considered as a defining part of a latent variable. Even though there are "rules of thumb" that indicate item loading should be higher than 0.3 to be acceptable, another approach is to decide the importance of the factor loading when compared to other ones; ideally there should be a homogeneous correlation and deviations from this may be caused by measurement errors. Modification indices are estimates of how much the chi-squared will be reduced if a particular extra parameter is estimated (i.e., the largest modification indices point towards model adjustments that would result in the biggest improvement in fit), it indicates which correlations of errors from pairs of variables should be applied for the model to fit better[158]. However, model modification based on modification indices alone can result in a data driven approach which may not be theoretically or logically coherent. As such, modification indices were used to guide but not prescribe model modification.

Results of goodness-of-fit indicators are shown in Table 5-2. An iterative model refinement process was undertaken which used evidence from the goodness-of-fit indices, item-factor loadings, modification indices and theoretical logic. As such, a balance was sought between data and theory-driven approaches to model fit which did not simply seek good fit at the expense of conceptual clarity. Model 1 did not show good fit. Modification indices suggested that correlating error terms between items would improve model fit and this was performed where this made conceptual sense (e.g. between items 1&3, 1&2, 3&4, 4&9, in Figure 5-4.) (Model 2). In Model 2, fit was improved but items 1, 2 and 3 on the PAS subscale showed very weak loadings (0.07, 0.14, 0.10), therefore items 1 and 3, which had the weakest loadings, where dropped for the next model. Model 3 therefore included the five items loading on the CS factor and 4 items loading on PAS (1 and 3 were excluded) and demonstrated improved fit over Model 2, even though the test scale (internal consistency) for PAS ($\alpha = 0.4969$) indicated that fit would increase to $\alpha = 0.5833$ if item 2 were erased. Model 4 raised the possibility of a model with three latent variables: Traffic safety (TS) comprising items 1, 2 and 3 from Figure 5-4, pedestrian safety (PS) comprising items 5, 6 and 7, and crime safety (CS) comprising items 4, 8, 9, 10, 11. As seen in Table 5-2, model fit for SRMR and RMSEA was good but not for CFI. Internal consistency estimates for the latent variables showed acceptable alpha coefficient for CS ($\alpha = 0.7941$), acceptable for PS ($\alpha = 0.5833$) and unacceptable for TS ($\alpha = 0.3290$)[159], suggesting that items 1, 2 and 3 should not be treated as items measuring one latent variable. Consequently, it was decided to delete items 1, 2 and 3

from the model and analyse separately item 2 in the multivariable regression as it was the item with the least weak loading (I2 = 0.14 compared to I1 = 0.07 and I3 = 0.10) to perception of pedestrian and automobile traffic safety that still represented the "transit and driving" part and that could contribute to understanding the association of perception of safety and physical activity in adolescents as an independent variable outside the CFA model.

The final model (Model 5) shown in Figure 5-5, comprised three items assessing PS (internal consistency $\alpha = 0.5833$) and five items assessing CS (internal consistency $\alpha=0.794$). This model exhibited good fit for CFI and SRMR, and even though RMSEA was not ideal, it was the best model because it identified that items 1, 2 and 3 were not related to perception of pedestrian safety and were driving down the internal consistency of the latent variable previously named as PAS.

Table 5-2 Results of iterative CFA model testing of the perception of pedestrian and automobile safety and crime safety.

	Models				
	1	**2**	**3**	**4**	**5**
Description of the model	2 factors PAS: 6 items CS: 5 items Correlation between factors	2 factors PAS: 6 items CS: 5 items Correlation between factors Correlated error terms: 9&4, 1&3, 1&2, 3&4	2 factors PAS: 4 items (no 1&3) CS: 5 items Correlation between factors	3 factors TS: 3 items (1&2&3) PS: 3 items CS: 5 items Correlation between factors	2 factors PS: 3 items (no 1&2&3) CS: 5 items Correlation between factors
$x^2(df)$	1694.761 (43)	837.983 (39)	745.911 (26)	1075.345 (41)	720.392 (19)
CFI	0.800	0.903*	0.903*	0.875	0.906*
SRMR	0.090	0.075*	0.046*	0.050*	0.048*
RMSEA (90% CI)	0.101 (0.097, 0.106)	0.075 (0.070, 0.079) *	0.085 (0.080, 0.091) *	0.082 (0.078, 0.087) *	0.098 (0.092, 0.104)

** Model meets Goodness-of-fit indicator*
df: Degrees of freedom
CFI: Comparative Fit Index
SRMR: Standardised Rood Mean Squared Residual
RMSEA: Root Mean Squared Error of Approximation
CI: Confidence Interval
PAS: Pedestrian and Automobile Safety
TS: Traffic Safety
PS: Pedestrian Safety
CS: Crime Safety

The arrangement of observed and latent variables resulting from the CFA is shown in Figure 5-5. As mentioned before the variable PAS has been edited to PS after dropping items 1, 2 and 3; referring to automobile safety, and will be referred as PS for the following sections of this thesis.

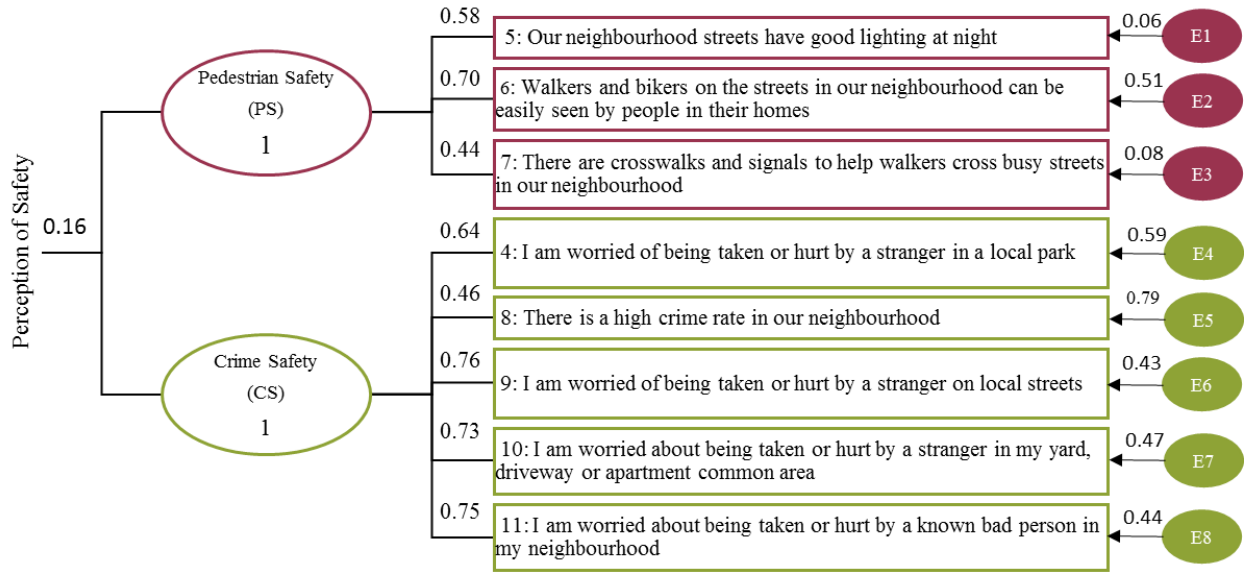


Figure 5-5 Perception of Safety final model output from STATA.

5.3.4 Assessment of Urbanicity

For Chapter 6, urbanicity scores and sub-scores were computed using location information (home postcode, street name, delegation/municipality and state) from each participant, and the urbanicity scale developed by Novak, Allender, Scarborough, West [77]. Location information was used to allocate each participant within a Basic Geostatistical Area (BAGA) from the CENSUS 2010 using the Digital Map of Mexico developed by INEGI[160]. A BAGA is a geographical unit defined by the Mexican Government as "a group of blocks (generally between one and 50) delimited by streets and avenues. In rural areas, a BAGA is a territorial extension delimited by paths, rivers/streams, railroad tracks and canyons"[161]. A group of BAGAS form a locality and a group of localities form a municipality within a state (Figure 5-6). BAGAs have unique serial numbers that identify them, and along with other codes for state, municipality/delegation and locality conform one unique serial number for each place in Mexico. These serial numbers appear in the database of the CENSUS, making possible the link between each participant's household location with information (e.g. paved roads, amount of light posts, public availability of internet...) from that area.

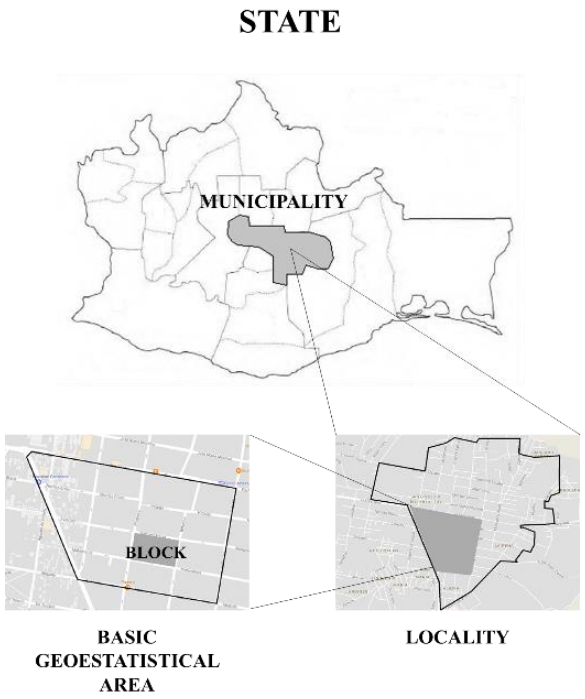


Figure 5-6 Geographical division of a state

The scale by Novak, Allender, Scarborough, West [77], as described in Chapter 2, is an objective measure of several elements of the environment that measure urbanicity. The original scale is formed by seven sub-scores but for Chapter 6, the urbanicity score had to be adapted to the information available at local level as follows:

1. Demographic: People per unit area living in this locality (Information obtained from Census, INEGI).
2. Economic Activity: Proportion of people involved in agriculture as a primary occupation (Information obtained from Census, INEGI and CONEVAL).
3. Built Environment: Amount of paved or unpaved roads, sewage services, electricity service (Information obtained from Census, INEGI).
4. Communication: Proportion of houses with television, mobile phone, public internet, public phone (Information obtained from Census, INEGI).
5. Education: Educational facilities per locality, primary schools, university, average education of mothers in community (Information obtained from SEP).

6. Health services: Health facilities available, health centres, dispensaries/pharmacies, health workers available, village health worker (Information obtained from Census, INEGI).

Each of the six domains is scored from zero to 10. Unlike the original urbanicity scale described in Chapter 2, the diversity sub-score was omitted due to lack of information of housing quality index at BAGA level. Consequently, the maximum value for the composite scale (sum of all subscales except diversity) was 60. All the formulas used to compute the sub-scores are explained in Appendix A. Urbanicity scores were merged with the physical activity data by BAGA, so that for each participant an urbanicity score was given according to their household location.

The validity, reliability and preference of this score over other ones has been previously discussed in Chapter 2. It is worth mentioning that the urbanicity scale has not been previously used in the Mexican population, even though it has been previously applied in other Latin American countries like Peru[77].

5.4 Multiple Imputation for Missing Data

To include information of all participants and increase statistical power, multiple imputation (MI) of missing data was implemented for 4,079 participants. Multiple imputation (MI) is a simulation-based statistical technique used for handling missing data[162]. Even though the MI methodology makes no assumption about the missing-data mechanism, several imputation methods require the missing-data mechanism to be ignorable otherwise there might be a risk of bias[163]. There are three reasons why data could be missing:

a) Missing data completely at random (MCAR): If the probability that data are missing does not rely upon observed or unobserved data, meaning that the missing values are a simple random sample of all data values, and so analysis that discards the missing values remains consistent, although inefficient.
b) Missing data at random (MAR): If the probability that data are missing does not depend on unobserved data but may depend on observed data. Missing values do

not contain any additional information given observed data about the missing-data mechanism. If missing values are missing at MAR, then the missing-data mechanism is said to be ignorable, making it possible to ignore the process that causes missing data in the imputation model.

c) Missing data not at random (MNAR): If there are systematic differences between missing values and the observed values.

It was assumed that the data used in Chapters 6 and 7 were missing at random. In Chapter 6, completeness of data (i.e. percentage of people who had complete data) was 82%; all physical activity measures (i.e., MVPA, sport activities, leisure time activities, PE class, active commuting to school), the six urbanicity sub-scores and participants' characteristics (i.e., sex, weight, height, parents' education level, age, school, time they have been living in their latest address and state) were potential predictors of missingness. In Chapter 7, completeness of data was 78% and all physical activity measures, Perception of Safety items (Pedestrian and Automobile Traffic Safety & Crime Safety) and participants' characteristics were potential predictors of missingness. The MI process is divided into three steps: imputation, completed-data analysis and pooling.

5.4.1 Imputation

An imputation represents a set of possible values for the missing data. In this step the chosen imputation model creates "x" imputations (i.e., completed datasets) that later are combined into a single MI result. In theory, the validity of MI relies on an infinite number of imputations even though the procedure also has good statistical properties with a finite number of imputations[162]. In practice, the number of imputations necessary for a satisfactory MI depends on the amount of missing information due non-response and on the analysis model and the data. In chapters 6 and 7, 20 imputation cycles were used, as recommended by The STATA Multiple-imputation Reference Manual[162], to reduce the sampling error due to imputations.

5.4.2 Completed-data Analysis

Completed-data Analysis is the primary analysis to be performed after missing data have been imputed. This analysis is performed separately on each imputation. In the analysis from Chapters 6 and 7, linear regressions separated by gender were used to examine the associations between urbanicity or Perception of Safety and physical activity.

5.4.3 Pooling

The results obtained from the completed-data analysis are combined into a single multiple-imputation result. These are shown as an output and final result of the MI.

Chapter 6
Association between Urbanicity and Physical Activity in Mexican Adolescents: The Use of a Composite Urbanicity Measure

6.1 Overview

The work presented in this chapter has been published in PLOS one and except for this overview, the methods section that has been summarized and previously addressed in detail in Chapter 5, and the implications sections at the end, it is as per the published article. The article title is: ***"Association between urbanicity and physical activity in Mexican adolescents: The use of a composite urbanicity measure"*** and is designed to answer the Research Question 2 of this thesis: What are the associations between different types of physical activity and urbanicity among adolescents in Mexico? Findings from this study reveal that there are positive and negative associations between elements of urbanicity and adolescents' physical activity. The rationale, methods (abbreviated), results and discussion are presented next, ending with a brief section of implications of the findings for the thesis.

6.2 Rationale

Physical activity is associated with reduced risk of developing non-communicable diseases[29]. The latest National Health and Nutrition Survey 2016 in Mexico reported that 39.5% (30.1% males & 48.8% females) of adolescents between 15 and 19 years old do not meet the WHO's guidelines for physical activity of at least 60 minutes of MVPA per day[29].

Overweight and obesity are a global health issue[164]. Mexico has one of the highest prevalence of obesity and overweight (combined prevalence 72.5%, 95% CI = 70.8 to 74.3) in the world[165]. The prevalence of overweight and obesity amongst adolescents is 26.4% and 12.8% respectively for girls, and 18.5% and 15% respectively for boys[166]. Previous research has found that physical activity is a viable strategy to treat and prevent overweight and obesity in adolescents[167]. Authors from a systematic review concluded that 155-180 minutes per week

of MVPA is effective for reducing body fat in overweight children and adolescents[168], while in another systematic review in Latin America, combined interventions targeting nutrition and physical activity were most successful for the prevention of overweight and obesity in young people aged five to 17 years old[169].

Urbanicity and environmental features (e.g., speed of traffic, number of pedestrian crossings and sidewalks) have been identified as potential correlates of physical activity[170]. Urbanicity is defined as "the impact of living in urban areas at a given point in time... the presence of conditions that are particular to urban areas or are present to a much greater extent than in non-urban areas"[72]. The study of urbanicity is particularly interesting in low and middle income countries such as Mexico due to the rapid rate of urbanisation and migration of people from rural to urban areas[171]. There is strong evidence that urbanicity is associated with increased odds of adults in India being classed as having low physical activity (men: OR: 3.26; 95% CI = 2.5 to 4.3 and women: OR: 4.13; 95% CI = 3.0 to 5.7)[7]. Similarly, the physical activity level (PAL= total energy expenditure/basal metabolic rate) of adults dwelling in urban areas of Papua New Guinea was lower (PAL=1.63±0.19, sedentary or light activity lifestyle) than those in rural areas (PAL= 1.88±0.26, active or moderately active lifestyle) ($p<0.01$)[89]. Further, overall urbanicity in Mexico accounted for a mean decrease of MPA between 10 and 17.6 minutes per week, and education and diversity urbanicity sub-scores were negatively associated with VPA amongst adults[170]. In a study with Kenyan adolescents, urban habitants reported lower MVPA (18 minutes per day in men & 25 minutes per day in women ($p<0.05$)), than those living in a rural environment[91]. Urbanicity involves the study of many components (i.e., built environment, presence of communication media, availability of health services and population density). Some of these elements have been found in the literature to have a positive effect in adolescents' physical activity. A meta-analysis found that features from the built environment (paved roads, walking paths, public lighting, traffic lights, street connectivity) had a positive effect on adolescents' MVPA[172]. Moreover, the presence of streets and pavements has been associated with greater odds of being active among adolescents[173] and the perception of walkable destinations and the presence of open space had been associated with meeting recommendations for walking[174, 175]. Even though these elements of urban environment have been positively associated with physical activity in adolescents, there are other elements of urbanicity that have been found detrimental for health. For example, the presence of television in the bedroom has been

associated with an increase of odds of having a large waist circumference and high levels of fat mass[176]; and residential density has been positively associated with adolescents' obesity[177]. The complexity of the association between urbanicity and physical activity might be a reason why people living in highly urbanised areas, who possibly have better access to pavements, cycling paths and recreation areas still have low physical activity. This evidence suggests that the urban environment has an important role in physical activity levels in developing countries such as Mexico. However, currently, there is a lack of evidence on whether urbanicity is associated with adolescents' physical activity in Mexico.

Urbanisation, as an environmental factor, is one of the fundamental parts of Socio-ecological models. Socio-ecological models, introduced in the 1970's, address the understanding of the relations between various personal and environmental factors; focusing in social, institutional and cultural contexts of people-environment relations[178]. The most recognized socio-ecological model is the Ecological Model for Human Development from Urie Bronfenbrenner, in which, in order to understand human development, the ecological system (microsystem, mesosystem, exosystem, macrosystem, chronosystem) needs to be taken into account. In 2006, Sallis, J.F. adapted Bronfenbrenner's levels of behaviour change to active living [179]. The study or urbanisation overlaps with the exosystem ring posed by Bronfenbrenner and its equivalent "Behaviour Setting" from Sallis' Ecological Model.

A number of different approaches have been used to measure urbanisation. At the simplest level, these approaches have dichotomised locations as urban or rural based on population size/density, economic activity or size of the city[91]. These measures are limited as they only consider basic aspects of urbanisation and fail to quantify other contributory factors, such as the number of paved roads, presence of communication media or proximity to markets which may be associated with physical activity. More recently, several composite measures have been developed which assess broader urbanisation[75-77]. These measures are tailored to the political and socioeconomic situation of a country, allowing the assessment of urbanicity over time and across different environments through multi-item scales (e.g., population size, population density, communication, transportation, educational facilities, health services, markets, housing, diversity, sanitation, & built environment). Recent research in Mexico examined the association between physical activity and urbanicity using the scale by Novak

et al., in this study, physical activity was negatively associated with population size/density, economic activity, communication and diversity sub-scales of urbanicity[170]. However, this study used state-level measures of urbanicity that may fail to quantify individuals' immediate environment, which is likely to have a stronger influence on their physical activity.

The aim of this study was to examine the association between multidimensional local-level urbanisation and the MVPA, sport activities, leisure physical activity, time spent in Physical Education (PE) class and active commuting to school of adolescents in two states of Mexico.

6.3 Methods (abbreviated)

Detailed methods can be found on Chapter 5. In summary, the study used a cross-sectional design and data were collected in Mexico City and Oaxaca between February and June 2016. Objectively-assessed urbanicity scores were derived from national statistics using a urbanicity measure based on the scale by Novak, Allender, Scarborough, West [77]. The urbanicity scale used comprised six sub-scores: 1) Demographic (people per unit area living in this locality), 2) Economic Activity (proportion of people involved in agriculture as a primary occupation), 3) Built Environment (amount of paved or unpaved roads, sewage services, electricity service), 4) Communication (proportion of houses with television, mobile phone, public internet, public phone), 5) Education (educational facilities per locality, primary school, university, average education of mothers in community) and 6) Health Services (health facilities available, health centres, dispensaries/pharmacies, health workers available, village health worker). Each of the six domains was scored from zero to 10. Adolescent physical activity was self-reported using the YPAQ and physical activity was grouped into five domains: 1) Moderate-to-vigorous physical activity (any activity with a metabolic equivalent $\geq$ 4 kcal·kg^{-1}·h^{-1})[150], 2) sports activities (e.g., baseball, football, gymnastics, swimming), 3) leisure time activities (e.g., bowling, roller-skating, playing with pets), 4) Physical Education (PE) class at school, and 5) active commuting to school (walking or cycling).

Physical activity variables were log-transformed due to violation of normality and all urbanicity sub-scores were standardised. To include information of all participants and

increase statistical power, multiple imputation of missing data was implemented. Descriptive statistics were calculated for all variables in the multiple imputed data set, BMI was computed by age and sex using BMI Cut-Offs for children (five to 19 years old) from the WHO[180]. The Wald test for an interaction between gender and the urbanicity-physical activity association revealed that including this variable improved ($p<0.05$) the fit of all the models. As such, linear regression models were performed for males and females separately to examine the association between urbanicity and the physical activity outcomes. Also, the Wald test revealed there was evidence of an interaction by state (Mexico City vs. Oaxaca) and the association between urbanicity and sports activities. There was no evidence for further interactions by state. Twenty-four linear regression models were run: twenty regressions of physical activity variables (MVPA, sports activities, leisure activities, PE class, active commuting) and urbanicity (total and sub-scores) differentiating between sex; and four regressions of sport activities and urbanicity (total and sub-scores) differentiating by state. All models were adjusted for parents' education level, participants' age and for school-level clustering using Robust Standard Errors. Interpretation of results was based on the impact of a standard deviation change in each variable. Analyses were performed using STATA, Version 13 (Statacorp, College Station, TX).

6.4 Results

The final sample (N = 4079) from the imputed dataset consisted of 1,752 adolescents from Mexico City and 2,327 from Oaxaca. Forty-nine percent were males, mean age was 16.55±0.01 years and BMI was "normal" on average [180]. Descriptive statistics of participants' physical activity by sex are presented in Table 6-1. Males reported higher MVPA (1,040.00 vs. 877.28 minutes per week), sports activity participation (731.07 vs. 573.15 minutes per week), time spent in PE class (15.83 vs 14.70 minutes per week) and active commuting (98.62 vs. 95.11 minutes per week) than females, while females reported more leisure physical activity (608.93 vs. 516.52 minutes per week).

Table 6-1 Descriptive Statistics of Participants by sex

	Males (n=2005)								Females (n=2074)							
Age in years	**n**			**%**					**n**			**%**				
15	274			13.66					340			16.37				
16	698			34.81					752			36.25				
17	573			28.57					598			28.84				
18	460			22.96					385			18.55				
Parents Education Level																
Primary School	155			7.73					257			12.37				
Secondary School	559			27.88					573			27.62				
College	725			36.18					740			35.69				
Undergraduate Level	365			18.19					339			16.36				
Postgraduate Degree	194			9.67					154			7.43				
None	7			0.35					11			0.54				
BMI per age	**Un**		**No**		**Ov**		**Ob**		**Un**		**No**		**Ov**		**Ob**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
15	5	1.8	157	57.2	87	31.8	25	9.1	7	1.9	246	72.4	69	20.3	18	5.4
16	17	2.4	437	62.6	201	28.8	43	6.1	17	2.1	553	73.6	159	21.2	23	3.1
17	10	1.8	395	68.9	130	22.6	38	6.7	14	2.3	449	75.1	121	20.2	14	2.4
18	10	2.3	315	68.4	108	23.4	27	5.9	4	1.2	298	77.3	65	16.9	18	4.5
Physical Activity	**n**	**Mean**	**SD**	**Range**					**n**	**Mean**	**SD**	**Range**				
Moderate to Vigorous Physical Activity (min/week)*	2005	1040.00	942.57	10.00-3360.00					2074	877.28	894.69	10.00-3360.00				
Sports Activities (min/week)*		731.07	766.11	0.00-3360.00						573.15	708.92	0.00-3360.00				
Leisure Activities (min/week)*		516.52	564.90	0.00-3360.00						608.93	562.06	0.00-3360.00				
PE Class (min/weekday)*		15.83	59.48	0.00-900.00						14.70	49.07	0.00-700.00				
Active Commuting (min/weekday)*		98.62	175.81	0.00-1020.00						95.11	164.29	0.00-960.00				

* T-test between males and females: p-value=0.00
Un: Underweight, No: Normal weight, Ov: Overweight, Ob: Obesity

Descriptive statistics of participants' physical activity by state are presented in Table 6-2. Participants living in Mexico City reported higher MVPA (1,025.47 vs. 910.56 minutes per week), leisure physical activity (625.80 vs. 514.83 minutes per week) and active commuting (129.40 vs. 72.11 minutes per week) than participants living in Oaxaca. Participants living in Oaxaca reported more time spent in PE class than those from Mexico City (20.16 vs. 8.83 minutes per week). Descriptive statistics for the unstandardized values of urbanicity sub-scores and scores by sex and state are reported in Table 6-3 and Table 6-4 respectively.

Table 6-2 Descriptive Statistics of Participants by state

	Mexico City (n=1752)								Oaxaca (n=2327)							
Characteristic	**n**	**%**							**n**	**%**						
Age in years																
15	166	9.47							447	19.23						
16	586	33.48							863	37.07						
17	573	32.71							598	25.69						
18	427	24.35							419	18.01						
Parents Education Level																
Primary School	101	5.76							310	13.32						
Secondary School	477	27.23							652	28.00						
College	723	41.29							744	31.95						
Undergraduate Level	313	17.85							394	16.91						
Postgraduate Degree	133	7.58							215	9.24						
None	5	0.29							13	0.57						
BMI per age	**Un**		**No**		**Ov**		**Ob**		**Un**		**No**		**Ov**		**Ob**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
15	2	1.45	99	59.72	48	28.99	16	9.84	9	2.02	306	68.35	109	24.38	23	5.24
16	13	2.26	410	69.96	142	24.28	21	3.50	20	2.29	586	67.89	220	25.56	37	4.26
17	9	1.57	420	73.38	118	20.63	25	4.42	15	2.53	428	71.55	134	22.35	21	3.57
18	10	2.23	254	59.56	138	32.24	25	5.97	5	1.28	263	62.69	117	27.96	34	8.07
Physical Activity	**n**		**Mean**		**SD**		**Range**		**n**		**Mean**		**SD**		**Range**	
Moderate to Vigorous Physical Activity (min/week)*	1752		1025.47		986.11		10.00-3360.00		2327		910.56		872.83		10.00-3360.00	
Sports Activities (min/week)*			656.15		788.47		0.00-3360.00				651.05		709.76		0.00-3360.00	
Leisure Activities (min/week)*			626.80		587.34		0.00-3360.00				514.83		543.60		0.00-3360.00	
PE Class (min/weekday)*			8.83		32.23		0.00-450.00				20.16		63.68		0.00-900.00	
Active Commuting (min/weekday)*			129.40		187.74		0.00-940.00				72.11		150.55		0.00-1020.00	

* T-test between Mexico City and Oaxaca: p-value=0.00
Un: Underweight, No: Normal weight, Ov: Overweight, Ob: Obesity

Table 6-3 Descriptive Statistics of Urbanicity Variables in males and females. Unstandardized values

	Males (n=2005)			Females (n=2074)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Demographic[a]	4.25	1.50	1.00-10.00	4.15	1.46	1.00-10.00
Economic Activit [a]	4.32	0.47	1.87-5.99	4.35	0.47	1.87-7.09
Built Environment[a]	8.74	0.86	5.5-10.00	8.75	0.88	1.00-10.00
Communication [a]	4.17	1.60	1.00-10.00	4.16	1.68	1.00-10.00
Education [a]	7.03	0.72	3.80-9.44	7.06	0.76	3.93-9.75
Health [a]	6.12	0.94	0.63-9.54	6.16	0.96	0.00-9.75
Overall [b]	34.65	2.04	25.29-45.49	34.66	2.05	23.29-44.42

[a] Sub-score values range from 0 to 10
[b] Overall from 0 to 60.

Table 6-4 Descriptive Statistics of Urbanicity Variables in Mexico City and Oaxaca. Unstandardized values

	Mexico City (n=1752)			Oaxaca (n=2327)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Demographic* [a]	5.01	1.42	1.00-10.00	3.59	1.20	1.00-10.00
Economic Activity* [a]	4.55	0.40	2.76-7.09	4.17	0.45	1.87-5.62
Built Environment* [a]	8.96	0.56	7.00-10.00	8.59	1.02	1.00-10.00
Communication [a]	2.86	1.10	0.75-7.76	5.16	1.25	0.44-10.00
Education* [a]	7.35	0.74	4.19-9.75	6.82	0.66	3.80-9.43
Health* [a]	6.22	0.79	0.00-9.75	6.09	1.04	0.63-9.54
Overall [b]	34.96	1.85	23.29-44.36	34.43	2.11	25.29-45.49

[a] Sub-score values range from 0 to 10
[b] Overall from 0 to 60.
* T-test between Mexico City and Oaxaca: p-value<0.05

The multivariable regression models of overall urbanicity and urbanicity sub-scores in males and females are presented by physical activity outcome in Table 6-5 and Table 6-6, respectively. For MVPA, in the base model, every standard deviation increase in overall urbanicity was associated with a mean increase of 5% of females' MVPA per week (95% CI=0.00 to 0.11), there was no evidence of an association for males. In the multivariable linear regression model, for every standard deviation increase in the demographic sub-score there was a mean increase of 6% (95% CI=0.01 to 0.10) MVPA per week for females. There was no evidence of an association between the other urbanicity sub-scores and MVPA.

Table 6-5 Linear Regression Models: Associations Between Urbanicity (Z-scores), Moderate to Vigorous Physical Activity, Sports Activities, Leisure Activities, Physical Education Class and Active Commuting in Males.

		MVPA				**Sports**				**Leisure Activities**				**PE Class**				**Active commuting**			
		Min/wk				**Min/wk**				**Min/wk**				**Min/wk**				**Min/wk**			
Linear regression	**Score/subscore**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**
Males (n=2005) **Base model**	Overall urbanicity	-0.01	-0.10	0.07	0.70	-0.04	-0.22	0.14	0.62	-0.08	-0.27	0.09	0.30	**0.15**	**0.04**	**0.25**	**0.01**	0.20	-0.00	0.42	0.05
Multivariable	Demographic	-0.01	-0.09	0.07	0.79	-0.02	-0.15	0.09	0.61	-0.01	-0.21	0.17	0.85	0.01	-0.13	017	0.79	**0.21**	**0.00**	**0.42**	**0.04**
	Economic Activity	0.01	-0.06	0.08	0.75	-0.02	-0.23	0.18	0.78	0.00	-0.14	0.15	0.97	0.18	-0.10	0.47	0.17	-0.06	-0.23	0.09	0.37
	Built Environment	0.01	-0.05	0.08	0.64	0.02	-0.05	0.11	0.45	-0.02	-0.21	0.15	0.73	0.07	-0.00	0.16	0.07	0.08	-0.06	0.23	0.21
	Communication	-0.00	-0.12	0.11	0.93	**0.23**	**0.00**	**0.46**	**0.04**	**-0.38**	**-0.71**	**-0.05**	**0.02**	0.16	-0.29	0.61	0.43	**-0.49**	**-0.91**	**-0.07**	**0.02**
	Education	-0.05	-0.15	0.04	0.21	0.03	-0.18	0.25	0.70	-0.05	-0.39	0.28	0.71	-0.15	-0.45	0.13	0.24	-0.15	-0.49	0.18	0.30
	Health	-0.01	-0.08	0.04	0.57	-0.00	-0.16	0.16	0.97	**-0.20**	**-0.37**	**-0.03**	**0.02**	**0.17**	**0.05**	**0.28**	**0.00**	-0.01	-0.19	0.16	0.87

[a]Adjusted by parents' education level and participants' age

Table 6-6 Linear Regression Models: Associations Between Urbanicity (Z-scores), Moderate to Vigorous Physical Activity, Sports Activities, Leisure Activities, Physical Education Class and Active Commuting in Females

		MVPA				**Sports**				**Leisure Activities**				**PE Class**				**Active commuting**			
		Min/wk				**Min/wk**				**Min/wk**				**Min/wk**				**Min/wk**			
Linear regression	**Score/subscore**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**	**Coef,**	**95% CI**		**P>|t|**
Females (n=2074) **Base model**	Overall urbanicity	**0.05**	**0.00**	**0.11**	**0.04**	-0.01	-0.14	0.12	0.85	0.02	-0.06	0.11	0.59	**0.16**	**0.05**	**0.27**	**0.01**	0.15	-0.04	0.35	0.11
Multivariable	Demographic	**0.06**	**0.01**	**0.10**	**0.01**	-0.02	-0.12	0.08	0.62	**0.06**	**0.00**	**0.12**	**0.04**	0.01	-0.14	0.17	0.86	**0.28**	**0.16**	**0.41**	**0.00**
	Economic Activity	0.00	-0.05	0.06	0.75	0.04	-0.07	0.16	0.40	-0.11	-0.29	0.06	0.18	0.09	-0.03	0.21	0.14	-0.03	-0.20	0.13	0.63
	Built Environment	-0.04	-0.09	0.01	0.13	**-0.07**	**-0.15**	**-0.00**	**0.04**	-0.08	-0.21	0.04	0.18	0.07	-0.02	0.16	0.12	-0.08	-0.21	0.04	0.15
	Communication	-0.09	-0.24	0.06	0.19	0.08	-0.21	0.39	0.50	**-0.36**	**-0.69**	**-0.03**	**0.03**	0.08	-0.31	0.49	0.62	-0.40	-0.90	0.09	0.09
	Education	-0.02	-0.15	0.10	0.65	-0.01	-0.25	0.22	0.90	0.07	-0.20	0.35	0.54	-0.09	-0.36	0.17	0.44	-0.01	-0.36	0.33	0.92
	Health	0.04	-0.00	0.09	0.70	0.07	-0.06	0.22	0.23	-0.02	-0.13	0.09	0.62	**0.22**	**0.06**	**0.38**	**0.01**	-0.07	-0.20	0.05	0.24

[a]Adjusted by parents' education level and participants' age

For sport participation, in the multivariable linear regression, for every standard deviation increase in the communication sub-score there was a mean increase of 23% (95% CI=0.00 to 0.46) of time spent in sport activities in males. Amongst females, every standard deviation increase in the built environment sub-score was associated with 7% decrease (95% CI= -0.15 to -0.00) in sport participation.

For leisure physical activity, in the multivariable linear regression, amongst males there was a mean decrease of 38% (95% CI=-0.71 to -0.05) minutes per week for every standard deviation increase in the communication sub-score and mean decrease of 20% (95% CI=-0.37 to -0.03) for every standard deviation increase in the health sub-score. Amongst females, there was a mean decrease of 36% (95% CI=-0.69 to -0.03) minutes per week for every standard deviation increase in the communication sub-score and a mean increase of 6% (95% CI=0.00 to 0.12) for every standard deviation increase in the demographic sub-score.

For time spent in PE class, in the linear regressions of the base models, there was a mean increase of 15% (95% CI=0.04 to 0.25) in males and a 16% increase (95% CI=0.05 to 0.27) in females for every standard deviation increase in overall urbanicity. In the multivariable linear regression, for every standard deviation increase in the health sub-score there was a mean increase of 17% (95% CI=0.05 to 0.28) minutes per weekday in males and an increase of 22% (95% CI=0.06 to 0.38) in females.

For active commuting, in the multivariable linear regression models, for every standard deviation increase in the demographic sub-score there was a mean increase of 21% (95% CI=0.00 to 0.42) in males and an increase of 28% (95% CI=0.16 to 0.41) in females, respectively. Additionally, for every standard deviation increase in the communication sub-score there was a mean decrease of 49% (95% CI=-0.91 to -0.07) minutes per weekday of active commuting in males.

Multivariable regression models of urbanicity and sport activities by state are presented in Table 6-7. Results are reported relative to the standard deviation units for the urbanicity values in Mexico City and Oaxaca.

Table 6-7 Linear Regression Models: Associations Between Urbanicity (Z-scores) and Sports Activities. By state.

		Sports Min/wk			
Linear regression	**Score/subscore**	**Coef,**	**95% CI**		**P>|t|**
Mexico City (n=1752)					
Base Model	Overall urbanicity	**0.16**	**0.02**	**0.31**	**0.03**
Multivariable	Demographic	**0.07**	**0.01**	**0.14**	**0.02**
	Economic Activity	-0.10	-0.32	0.11	0.26
	Built Environment	0.15	-0.09	0.40	0.16
	Communication	-0.05	-0.42	0.30	0.66
	Education	-0.17	-0.50	0.16	0.22
	Health	**0.26**	**0.02**	**0.50**	**0.03**
Oaxaca (n=2327)					
Base Model	Overall urbanicity	**-0.09**	**-0.14**	**-0.03**	**0.01**
Multivariable	Demographic	**-0.05**	**-0.11**	**0.00**	**0.05**
	Economic Activity	0.07	-0.01	0.16	0.07
	Built Environment	**-0.08**	**-0.12**	**-0.03**	**0.00**
	Communication	-0.03	-0.40	0.33	0.77
	Education	-0.05	-0.35	0.23	0.55
	Health	-0.04	-0.15	0.05	0.26

*Adjusted by parents' education level and participants' age.

In the base models, for every standard deviation increase in overall urbanicity there was a mean increase of 16% (95% CI=0.02 to 0.31) in the time spent in sport activities of participants from in Mexico City and a mean decrease of 9% (95% CI=-0.14 to -0.03) in the time spent in sport activities of participants from Oaxaca. In the multivariable regression models, there was a mean increase of 7% (95% CI=0.01 to 0.14) minutes per week with every standard deviation increase of the demographic sub-score and a mean increase of 26% (95% CI=0.02 to 0.50) minutes per week per standard deviation increase in the health sub-score in Mexico. In Oaxaca, for every standard deviation increase in the built environment sub-score there was a mean decrease of 8% (95% CI=-0.12 to -0.03) time spent in sport activities.

6.5 Discussion

This study investigated the association between five domains of physical activity and different indicators of urbanicity in adolescents from two contrasting states in Mexico; Mexico City which is 58.2 and Oaxaca which is comparatively 39.7. Household electronic media presence (assessed by the communication scale) was negatively associated with leisure time physical activity and active commuting in males. This finding is comparable to previous findings of a negative association between TV watching and time spent in leisure physical activity amongst Taiwanese adolescents[181]. There is no previous evidence that directly associates household electronic media presence and active commuting. However, there might be a potential causal pathway between home electronic media and active commuting. Previous research has found electronic media to be negatively associated with sleep quality[182-184], and adequate sleep duration has been found to be associated with greater active commuting to school[185]. Findings from this study strengthen the argument of the last part of the pathway, suggesting that maybe the vast research between sleep quality and media use might lead to adolescents to not actively commute to school.

Compared to adolescents from areas of low population density (demographic sub-score), adolescents who lived in areas of higher population density did more active commuting to school. Previous research has shown contrasting findings. Studies in Irish and German adolescents have found that living in more densely populated areas had greater odds of active commuting than those in less densely populated[186], and that living in rural areas was associated with lower levels of cycling compared to medium-sized towns[187]. In contrast, research in Mexico found that adolescents from urban areas were 32% less likely to engage in active commuting than their peers from rural areas [188]. The positive association between urbanicity defined by density and active commuting might be explained by the higher school concentration in highly populated areas, making it easier to walk or cycle to school. Also there might be a higher presence of walking trails or cycling routes that make it easier to commute[189]. On the other hand, the negative association previously found in Mexico[188] might be explained by the measurement of urbanicity an urban-rural dichotomy compared with our measure based on population density. An alternative explanation might be car ownership; with people dwelling in high

density places more able to buy a car and primarily commute in that way [190]. More in-depth work is needed to further understand these associations.

Adolescents living in places with higher urbanicity and more health services spent more time in PE class. In line with our findings, children from urban areas in the United States reported a greater frequency of physical activity during PE class than children from rural areas[191]. We are not aware of evidence that supports the association between health services with time spent in PE class, and it might be the case that the health sub-score, which measures availability to health services that are more likely to be in more urbanised areas, is a proxy for broader urbanicity which may also reflect more well-developed PE provision in schools. Even though rural adolescents might be getting their physical activity from other sources, it is useful to identify PE as a potential setting in which to increase total physical activity in these areas of lower urbanicity.

Adolescents living in more urbanised areas of Mexico City spent more time in sport activities, compared to adolescents from more urbanised areas of Oaxaca. Adolescents in Mexico City living in a place with high urbanicity would spend 8% more time in sport activities than their peers living in a place with low urbanicity, while adolescents living in a place with high urbanicity in Oaxaca would spend 4.5% less time in sports than their peers living in a place with low urbanicity. Previous evidence coincides with the positive association found in Mexico City; for example, in Taiwan adolescents living in rural areas were less interested in recreational sports than adolescents living in urban areas [192]. Further, parents of children from urban schools were more likely to drive their children to sport facilities than parents from rural areas, and the weekly frequency of sports club attendance was higher amongst urban children[193]. The opposite association found in Oaxaca could be explained by the density of sport facilities per square kilometre which is 0.01 in Oaxaca and 2.30 in, Mexico City [194]. In this instance, higher urbanicity may be supporting adolescent physical activity by providing access to places to do structured physical activity.

In relation to confounders in this study, the associations between urbanicity and physical activity were adjusted for parents' education level and participants' age. According to Skelly, A. C., a confounder is a factor that predicts the outcome (i.e. physical activity) even in the absence of the exposure (i.e. urbanicity)[195]. The main requirements of a confounder are: first, to have an independent relationship with the outcome and second, not to be a result of the exposure. The confounding factor might be associated with the exposure but without being a proxy measure of it. Failing to account for confounding might lead to bias and weak credibility. In the current study, parents' education level and participants' age may act as predictors of physical activity and be present in the study of urbanicity, but they are not a result of urbanicity or act as proxy measures. Likewise, there might be other variables acting as confounders that are not being accounted in the analysis of this study, therefore results need to be interpreted with care. Socio-economic status, household income, BMI and car ownership might be variables with an independent relationship with physical activity. Previous research found that adults and adolescents living in a household with one or more cars reported less physical activity compared to adults and adolescents without an access to a car[196, 197]. Moreover, there is extensive literature addressing the associations between physical activity and socio-economic status[198], household income[199] and BMI[200].

Among the strengths of the study is the use of a large data set which allowed various forms of physical activity to be examined. In addition, we sampled from a population that have not been fully studied in Mexico which was enhanced by use of a robust multiple imputation method. Further, we used a comprehensive measure of multidimensional urbanicity components that extend beyond the rural-urban dichotomy that has been used in other developing countries. Urbanicity data were derived using the most precise location level of data available (i.e., BAGA), which gives a better understanding of the environment in which each individual resides. Notwithstanding these strengths, the cross-sectional design prevents an understanding of the causal pathways at play in the urbanicity-physical activity association. Further, representativeness is limited to adolescents between 15 and 18 years old attending public schools as private schools were not sampled, also it is important to recognise the potential selection bias due to non-response to participate from 79 schools. Finally, schools from regions considered as

unsafe in both states were excluded which may have implications for the variability of the urbanicity measure.

Understanding urbanicity and behaviours in the context in which they take place is key for the development of health programmes. The findings have implications at global and local level. Global physical activity guidelines should refer to the need to consider urbanicity in the physical activity plans of developing countries. Local health promotion teams should consider the nature and downstream effects of urbanicity such as increased communication infrastructure and access to media devices, in their local context.

6.6 Conclusions

Urbanicity is related to young people's physical activity in Mexico, however the associations are varied, with some components of urbanicity positively, and some negatively associated with different domains of physical activity. Our findings suggest that some urbanicity-physical activity associations may be different in places with different urbanicity. In Mexico City, areas with high urbanicity were associated with more time spent in PE class in males and females and more time spent in sport activities. In contrast, high urbanicity areas in Oaxaca were associated with less time spent in sport activities. The presence of electronic media at home (communication sub-score) was associated with less time spent in leisure physical activity in males and females and active commuting to school in males. High densely populated areas were associated with more active commuting.

6.6.1 Acknowledgements

The first author (MHG) would like to thank Daniel Avila Fernandez from the Secretariat of Public Education (Mexico) for his support throughout the recruitment process, and the head teachers from the schools in Mexico City and Oaxaca. MHG is funded by the National Council of Science and Technology of Mexico (CONACyT), fellow no. 218160.

6.7 Implications for the Thesis

The positive and negative associations of the urbanicity sub-scales with physical activity found in this chapter agree with the dual associations found in Chapter 4, reinforcing the complexity of urbanicity and the need for multicomponent urbanicity measures that allow to investigate each sub-score of urbanicity and their association with the dependent variable. Furthermore, the associations in this chapter in adolescents are different from the ones found in Chapter 4 among adults, stressing the different interaction both populations experience with their environment; suggesting that in urbanicity studies adolescents and adults must be studied separately. This chapter also confirmed that it is possible to assess urbanicity at a local level with public government information (except from the diversity sub-score originally featured in the urbanicity scale by Novak et al.), enabling a more accurate urbanicity measure that is more likely to portray the immediate environment of the adolescent.

Chapter 7
Perception of Safety and its Association with Physical Activity in Adolescents

7.1 Overview

The work presented in this chapter is aimed to be submitted to the Journal of Physical Activity and Health as it stands with exception of this overview, the methods section that has been summarized and previously addressed in Chapter 5, and the implications sections at the end. Also, Appendices J and K of this thesis will be submitted as supplementary material. ***"Perception of Safety and its Association with Physical Activity in Adolescents"*** answers the Research Question 3 of this thesis: Is there an association between perception of safety and adolescents' physical activity? Results from this study provide an insight of the association of one of the many elements of urbanisation, currently not considered within the urbanicity score, and different types of physical activity in adolescents. The rationale, methods, results, discussion and a brief section of implications of the findings for the thesis are presented below.

7.2 Rationale

Low levels of physical activity are associated with several non-communicable diseases (NCDs). Physical inactivity is responsible for 10% of the burden of disease of colon cancer, 10% of breast cancer, 7% of type 2 diabetes, and 6% of coronary heart disease worldwide[11]. Moreover, physical inactivity was responsible for 5.3 million of the 57 million deaths in 2008[11]. In Mexico, 9.4% of adults have been diagnosed with diabetes, 25.5% with hypertension[201] and approximately 16% of premature deaths of people between 30 and 70 years old is attributed to NCDs[202].The latest National Health and Nutrition Survey in Mexico (2016) reported that 39.5% of adolescents (48.8% females, 30.1% males) do not meet the WHO's physical activity guidelines (60 minutes per day of moderate-to-vigorous physical activity)[201].

Mexico is a middle-income country which has experienced a fast pace of recent urbanisation. Currently, 63% of the population lives in urban areas and this is expected to reach 79% by 2050[203]. The rapid urbanisation poses a number of challenges to physically active lifestyles such as creating recreational public spaces or cycling/walking trails, guaranteeing safety and creating means to facilitate physical activity[203,170]. In Mexico, after lack of time (56.8%), the second most common barrier to performing physical activity is lack of adequate and safe spaces (37.7%), [201] and the perception of safety has worsened in the last few years[78]. In a 2016 survey, 74% of Mexicans reported that they perceive their city as unsafe to live in and 33.5% have stopped going out for walks as a result. In terms of safety related to crime, in 2016, the incidence of criminal activity for street and public transport armed robbery and assault was 9,599 per 100,000 habitants[204]. Furthermore, 67.7% of the entire population considers that living in their city is unsafe in terms of crime and 67.1% has witnessed a robbery or assault[78]. Regarding pedestrian safety, 62.6% Mexicans identified insufficient public lighting as an issue, 49.6% perceived streets and avenues in their city to be frequently full with traffic and 38% mentioned neglected parks and public spaces[78]. Consequently, 68.6% of adults would not let their underage children (<18) go out alone[205], possibly constraining their physical activity to indoor areas or nearby spaces considered as "safe". There is a risk that rapid and unplanned urbanization in Mexico will affect crime and pedestrian safety, and therefore may reduce physical activity.

Previous literature has explored the associations between perception of safety (crime safety, pedestrian safety) and physical activity. A recent meta-analysis found that people reporting feeling safe from crime had 27% greater odds of achieving higher levels of physical activity, compared to those living in areas with higher crime rates who had 28% reduced odds of achieving higher levels of physical activity[206]. However, only 10.1% of the papers from a systematic review found a negative association between physical activity and crime safety[207]. This surprising finding could be because studies were conducted in high-income countries where crime rates are significantly lower than in low-and-middle income countries like Mexico. Pedestrian safety, the presence of traffic lights and walking tracks have been associated with greater active travel among female adolescents[111], while living in areas with low neighbourhood safety decreased the odds of being physically active outside school by 48%[208]. Although these studies indicate how the

perception of safety is associated with physical activity, information is needed about this relationship in middle-income countries where a high rate of crime is experienced along with a rapid urbanisation. Also, as most of data pertaining to perceptions of safety in Mexico is amongst adults, and therefore there is a need to better understand how young people's perceptions of safety are associated with their physical activity.

The aim of this study was to examine the association between perceived safety (crime and pedestrian safety) and five domains of physical activity (moderate-to-vigorous physical activity, sport participation, leisure physical activity, Physical Education class, and Active Commuting) in a sample of Mexican adolescents between 15 and 18 years old.

7.3 Methods (abbreviated)

Detailed study design and recruitment of schools and participants of this cross-sectional study can be found on Chapter 5. In summary, data for 4,079 adolescents were collected in Mexico between February and June 2016 from six schools from Mexico City and four schools from Oaxaca State. Adolescent physical activity data and perception of safety were self-reported. The duration and frequency of physical activity in the last 7-days was measured with the YPAQ and grouped into five domains: MVPA, sport activities, leisure time activities, PE class at school, and active commuting; according to the classification proposed in Appendix I. Perception of Safety was assessed using Spanish translations of the "Pedestrian and Automobile Traffic Safety" and "Crime Safety" sub-scales from the NEWS-Y.

7.3.1 Statistical analysis

The five domains of physical activity were assessed for normality through Shapiro-Francia test, skewness and kurtosis. Due to non-normality, physical activity data was log-transformed. The continuous variables of Pedestrian Safety and Crime Safety had a normal distribution.

There is no existing evidence for the construct validity of the safety sub-scales of the NEWS-Y in Mexican adolescents, therefore, a Confirmatory Factor Analysis (CFA) was performed to examine the construct validity of the hypothesised structure and relation between the subscales. Full methods and results can be found in Chapter 5. The final model comprised of three items assessing pedestrian safety ($\alpha = 0.583$) and five items assessing crime safety ($\alpha = 0.794$). Even tough item 2 (Speed of traffic on most streets is usually slow) did not load on pedestrian safety, it was retained and analysed separately to minimise a loss of information about this component of safety perceptions.

To increase statistical power, multiple imputation of missing data was implemented for the 4,079 participants. Completeness of data was 78% and values were missing at random. Moderate-to-vigorous physical activity, sports activities, leisure time activities, PE class, active commuting to school, the items resulting from the CFA for pedestrian safety and crime safety, and participants' characteristics that were potential predictors of missingness (i.e. gender, weight, height, parents' education level, age, school and state) were included in the imputation method. Twenty imputed datasets were created using 20 cycles of regressions and results were then averaged over these datasets using Rubin's rules[209]. Complete case analysis of the original dataset is available in Appendix L.

Descriptive statistics were calculated for all variables in the imputed data. Body Mass Index (BMI) was computed by age and sex using BMI Index Cut-Offs for overweight and obese children (five to 19 years old) from the World Health Organization[180]. The associations between the three Perception of Safety variables (i.e. high speed of traffic, Pedestrian Safety, Crime Safety) and the five physical activity domains were examined using linear regression models. The Wald test for an interaction between gender and the perception of safety to physical activity association showed that by including gender in the model, the fit would be improved ($p<0.05$). Five linear regression models were run with physical activity outcome variables (MVPA, sport activity, leisure activities, PE class, active commuting) and exposures of Perception of Safety (i.e., High Speed of Traffic, Pedestrian Safety, Crime Safety) for males and females separately. All models were adjusted for parents' education level and participants' age. Robust standard errors

were used in all models to account for the clustering (non-independence) of children in schools. All analyses were performed in STATA (Version 13), College Station, TX.

7.4 Results

The factor loadings, item means, standard errors, standard deviations and squared multiple correlations of the CFA are shown in Table 7-1. Factor loadings for Pedestrian Safety showed a strong association to the underlying factor (ranged from 0.44 to 0.68) as well as factor loadings for Crime Safety (0.46 to 0.75). Pedestrian safety and crime safety showed mean values greater than 2 (1 being safe and 4 unsafe), being greater among females than males.

Table 7-1 CFA Factor Loadings, Item Means, Standard Deviation, Standard Error, Squared Multiple Correlation of Model 5. Standardized values.

			Factor			
Item	**M**	**SD**	**I Pedestrian Safety**	**II Crime Safety**	**SE**	**SMC**
Pedestrian Safety						
Streets do not have good lighting at night (B5)	2.61	0.76	0.59		0.00	0.34
Walkers and cyclists cannot be easily seen by people in their homes (B6)	2.56	0.70	0.68		0.00	0.46
There are not crosswalks and signals on busy streets (B7)	2.57	0.72	0.44		0.00	0.19
Crime Safety						
I am afraid of being taken or hurt by a stranger in a local park (B4)	2.41	0.86		0.64	0.00	0.54
There is a high crime rate (B8)	2.48	0.78		0.46	0.00	0.51
I am afraid of being taken or hurt by a stranger on local streets (B9)	2.44	0.81		0.75	0.00	0.56
I am afraid of being taken or hurt by a stranger in my yard, driveway or apartment common area (B10)	2.11	0.84		0.72	0.00	0.21
I am afraid of being taken or hurt by a known "bad" person in my neighbourhood (B11)	2.32	0.82		0.74	0.00	0.40
SD: Standard deviation **SE:** Standard Error **SMC:** Squared Multiple Correlation						

Descriptive statistics of participants' physical activity by gender are shown in Table 7-2. Mean moderate-to-vigorous physical activity exceeded in both cases the WHO's

guidelines for adolescents between 5 and 17 years old (60 minutes of MVPA per day). Sixty-two percent of males and 55% of females met the WHO's physical activity guidelines. In all the physical activity domains, except from leisure physical activity, males reported more minutes per week than females. The prevalence of overweight for males was 26.71% and for obesity 6.13%, while in females it was of 20.46% and 2.85% respectively.

Table 7-2 Descriptive Statistics of Participants' Physical Activity by gender.

	Males (n=2005)			**Females (n=2074)**		
	Mean	SD	Range	Mean	SD	Range
BMI(Kg/m^2) by age:						
15	22.27	3.55	12.49-43.82	21.76	3.38	10.25-35.55
16	22.36	3.55	8.31-43.82	22.16	3.24	8.43-38.19
17	22.78	3.40	10.69-35.15	22.27	3.17	8.90-37.36
18	23.40	3.72	11.51-46.29	22.76	3.41	8.15-43.11
High Speed of Traffic*	2.37	0.77	1.00-4.00	2.41	0.71	1.00-4.00
Pedestrian Safety*	2.55	0.54	1.00-4.00	2.62	0.53	1.00-4.00
Crime Safety*	2.22	0.60	1.00-4.00	2.48	0.59	1.00-4.00
Moderate to Vigorous Physical Activity (min/week)	824.27	713.03	10.00-3360.00	671.61	615.48	10.00-3360.00
Sports Activities (min/week)	604.60	585.46	0.00-3360.00	450.17	459.35	0.00-3360.00
Leisure Activities (min/week)	605.28	592.21	0.00-3360.00	679.69	596.40	0.00-3360.00
PE Class (min/weekday)	156.19	144.14	0.00-700.00	137.26	129.10	0.00-700.00
Active Commuting (min/weekday)	196.37	195.29	0.00-1020.00	174.54	178.50	0.00-960.00

* Items scored from 1(safe) to 4(unsafe).

The associations between perceived safety and physical activity are shown in

Table 7-3. To interpret the results, the logistic transformation of physical activity ($\log Y_i = \alpha + \beta X_i + E_i$) needs to be considered. For a quick interpretation of small values of the

coefficient (β), the approximation 100 x β may be used for the expected percentage change in the dependent variable (y) for a unit increase in the independent variable (x)[210]. Hence in females, every unit increase of pedestrian safety was associated with 12% lower MVPA per week (95% CI = -0.19 to -0.05), and 13% less sport activity per week (95% CI = -0.23 to -0.03). Confidence Intervals were relatively wide, indicating variability in these estimates. Crime safety was not associated with physical activity participation in females. There were no associations between either crime or pedestrian safety and any physical activity variables amongst males.

Table 7-3 Linear Regression Models: Associations between Perceived Safety and Moderate to Vigorous Physical Activity, Sports Activities, Leisure Activities, Physical Education Class and Active Commuting. By gender.

	Males (n=2005)			**Females (n=2074)**		
	High Speed of Traffic	Pedestrian Safety	Crime Safety	High Speed of Traffic	Pedestrian Safety	Crime Safety
MVPA min/week						
Coef (95% CI)	0.00 (-0.07 to 0.07)	-0.07 (-0.18 to 0.03)	-0.00 (-0.12 to 0.10)	0.01 (-0.05 to 0.09)	-0.12 (-0.19 to -0.05)	0.03 (-0.05 to 0.12)
P>|t|	0.99	0.13	0.85	0.63	0.00	0.42
Sports min/week						
Coef; (95% CI)	0.00 (-0.07 to 0.08)	-0.06 (-0.22 to 0.08)	0.03 (-0.08 to 0.15)	0.03 (-0.03 to 0.09)	-0.13 (-0.23 to -0.03)	0.07 (0.00 to 0.15)
P>|t|	0.86	0.34	0.52	0.24	0.01	0.06
Leisure Activities min/week						
Coef; (95% CI)	0.05 (-0.04 to 0.14)	-0.05 (-0.18 to 0.07)	-0.05 (-0.21 to 0.09)	-0.01 (-0.10 to 0.08)	-0.04 (-0.15 to 0.06)	-0.05 (-0.12 to 0.02)
P>|t|	0.26	0.31	0.40	0.78	0.34	0.13
PE Class min/week						
Coef; (95% CI)	0.07 (-0.16 to 0.32)	0.05 (-0.25 to 0.36)	-0.10 (-0.40 to 0.20)	0.06 (-0.14 to 0.28)	0.06 (-0.49 to 0.62)	-0.05 (-0.38 to 0.27)
P>|t|	0.29	0.53	0.28	0.30	0.50	0.55
Active Commuting min/week						
Coef; (95% CI)	-0.01 (-0.14 to 0.12)	0.00 (-0.19 to 0.20)	-0.04 (-0.16 to 0.08)	0.00 (-0.12 to 0.14)	0.06 (-0.07 to 0.20)	0.00 (-0.12 to 0.14)
P>|t|	0.79	0.99	0.42	0.85	0.22	0.86
*Adjusted by parents' education level, age, state						

7.5 Discussion

In this study, the perception of lower pedestrian safety was associated with lower MVPA and sport participation amongst females. Results of this study suggest that the lack of crosswalks, walking/cycling trails and proper lighting is associated with less MVPA and

sport participation in females by 12% and 13% respectively. This increment of MVPA and Sport participation might be the difference between meeting and not meeting the WHO's physical activity guidelines for some Mexican females.

As in many studies[211, 212], females reported less physical activity than males, and the data reported here suggest that pedestrian safety might be a contributing factor of this, as it is not associated with physical activity in males, but it is in females. It is feasible that the lack of lighting in public spaces generates uneasiness and a feeling of being a target of crime among females. It has previously been shown that the presence of traffic lights is associated with greater active transport among female adolescents[111]. Evidence suggests that accessibility (i.e. how easy it is to get to…) to sport facilities (basketball courts, parks, swimming pools, tennis courts...) is positively associated with the MVPA of female adolescents'[213, 214], further, the total length of walking trails has been associated with greater active transport among this population[111]. Another explanation why perception of pedestrian safety affect females might be previous negative experiences in the neighbourhood or around the city and a sense of risk. It has been suggested that females respond differently to risk-taking behaviours than males. As such, it may be the case that the lack of cycling/walking trails and crosswalks in areas with heavy traffic might be discouraging for females' MVPA and sport involvement[208].

In this study there was no association between active commuting and the perception of safety. This lack of an association could be because in Mexico children have to walk or cycle to school in spite of safety perceptions as their family does not own a private vehicle. Leisure activities might have not shown any association as they are frequently performed indoors or in private areas (e.g. play with pets, rope skipping), while participation in PE class is usually performed inside school or on external school facilities in which cases transport is provided.

In this study a Spanish version of the NEWS-Y scale was used to assess Pedestrian Safety and Crime Safety. While testing the hypothesised factor structure, three items from the Pedestrian Safety subscale, showed weak associations with other items of the same latent

variable and also cross-loaded with Crime Safety. Cross-loading could be explained by the order in which the questions were asked (i.e., one item belonging to Crime Safety is placed in the middle of the Pedestrian Safety items) and participants could have followed a pattern of answers without fully reading the individual items. Future research should test new arrangements of items. Further, although we translated the NEWS-Y items, we did not engage in more extensive piloting or examination of the clarity of the questions in Spanish and these steps are needed in order to develop a more robust measure of Perception of Safety.

In this study, the reported mean physical activity was greater than the WHO's guidelines, this could be due to over-reporting, as it has been suggested that the YPAQ overestimates MVPA by 25.6±50.2 minutes per day (95% CI = 10.4 to 40.9)[215]. On the other hand, a previous cross-sectional study in the same population found similar results to the current study of over-reporting by 143 minutes per day of MVPA in males and 89 minutes per day in females[216]. In terms of percentage of adolescents, 62.35% of males and 55.32% of females met the WHO's guidelines, compared to the 69.9% and 51.2% respectively reported in ENSANUT 2016.

The prevalence of overweight and obesity for males in this study was 26.71% and 6.13% respectively, and 20.46% and 2.85% for females. Comparatively, the latest health survey in Mexico reported a prevalence of overweight and obesity for males of 18.5% and 15% respectively, and females 26.4% and 12.8%. These different values might be explained by the different method of assessing weight and height as ENSANUT (2016) employed trained staff to collect objective measurements (electronic scale and stadiometer) and this study relied on self-reported weight and height which may be biased towards underestimation of body weight and over estimation of height[217].

7.5.1 Strengths and limitations

Among the strengths of the study is the use of a large dataset with complete physical activity information for 4,079 adolescents. In addition, we provided some support for the validity of the NEWS-Y measures of Pedestrian Safety and Crime Safety among Mexican

adolescents. The study is limited by the assessment of perceived safety, as opposed to an objective measure of safety. This limitation is important because perceived safety acknowledges how people feel in their neighbourhood and surroundings in terms of safety, instead of using data provided by the government. The study is also limited by the cross-sectional design that prevents the drawing of conclusions pertaining to the causality of the perception of safety-physical activity relationship. Also, schools were excluded if they were in a very unsafe area, which could lead to an overestimate of perceptions of safety and not be generalizable to unsafe areas.

7.6 Conclusions

Perception of pedestrian safety was negatively associated with MVPA and sport participation in females, there was no association among males. Results from this study suggest that environments with better lighting, crosswalks, walking trails and signals on busy streets could increase females' MVPA and sport participation. More research is needed in the perception of pedestrian safety and crime safety in low-and-middle income countries.

7.7 Implications for the Thesis

Findings from this chapter confirmed that there is a negative association between the perception of pedestrian safety and physical activity in female adolescents. In other words, the lack of appropriate street lighting, crosswalks and walking/cycling trails potentially hinders females' physical activity, showing the importance of the presence of these elements on the Ecological Model to change physical activity behaviour. Furthermore, this chapter showed that there are other elements that are particular to urban areas or present to a much greater extent than in rural areas that are not considered within the urbanicity score and also play a role in the physical activity of the population.

Chapter 8 Discussion

This thesis investigated associations between urbanisation and adults' and adolescents' physical activity in Mexico by addressing three key questions: 1) Is there an association between physical activity, sitting time and urbanicity in an adult population in Mexico? (Chapter 4); 2) What are the associations between different types of physical activity and urbanicity among adolescents in Mexico? (Chapter 6); and 3) What is the impact of the perception of safety on adolescents' physical activity (Chapter 7)? To address these questions, this chapter will bring together the findings from Chapters 4, 6 and 7. This chapter also discusses the implications for future research policy, the strengths and limitations of the work, and provides suggestions for future research in this area. The chapter concludes with a section of self-reflections and insights from my PhD experience.

8.1 Summary of findings

This section comprises the main findings from Chapters 4, 6 and 7 starting with a brief section about the physical activity in adults and adolescents studied in this thesis compared with the latest physical activity data from the Mexican government, followed by the implications of measuring urbanisation in Mexico and its associations with physical activity.

8.1.1 Physical Activity in Mexico

As seen in Chapter 4, adults (18 to 69 years old) reported an average of 255.21 minutes per week of MPA, 117.55 minutes per week of vigorous physical activity VPA, 214.20 minutes per week of walking, and 1,470 minutes per week of sitting time. In Chapter 6, mean values of physical activity for adolescents (15 to 18 years old) were 1,040 minutes per week of MVPA for males and 877.28 for females, 731.07 minutes per week of time spent in sport activities in males and 573.15 in females, 516.52 minutes per week of time spent in leisure activities in males and 608.93 in females, 15.83 minutes per weekday of time spent in PE class for males and 14.70 for females, and 98.62 minutes per weekday spent in active commuting to school in males and 95.11 in females. Consistent with

previous research, these data provide evidence of higher activity in males than females among both adolescents and adults[211, 212].

The results from this study are compared with evidence from previous studies in Table 8-1. Comparisons demonstrate minimal agreement in terms of minutes of physical activity between studies that have used the IPAQ to investigate physical activity levels in both adults and children. The differences might represent a degree of measurement error or could be a result of sampling variation; one study included in Table 8-1 investigated physical activity in females with fibromyalgia[218], which may have implications for physical activity levels. On the other hand, YPAQ shows similar physical activity values across studies among adolescents and the ones obtained in Chapter 6; even though the studies cited on Table 8-1 are not directly comparable to the ones of this thesis due to being from different age groups. Unfortunately, there were not many studies measuring physical activity as "minutes per week" as they used "MET minutes", therefore the information from this table is not a true representation of adults' and adolescents' physical activity information that is available in the literature. The use of minutes per week over MET minutes in this thesis was due to minutes per week being more interpretable than MET minutes, especially for non-specialists.

Preliminary results from the latest health and nutrition survey (ENSANUT 2016)[14], carried out in 2016 by the Mexican government, indicate that 69.9% of male adolescents and 51.2% of female adolescents reported at least 60 minutes of MVPA per week, and 86.2% of male adults and 84.9% of female adults reported at least 150 minutes per week of physical activity. Considering current population health issues in Mexico (e.g. high prevalence of diabetes, hypertension, heart diseases, etc...), and the high amount of sedentary time (approximately 81.8% of time reported from the ENSANUT 2012 survey), the high levels of physical activity reported in the current thesis should be interpreted with caution. Nonetheless, the findings from this thesis provide evidence of the importance of urbanisation in both adults and adolescents' physical activity, as discussed below.

Table 8-1 Physical activity results from other studies using IPAQ and YPAQ

Author	Country of the study	Sample	Measurement used	Physical Activity
Adults				
Van Holle, De Bourdeaudhuij, Deforche, Van Cauwenberg, Van Dyck [219]	Belgium	n = 434 (65y and older)	IPAQ-L	MVPA = 630.1±492.8 (min per week) Total PA = 687.3±577.5 (min per week)
Segura-Jimenez, Munguia-Izquierdo, Camiletti-Moiron, Alvarez-Gallardo, Ortega, Ruiz, Delgado-Fernandez [218]	Spain	n = 183 (mean 51.1±8.2y) * Fibromyalgia patients	IPAQ	**Females** Walking = 96.55 (min per week)
Rosa, Gracia-Marco, Barker, Freitas, Monteiro [220]	Brazil	n = 40 (mean 45±16y)	IPAQ	**Males** LPA = 900 (min per week) MVPA = 60 (min per week) Total PA = 1,134 (min per week) **Females:** LPA = 1,260 (min per week) MVPA = 0.0 (min per week) Total PA = 1,680 (min per week)
Adolescents				
McCrorie, Perez, Ellaway [146]	UK	n = 44 (12 to 13 y)	YPAQ	**Females:** MVPA = 88.44±55.08 (min per day) **Males:** MVPA = 117.76±54.83 (min per day)
Raistenskis, Sidlauskiene, Cerkauskiene, Burokiene, Strukcinskiene, Buckus [221]	Lithuania	n = 532 (11 to 14 y)	YPAQ	**Town:** MVPA = 89.2±83.7 (min per day) **City:** MVPA = 98.5±90.1 (min per day)
Smith, Lewis, Fahy, Eldridge, Taylor, Moore, Clark, Stansfeld, Cummins [222]	UK	n = 3,105 (11 to 12y)	YPAQ	**Females:** PA = 12.6 (11.8 to 13.4) (min per day) **Males:** PA = 14 (13.3 to 14.8) (min per day)

y: years old
PA: physical activity
MVPA: Moderate-to-vigorous physical activity
LPA: Light physical activity
IPAQ: International Physical Activity Questionnaire
IPAQ-L: International Physical Activity Questionnaire Long Version
YPAQ: Youth Physical Activity Questionnaire

8.1.1.1 Physical Activity Assessment: Objective vs. Subjective Measures

As mentioned in Chapters 4, 6 and 7, self-report questionnaires (IPAQ in adults and YPAQ in adolescents) were used to assess physical activity. These subjective measures used in these studies pose several advantages compared to objective measures that could have been used (heart rate measurement, accelerometer, pedometer). The first one is the low cost of their use in data collection as using printed questionnaire copies was cheaper that using accelerometers or pedometer to assess physical activity. Secondly, they were easier to administer and allowed reaching a bigger sample. And thirdly, the physical activity questionnaires allowed the participant to report various types of physical activity according to different settings (i.e. leisure physical activity, walking time, active commuting, time spent in sports etc...), whereas objective measures would have been limited to the number of steps, heart frequency or physical activity intensity (i.e. low, moderate, vigorous). However, there are disadvantages of having used self-reported measures, the first one being recall bias. Recall bias is a systematic error that occurs when participants do not remember previous experiences accurately. Another disadvantage would be overreporting, when participants, intentionally or unintentionally, report behaviours above to their true value and might lead to affecting the validity of self-reports.

It is possible that the choice of outcome measure (self-report questionnaires) is responsible for the high physical activity data reported in this thesis and in addition recall bias should definitely be considered. However, the direction of the associations between urbanicity and perception of safety and physical activity would have likely remained the same as if an objective approach had been used. It is possible that the magnitude of the associations would have been different, but the direction of the associations would have remained equal. Moreover, the physical activity data collected in Chapter 6 and 7 should not be interpreted as a true representation of the physical activity of adolescents in Mexico.

8.1.2 Measuring Urbanisation in Mexico

As outlined in Chapter 2, urbanisation is defined as the "the rate of increase in the proportion of people living in urban areas and the expansion of built-up areas"[72].

Urbanisation is seen as a process, and therefore very hard to measure accurately. However, urbanicity is a static concept that has been defined as "the impact of living in urban areas at a given point in time, the presence of conditions that are particular to urban areas or present to a much greater extent than in non-urban areas"[72]. Therefore, urbanicity can be used to estimate the degree of urbanisation. The urbanicity measure used in the current thesis includes elements that are generally higher in urbanised areas but that are also present in less urbanised areas (population density, economic activity, diversity, education, health services, built environment, communication). It is important to note that whilst it is an extensive measure of urbanicity, there are other conditions that form part of urbanicity that are not incorporated in the urbanicity measure used (e.g. air pollution, substance and drug use, availability of motorised transport and perception of safety etc.) and that might be key for physical activity.

As demonstrated in Chapters 4 and 6, it is possible to measure urbanicity based on the validated urbanicity measure by Novak, Allender, Scarborough, West [77] and using publicly available data from the Mexican Government, with the exception of the diversity sub-score. This has not been done before and therefore the application of this method to national data is an original contribution to the literature. The sub-scores from the urbanicity measure were able to be calculated using state level data information. This was not possible in Chapter 6, in which the need for the urbanicity measure to be more specific drew me to analyse the data at local level, a level at which the information required to calculate the diversity sub-score was not available. A thoughtful review was done between calculating all the urbanicity sub-scores at state level like the study in Chapter 4 or having one sub-score less than the original measure and have local level data. Having a local measure of urbanicity was more important for the study presented in Chapter 6 than having all complete sub-scores at a higher level. It is important to highlight that by doing this the validity of the urbanicity measure might be compromised, but nevertheless the results are extremely valuable for the field and for the Public Health sector in Mexico and Latin America as urbanicity has not been measured quantitively before with the level of specification this scale can provide.

For this thesis the demographic sub-score was modified for both Chapter 4 and 6. The authors of the original urbanicity scale[77] proposed measuring the demographic sub-score by population size, in which specific ranges of amount of people give a certain amount of points, regardless of geographical size of the state. Consequently, this means that higher values of the sub-scale indicate more urbanised areas. Such an approach was deemed in appropriate for measuring urbanicity in Mexico. In some Mexican states a higher population does not necessarily mean that the state is more densely populated. For example, Oaxaca, a state location in the south of Mexico, has a population of 3,970,000 but this is spread across a land size of, 93,757 km^2, equating to approximately 42 people per square kilometre. Using the Novak, Allender, Scarborough, West [77] approach of population, numbers would greatly over inflate the urbanicity of this state. Consequently, an approach that considers land size in combination with population was developed to estimate the demographic sub score of the urbanicity measure. Results were similar in terms of the association of other sub-scores with physical activity, but in terms of the demographic sub-score itself, it presented very different associations (MPA: coef = -17.10, 95% CI=-32.57 to -1.63 in population size vs. no association in population density; walking time: coef = -14.48, 95% CI=-26.99 to -1.97 in population size vs. no association in population density; and sitting time: coef = 17.23, 95% CI=-4.18 to 30.28 in population density vs. no association in population size). However, measuring the demographic sub-score by population density suits better countries with large states with big populations but not necessarily dense populations.

8.1.2.1 Specificity of the Ecological Model in Physical Activity

As mentioned in Chapter 2, urbanisation, as an environmental factor, is one of the essential parts of socio-ecological models. Results from the studies of Chapters 4, 6 and 7 provide a better understanding of the role of urbanisation in the Ecological Model of Active Living[70]. However, this general approach to studying the environmental correlates may underestimate the association between urbanisation and physical activity. In a review, Giles-Corti, Timperio, Bull, Pikora [223] refer to the need for ecological models to be specific to behaviours. This means that it is not enough to study a behaviour in a setting (e.g. physical activity in recreational areas) but to study a specific behaviour within clearly defined environments (e.g. leisure physical activity in parks). Doing so could enhance the inferring capacity of ecological models by making individual and

socio-environmental variables behaviour-specific and contextualised. A downside of specificity of models in physical activity is that they require a thorough review of the literature in order to define the ecological model for a specific behaviour and setting and doing this for every physical activity behaviour and element of urbanicity addressed in this thesis would have bn a task greater than the scope of this PhD. However, hopefully the findings from this thesis can be used to prompt context-specific behaviours for future research in urbanisation.

In addition to possibly underestimating the association between urbanisation and physical activity, the issue of residual confounding on these associations must be considered. There is a possibility that even though the variables of socio-economic status, education level and BMI in Chapter 4, and parents' education level and participants' age in Chapters 6 and 7, were adjusted in the linear regression models, they were not appropriately measured to eliminate their confounding onto the association between physical activity and urbanicity. Moreover, there might be additional confounders (i.e. car ownership) that were not considered and might be influencing the outcome variables.

8.1.3 Associations Between Physical Activity and Urbanicity

In this thesis there was some evidence that urbanicity (as an overall score and sub-score) was associated with physical activity in Mexico, but the magnitude of associations was weak and inconsistent at the sub-score level. This section reviews all the associations from Chapters 4 and 6 separated by sub-score. Some sub-scores had a positive association with physical activity and whereas others had negative associations. This highlights the need to measure urbanicity with a composite scale that allows researchers to look into each sub-scale independently and study its own association with physical activity.

8.1.3.1 Overall Urbanicity

Overall urbanicity had a negative association with MPA and VPA in adults (Chapter 4), a positive association with MVPA in female adolescents and a positive association with PE Class in male and female adolescents (Chapter 6).

In adults, a mean decrease of MPA between 1.44 and 2.08 minutes per week and 2.31 and 3.60 minutes per week of VPA was found with every unit increase of overall urbanicity (MPA by population size: β = -2.08, 95% CI = -3.90 to -0.27; by population density: β = -1.44, 95% CI = -2.71 to -0.17) (VPA by population size: β = -3.60, 95% CI = -5.03 to -2.71; by population density: β = -2.31, 95% CI = -3.31 to -1.32). While this association might seem small, it needs to be remembered that it corresponds to "1" unit increase in the urbanicity scale, meaning that a change of 10 points in urbanicity would mean between 14.4 and 20.8 minutes per week less of MPA for example. Given that the WHO recommends 30 minutes per day, such reduction in physical activity could have serious implication for population health. This negative association is in line with previous international literature. A negative association between urbanicity and physical activity was found in studies from Sri Lanka and India where low physical activity was more likely in a place with high urbanicity activity compared to a place with low urbanicity (males: OR = 3.22; 95% CI = 2.27 to 4.57; females: OR = 2.92; 95% CI = 2.41 to 3.55)[6](males: OR = 3.26, 95% CI = 2.5 to 4.3; females: 4.13; 95% CI = 3.0 to 5.7)[7], in Uganda where urbanicity was associated with an increase of physical inactivity (RR = 1.19, 95% CI = 1.14 to 1.24)[87], and in China there was an increase in odds of 68% in males (OR = 1.07, 95% CI = 1.05 to 1.09) and 51% in females (OR = 1.06, 95% CI = 1.04 to 1.08) of performing light physical activity over heavy physical activity given the mean change in urbanisation over a six years period[120]. Mexico is still a developing country and its association between urbanicity and adults' physical activity is in line with that reported in other developing countries.

Evidence from studies conducted in Belgium[118] and the United States of America[119] found a positive association between urbanicity and physical activity, perhaps because in urban areas of developed countries there is a higher proportion of public areas dedicated to physical activity or the average income is enough to pay access to private gyms and sport clubs. It is worth mentioning that the negative association found in Mexico and other developing countries may change with time, as is the case in China[93]. Longitudinal work has shown differences in physical activity in rural and urban places narrowed over time due to the increase of the individual level income. Perhaps, with more research, governments would decide to narrow even more this difference and invest in public physical activity places in more urbanised areas. Collectively, the evidence suggests that

long-term monitoring of the role of urbanicity is needed to understand associations and the potential for using urbanisation to change behaviour.

The positive association between overall urbanicity and MVPA in female adolescents reported in Chapter 6, which showed an increment of 5% of their mean MVPA per week for every unit increase of overall urbanicity, was an unexpected finding. Contrasting with this result, a study in Portugal found that females in urban places were less physically active than their peers in rural areas, this was the opposite for the males in the study[224]. The positive or negative association between these variables does not seem to follow a trend, with evidence indicating higher physical activity in urban areas in countries like Poland[225], and higher physical activity in rural areas in Brazil[226] and Kenya[91]. This suggests that maybe the association between adolescents' physical activity and urbanicity is unique to the context of the population sampled, as there might be other undetected characteristics specific to the place that might have an effect on physical activity (e.g. culture, climate, SES, etc...).

8.1.3.2 Demographic – Population Density and Population Size

The demographic sub-score essentially measures the amount of people in a place as both population density and as population size. When measured as population size in Chapter 4, it had a negative association with MPA[1] (coef = -17.10, 95% CI = -32.57 to -1.63) and walking (coef = -14.18, 95% CI = -26.99 to -1.97) in adults, and when measured as population density in Chapter 6, it had a positive association with MVPA (coef = 0.06, 95% CI = 0.01 to 0.10) and leisure physical activity (coef = 0.06, 95% CI = 0.00 to 0.12) in female adolescents and a positive association with active commuting to school in male (coef = 0.21, 95% CI = 0.00 to 0.42) and female (coef = 0.28, 95% CI = 0.16 to 0.41) adolescents. It is possible to explain the disparity of the association as a product of the different way the demographic sub-score is being measured. Equally it could be the case that there is a real difference, which reflects the effect the demographic sub-score has in an adult population compared to an adolescent population. Further work is needed to

[1] MPA was calculated in Chapter 4 whereas in Chapter 6 it was MVPA.

investigate these variations and to develop a more appropriate measure of urbanicity that encapsulates demographics more comprehensively.

As reported in Chapter 4, for every unit increase in the demographic sub-score there was a decrease of 17.10 and 14.48 minutes per week of MPA and walking time in adult males and females, and an increase of 17.23 minutes per week of sitting time. Previous research in adults has shown different results regarding the association between population size or density with physical activity. In the Black Women's Health Study, women who moved to less dense neighbourhoods were more likely to report decreased levels of utilitarian walking (OR = 1.36, 95% CI = 1.14 to 1.62)[227], while results from the Twin Cities Walking Study reported increased odds of travel walking in higher density areas (OR = 1.99, 95% CI = 1.29 to 3.06)[228]. Opposing this finding, a negative association between higher residential density and physical activity has been reported in an urban multi-ethnic sample of adults (beta coefficient = -0.03, SE = 0.01, p = 0.01)[229]. It is important to highlight, however that these studies are not directly comparable with the results of this thesis as they measure neighbourhood or household density rather than population density but could give a proxy measure.

Unlike the results in adults, there was a positive association of densely populated areas with MPVA and leisure physical activity in female adolescents, and with active commuting in female and male adolescents in Chapter 6. A possible explanation for this positive association could relate to the higher concentration of school and public facilities in highly populated areas, which may make it easier to either actively commute to school or to nearby recreational spaces. A similar positive association has been found in studies in developed countries in which adolescents living in more densely populated areas had greater odds of active commuting (χ^2 (df = 3) = 839.64, p < 0.001) than their peers living in areas with less population density[186]. Moreover, evidence suggests that living in rural areas lowers the chance of walking (females: OR = 0.29, 95% CI = 0.18 to 0.50; males: OR = 0.54, 95% CI = 0.32 to 0.93) and cycling (females: OR = 0.12, 95% CI = 0.06 to 0.24; males: OR = 0.34, 95% CI = 0.21 to 0.56) compared to living in cities[187]. In contrast, research in a population of Chinese adolescents show residential density negatively associated with recreational physical activity (OR = 0.64, 95% CI = 0.42 to

0.97)[230]. Moreover, a negative association has been found in previous research in Mexico where adolescents from urban areas were 32% less likely (p = 0.027) to engage in active commuting than adolescents from rural areas[188]. The difference in findings from previous research conducted in Mexico and those reported in Chapter 6 might be explained by the difference in the urbanicity measure used; the previous study had an urban-rural dichotomy approach, whereas findings reported in this thesis were found using a composite urbanicity subscale. Another possibility could be that the samples in question represent different groups of adolescents or differ in time. Either way, more work is needed to further understand the association between population density and physical activity in adolescents.

8.1.3.3 Built Environment

The built environment sub-score measures the number of paved roads, sewage services, availability of flushing toilets and electricity (with a high score indicating greater or more progressed urbanicity). The built environment sub-score had a positive association with adults' VPA in Chapter 4, and a negative association with sport participation in females and sport participation in adolescents from Oaxaca in Chapter 6. In adults (Chapter 4), every unit increase of the built environment sub-score was associated with a mean increase between 12.35 and 14.75 minutes of VPA per week. This finding supports previous literature, in which the presence of certain elements of the built environment (e.g., pavements, public lighting) were positively related to adults' physical activity[130]. It should be noted, that the majority of papers cited were based on samples living in developed countries in which the built environment measure included elements such as the presence of enjoyable sceneries, adequate roads for cycling/walking, elements that are related to "desired" aspects of the built environment that are expected to promote physical activity.

In female adolescents (Chapter 6), every unit increase of the built environment was associated with a decrease of 7% of time spent in sport. A possible explanation for this is that places with rapidly growing urbanisation do not consider the accessibility of sport centres as part of their urban development plan. Studies in China, a country with similar fast urbanisation development compared to Mexico, have found that difficult access to

sport facilities and community recreational facilities (i.e. lack of sidewalks) diminish sport participation and physical activity in both male and female adolescents[102]. However, this association might only be happening in the female population in Mexico, where lack of paved roads and street lighting inhibit their sport participation. Evidence suggests that female adolescents who experience difficulty to access their nearest gym (i.e., living further away from it) are less likely to engage in indoor sport activities[231].

In male and female adolescents living in Oaxaca (urbanicity score: 39.70, from a 0 to 70 scales), every unit increase in the built environment scale was associated with an 8% decrease of time spent doing sport, no association was found in Mexico City. Regarding the result obtained between overall urbanicity and time spent in sport in the two states, in which there was a positive association in Mexico City but a negative association in Oaxaca, suggests that perhaps the built environment sub-score is acting as a proxy measure of urbanicity and that is having the same effect on sport participation as overall urbanicity has. As explained in Chapter 6, section 6.5, the direction of the association between overall urbanicity and participation in sport depends on the state. Oaxaca has a lower density of sport facilities per square kilometre than Mexico City (0.01 vs. 2.30). Evidence suggests that perceived availability of sports is positively associated with being sufficiently active[232] and increasing the perceived availability of sport facilities predicts more leisure-time physical activity in adolescents[233].

8.1.3.4 Communication

Communication based urbanicity relates to the amount of televisions, computers and mobile phones within households as well as internet availability and pay phones on roads. Communication based urbanicity was negatively associated with MPA and VPA in adults and negatively associated to leisure time physical activity in female and male adolescents, and negatively associated to active communing in males. Only one positive association was found, sport participation in males. In adolescents, the negative association between leisure time physical activity and active commuting has previously been found in similar studies where watching TV diminished the time spent in leisure physical activity amongst Taiwanese adolescents[181]. Also, even though there is no previous evidence that directly associates household electronic media presence with active commuting, electronic media

is negatively associated with sleep quality[182-184], and adequate sleep duration is associated with greater active commuting to school in adolescents[185].

8.1.3.5 Economic Activity, Diversity, Education and Health

There was little evidence to suggest that the urbanicity indicators of economic activity, diversity, education and health were associated with physical activity. In most cases this association was not present after adjusting for the other indicators of urbanicity. Therefore, it is likely these associations are merely proxy measures of other sub-scores like the built environment and by themselves are unimportant. In summary, economic activity and diversity had a negative association with VPA and walking in adults, respectively; while the presence of school facilities had a positive association with walking in adults. In terms of the health sub-score, the presence of health-related buildings and medical personnel had a positive association with sitting time in adults, a positive association with physical activity during PE class in adolescents, and a negative association with leisure physical activity in male adolescents. Furthermore, the education and health sub-scores are related to the built environment by taking into account the presence of buildings; consequently, its association with physical activity might be due to this similarity of measure.

8.1.4 Association Between Physical Activity and Perception of Safety

There was evidence that perception of pedestrian safety was associated with MVPA and sport activity in female adolescents. Results from this thesis suggest that the lack of crosswalks, walking/cycling trails, and proper lighting are associated with 12% less MVPA and 13% less sport participation among female adolescents. Various factors might explain this finding, for example feelings of being a target in public spaces with lack of lighting, mobility being hindered by the lack of crosswalks, not enough accessibility to sport facilities, and a possible unwillingness to engage in risk-taking behaviours like cycling and walking in areas with heavy traffic. As these findings are discussed in greater depth and compared and contrasted to previous literature in Chapter 7, this in not repeated here.

8.2 Implications for Research

The findings presented in this thesis build upon previous research and provide an insight into the role urbanisation plays in adult and adolescent physical activity. There are four main research implications that can derive from the findings reported in this thesis (Figure 8-1). The first implication relates to the use of urbanicity to measure urbanisation. Until now, it was common to think that urbanisation had a negative impact on physical activity[89-91]. This belief might be product of an instant association of urbanisation with the built environment, which in part and as mentioned throughout this chapter, is true. However, such a belief may not accurately represent the wider and more complex picture. Urbanisation goes beyond the built environment and the presence of paved roads, households with electricity service and availability of sewage services. Urbanisation is a collective of different elements which all affect the way individuals perceive their environment, and subsequently the way they behave. Considering urbanisation as a multi-faceted construct fills the current gaps in research regarding wider correlates of health-related behaviours such as the social, economic and physical environment. This approach extends beyond the dichotomised measure of urban and rural and makes a unique contribution to the literature.

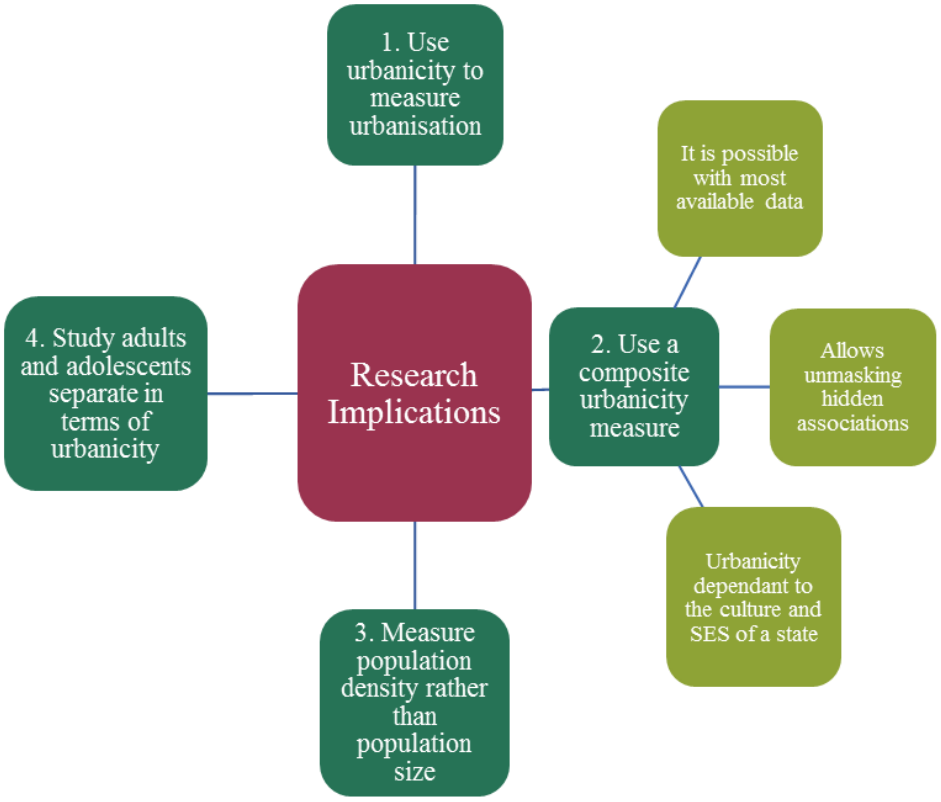


Figure 8-1 Main Research Implications of the Thesis

The second research implication relates to the use of Mexican population data which could be considered a methodological advancement. Using large datasets collected by the government allowed for an in-depth exploration of urbanicity and its impact on PA. Such an approach could be applicable to other countries with open government data sources and similar cultural background to Mexico, such as El Salvador, Nicaragua, Colombia, Brazil, Peru, Argentina and Uruguay[234]. Moreover, it is important to understand that overall urbanicity might have a different association with physical activity than, in some cases, its sub-scores with physical activity as was shown in Chapters 4 and 6. If this is the case, future research should consider the use of a multidimensional measure of urbanicity, which allows research to study individual associations between sub-scores and physical activity. Such an approach would avoid measures of overall urbanicity that potentially mask the component effects. Furthermore, urbanicity is dependent on cultural and socioeconomical factors of a place[235], therefore it may be more appropriate to measure it

by state or by an area with similar background and collate information if and when necessary.

The third research implication is the need to consider whether to measure population density instead of population size in urbanicity related studies. As discussed above (section 8.1.2), countries with state divisions that have several large territories might not be well suited to a population size measurement as their natural large population size would give them a high urbanicity score despite the population being widely spread. Population density measures address this problem by measuring the amount of people per km^2 and assigning high density population areas with high urbanicity. The work of this thesis suggests the use of population density over population size when assessing the demographic aspect of a country.

The fourth research implication is that the impacts of urbanicity on physical activity may not be the same for adults and adolescents. Findings from this thesis showed that adults and adolescents do not share the same associations with urbanicity and their sub-scores, therefore keeping them separate in urbanicity studies might avoid confounding results, also, age-specific studies are needed in the future.

The work presented here highlights the need for future research to investigate the impact of urbanicity on PA. Whilst not comprehensive of all the work required, Table 8-2 outlines several suggestions for future research. Firstly, there is a need for a prospective study that investigates the changes of physical activity on adults and adolescents moving from a less urbanised area to a more urbanised one. Secondly, a multilevel approach could be used to account for the effect of hierarchical structures of urbanicity (state, municipality, locality, set of blocks, individual physical activity). Finally, the field of research would benefit from using qualitative methods to explore how perception of safety, and whether particular safety concerns, impacts on physical activity choices and behaviours.

Table 8-2 New Research Studies that Findings Might Inspire

	Description of Study	***Type***
1	Study the effect of exposure to high urbanicity on the decrease of physical activity in adults and adolescents	Prospective Study
2	Use multilevel analysis to study urbanisation and physical activity.	Quantitative
3	Explore other features from the environment that make female adolescents feel unsafe.	Qualitative

8.3 Implications for Policy

The main aim of the thesis was to address the lack of research evidence regarding the impact of urbanisation on physical activity in Mexico. To do so, a composite scale of urbanicity was used to measure the environment and study its association with physical activity. Also, perception of safety, a component of urbanisation currently not considered in the urbanicity scale, was measured and its association with physical activity was studied. The results from Chapters 4, 6 and 7 show that it is possible to measure urbanisation and that it is associated with physical activity. In terms of projecting the results to other settings, generalisability of the findings must be done with care considering that the sample used in studies from Chapters 6 and 7 is not representative and poses selection bias (explained in 6.5 Discussion). However, the sample used in Chapter 4 is representative at state level and was initially randomly selected by the government, suggesting that the association between urbanicity and adults' physical activity might be true to the population. Nevertheless, the acknowledgement of unaccounted confounders in its analysis should be considered when generalising the results to the adult population in the country and to other countries that share a similar cultural, political and economic background with Mexico.

The findings of the thesis that fit directly within current Government Strategies at National and Local level are presented in Table 8-3 with their contributions to the health

programmes, while a list of other strategies that do not necessarily fit within the current health and wellbeing plan but could be used to promote physical activity among the Mexican population are showed in Figure 8-2.

Table 8-3 Summary of Thesis Implications for Policy in Mexico

<table>
<tr><th>Finding</th><th>Programme</th><th colspan="2">What is the programme about?</th><th>Implication</th></tr>
<tr><td rowspan="2">1. Elements of the environment like good street lighting, the presence of crosswalks and signals might increase MVPA and sport participation in female adolescents (part of perception of safety).</td><td rowspan="2">National Level Secretariat of Health (Mexico)
The Food and Physical Activity Programme (2013 – 2018)</td><td rowspan="2">The creation of clean, safe, and accessible “healthy environments” through:</td><td>1. Adequate infrastructure: Public spaces for physical activity (e.g. parks, gyms, sport centres, pits...)</td><td>- Invest in adequate signalling of public spaces and promote the importance of proper lighting.</td></tr>
<tr><td>2. Functional walking/cycling routes</td><td rowspan="2">- Stress the importance of lighting, crosswalks and signals in walking/cycling routes likely used to access public spaces intended to physical activity.
- Link public spaces destined to sport and physical activity through cycling/walking trails → “Active Space Network”.</td></tr>
<tr><td rowspan="4">State Level (Mexico City) Get Moving and Take Care of Yourself (launched 2008).</td><td rowspan="4">Prevention and treatment of overweight and obesity through health prevention actions</td><td>1. Move in the Park:
- Provide free activities in parks and public areas (yoga, Zumba, kick boxing...)</td></tr>
<tr><td>2. Population density positively associated with active commuting</td><td>2. Move around the City:
- Night rides
- Cycling classes
- Sunday rides</td><td>- Encourage the population to cycle as a way to commute to school/work, rather than a leisure activity.
- Implement the campaign in other states with high population density.</td></tr>
<tr><td>3. PE class is a possible way to increase physical activity in adolescents living in low urbanicity areas</td><td rowspan="2">3. Move at School:
- Participation in exercise routines and physical activity at school.
- Monthly sport tournaments and sport events.</td><td>- Design and monitor the general structure and minimum requirements of a PE class and train personnel to deliver it.
- Treat PE class as an important way to increase total physical activity in areas with low urbanicity.</td></tr>
<tr><td>4. The presence of electronic devices is negatively associated with active commuting to school in male adolescents and leisure physical activities in male and female adolescents</td><td>- Include the concept “Move <u>to</u> school” in the campaign, promote active commuting.
- Campaign of the presence of electronic media in modern life and how is affecting physical activity.</td></tr>
</table>

The work reported in this thesis could have implications at a national level and could be used to inform the Food and Physical Activity Programme (2013 – 2018) of the Secretariat of Health (Mexico). This programme seeks the improvement of nutritional and physical activity habits of the population by promoting and encouraging healthy lifestyles. The complete objectives and all strategies of the programme can be found in Chapter 2. In terms of physical activity, it aims to create "healthy environments" by creating, developing and maintaining adequate infrastructure and functional active commuting routes. Based on the Government response, these elements should at least include appropriate street lighting, cleanness, vigilance, universal access, pavement in good condition and signalling. Findings from this thesis point out that elements of the environment, such as good levels of street lighting and the presence of crosswalks and signals, might help to increase moderate-to-vigorous physical activity and sport participation in female adolescents as they contribute to the perception of safety. This could mean that providing safe spaces for physical activity and recreation is as important as the infrastructure is to active commuting to these spaces. Currently, there are walking and cycling routes available in Mexico, but they are uncommon and tend not to link with public spaces designed to encourage physical activity and recreation. One action point is to improve this connectivity and to make walking and cycling routes clearer, perhaps by creating an "active space network" with all the public spaces for physical activity and recreation sites with the routes to get there. Furthermore, there is also a need to invest in adequate signalling of public spaces and stress the importance of proper lighting.

The second contribution of the thesis to policy, is at state level in the plan "Get Moving and Take Care of Yourself" (In Spanish: "Muevete y metete en cintura") launched in 2008 in Mexico City. The campaign seeks to influence the modification of the determinants of overweight, obesity and sedentarism, and encourage the incorporation of physical activity in the daily life of the community. The campaign encourages strategies for different settings, including "Move in parks", "Moving around the City", and "Move at School".

Move at the Park provides free physical activity classes (e.g. Zumba, yoga, kick boxing, etc...) once a week at different parks in Mexico City. The attendance to these events

might increase if walking/cycling routes and street elements such as proper lighting, crosswalks and signals are improved. Findings from this thesis suggest that these elements might increase physical activity and sport participation in female adolescents by creating a better perception of a safe environment, therefore their presence might be key for increasing female participation in the Move at the Park campaign.

Move around the City encourages people to cycle around the city by organising "night rides", facilitating cycling classes and closing main avenues in the city for the weekly "Sunday ride". These events have become very popular in Mexico City. Findings from this thesis align with the popularity of this programme; adolescents living in places with higher density are more likely to actively commute to school. This could be an inspiration for other states with high population density to develop and include a cycling program as part of their health policy to increase physical activity in the population.

Move at School seeks participation from children and adolescents in exercise routines and physical activity at school through weekly PE classes and monthly sport tournaments. Findings from the thesis report PE class as a possible way to increase physical activity in adolescents living in places with low urbanicity. Local authorities should design and monitor the minimum requirements and general structure of a PE class and train personnel to deliver it. Also, it should be stressed to schools in low urbanicity areas the importance of PE class in the health of their students. Moreover, within school strategies, it would be a good idea to introduce the concept "Move to school" to promote active commuting to school in line with findings from this thesis along with an audit of active commuting infrastructure for and around schools. At the moment there are no school policies about this.

Another point that needs to be included within school health policies is the presence of electronic media and how it affects physical activity in adolescents. According to findings from the thesis, electronic devices are negatively associated with active commuting to school and leisure physical activity. Campaigns from local governments in Chile[236] have been informing in schools the detrimental effect of mobile phones in learning and France

is, at the time of writing, considering a ban at schools, but the impact on physical activity has not yet been addressed. Therefore, the implications for policy from this thesis are to provide support to the Move at School program by stressing the importance of PE class, to suggest the promotion of active commuting to school and audit related infrastructure, and to add an awareness campaign about the health impact of the use of gadgets at school.

The implications discussed above relate to programmes that are currently happening in Mexico that could be complemented and enriched with the findings reported in this thesis. Other strategies that could be useful to promote physical activity among the Mexican population are mentioned in Figure 8-2. The first one refers to help people think about how their environment might be influencing their behaviour and the impact on their physical activity. The Secretariat of Health in Mexico can put this point across by including the urbanisation factor in public health campaigns or even in the National Day of Physical Activity in Mexico (6th of April). At the moment these physical activity and health campaigns do not include urbanisation as a potential correlate of physical activity.

The second strategy is to increase the number of pavements, street lights, improve safety in the streets and building safe paths to school to force the environment to change in ways that support healthier living. For example, safe street environments might inspire weekly group runs, weekend walks, "walk buses" to school, active play groups at parks and more. A similar approach has been taken by some cities in Europe, for example, Istanbul makes some streets only accessible for pedestrians between 10:00 am and 6:00 pm; Moscow has been transforming places, once intended for cars, into places for people; Ljubljana in Slovenia has closed one of its main avenues to motor traffic; and Barcelona has introduced the "superblocks" which are groups of block areas where traffic is limited to their boundaries whereas within them they are restricted to pedestrians[237]. Exploring these opportunities in an informal way with people from the same neighbourhood, university or workplace could play an essential role in increasing physical activity at an immediate local level.

The third strategy is to create an app with all the cycling routes and how they can be paired with public transport services. At the moment, the app "EcoBike" (EcoBici in Spanish) allows users to check availability of bikes and cycling stations and facilitates cycling routes but without linking the cycling experience to the public transport system in Mexico. It is unusual that the daily commute of a person in Mexico City can be achieved entirely by cycling due the size of the city and the sparse availability of cycling routes. Most of the time cycling has to be paired with another type of transport system (e.g. tube, bus, etc...). Having one single app that combines the availability of cycling routes with the availability of other type of transport might be more appealing for the population and might inspire active commute for at least one part of their daily journey, and by so, probably increasing their daily physical activity.

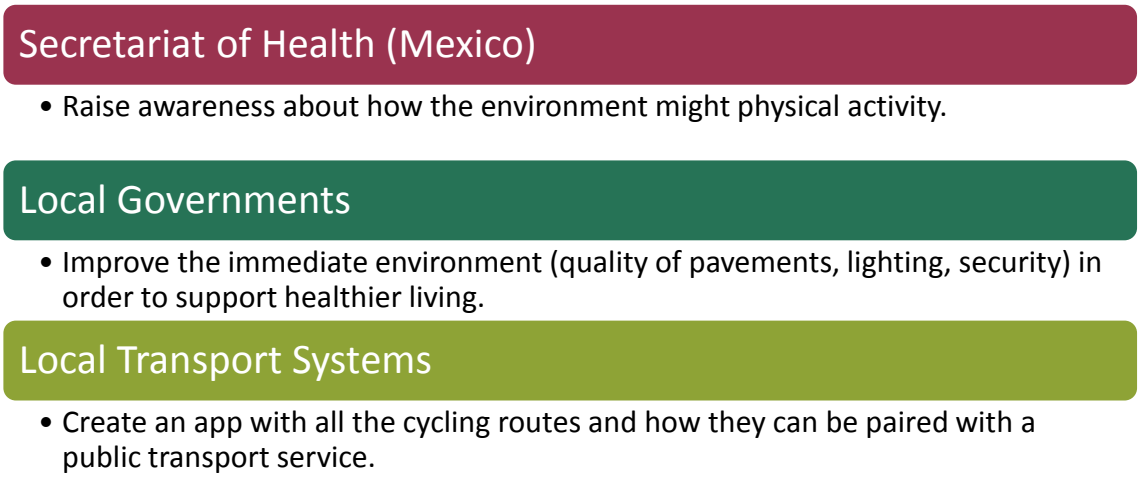


Figure 8-2 National and Local Health Strategies inspired from findings of this thesis

8.3.1 Global Action Plan on Physical Activity by the WHO

The Global Action Plan of Physical Activity (GAPPA) by the WHO aims to reduce physical inactivity of the population by 15% by 2030 through a system-based approach of four objectives (described in Chapter 2, section 2.1.3). Findings of this thesis provide valuable information of the role of urbanisation in adults' and adolescents' physical activity that could be used to accomplish objectives *1. Create an active society* and *2. Create active environments* from the global action plan. The strategies of *"Create an active society"* seek to create awareness and knowledge about physical activity and sedentary behaviour. As seen in the current thesis in Chapters 4 and 6, there are several

elements of urbanisation that either enhance or diminish physical activity, sometimes differing between gender and population (adults vs. adolescents). It is important that these elements are considered when planning communication campaigns and mass participation events as proposed in the GAPPA. For example, the use of electronic devices is negatively associated with leisure physical activity in adolescents (Chapter 6, section 6.4), so a physical activity campaign in adolescents could raise awareness about the excessive use of electronic devices and their role in sedentary lifestyles. The second objective *"Create active environments"*, refers to integrating transport and urban planning policies, improving active commuting networks and strengthening road safety.

Findings from Chapter 6 showed that adolescents actively commute in densely habited places. There is opportunity to enhance this behaviour in adolescents by providing trails and paths that join in a commuting network. Regarding road safety, as seen on Chapter 7, perceived road safety could increase physical activity in females. Therefore, ensuring safety of places destined to recreation and exercise and their connecting paths and trails is key for increasing physical activity in adolescents.

8.4 Strengths and Limitations

There are three main strengths of the work reported in this thesis. The first strength of the thesis is the use of two large samples. The first one in Chapter 4, referred to the national sample taken by the Government in 2012, which is representative of Mexico at state level. The second sample used in Chapter 6 corresponded to a population that has not been fully studied in Mexico up to date: adolescents. This large data set was gathered from schools from different locations in Mexico City and Oaxaca; aiming to have one school from each municipality/zone. Moreover, by using multiple imputation approaches it was possible to create complete physical activity data for all participants.

The second strength of the current thesis is the use of a composite tool to measure urbanicity. This measure goes beyond the urban-rural definition and gives a better understanding of the context of the location that is being measured by using different databases from the Mexican Government. The urbanicity score can be used regardless of

the size of the place if the demographic sub-score is calculated as population density (as done in Chapters 4 and 6) and not as population size. The differentiation of sub-scores within the urbanicity score enables the association of each one of them to an outcome and study its own positive or negative impact. In the case of physical activity, studying these sub-scores separately prevented the potential masking of associations that could have occurred if only the overall score had been considered. Finally, the third strength is the use of a subjective measure of perception of safety that accounts for how the adolescents feel in their surroundings instead of using data of incidence of crime and amount of road signs and light posts that might not necessarily represent the perception of safety of the population.

Despite these strengths, the cross-sectional design of all studies prevents an unequivocal understanding of the true urbanicity-physical activity association due to causality. Also, there is the possibility of self-reported physical activity being over-reported by adults and adolescents. Moreover, the use of the IPAQ, as in Chapter 4, in populations in developing countries has been questioned before[136]. Ideally, it would have been desirable to use objective measures for the assessment of physical activity, but this was not possible due to limited funding for this thesis. Regarding data quality in Chapter 4, it is important to recognise that even though random checks of scanned questionnaires with the database were performed, and that the procedures and methods for computing the urbanicity measure where documented; data quality could have been better assured by having access to data collection protocols from the government, obtaining proof that the staff in charge of data collection were trained to perform that task, and that there was a data entry quality control (i.e. double data entry). Without this, quality of the data used in Chapter 4 can only be guaranteed to an extent. It is also important to highlight that the sample for Chapter 6 and 7 was limited to public school students between 15 and 18 years old. As 10% of pupils attend private schools[238], this might mean that the sample is under-representative of this demographic. The sample was also limited as no data was collected from areas in Mexico City and Oaxaca considered as unsafe as it would risk the researcher's safety. This might have implications for the variability of the urbanicity measure and results not being generalizable to unsafe areas, but most importantly, could lead to an overestimate of perceptions of safety in Chapter 7.

8.5 Self-reflections

Initially, when designing the first study in Chapter 4, I did not know whether there was going to be an association between urbanicity and physical activity in Mexico nor whether it was going to be possible to use the urbanicity scale by Novak in Mexico. Therefore, I see my first paper as an exploratory work that examined if there was something there that needed more study. Because of this, the design of my second study (Chapter 6) was done after having results from study one and realising how to improve the study design by using local level data for the assessment of urbanicity. The idea of being able to give each individual its own urbanicity values was very exciting and represented a big challenge for two reasons: first, the success of locating each participant in its household area relied on him/her providing their full address, information difficult to obtain because of a cultural perception of unsafety/mistrust. Second, once the full address was available, I had to learn how to use the government programme to localise the Basic Geographical Area code of each participant using their address in order to link that location with the data used from the Census to calculate the urbanicity sub-scores. This process was done manually for each one of the 4,079 participants.

In terms of physical activity assessment, I initially started using data from the ENSANUT, which used the IPAQ to assess physical activity, reported as minutes per week. My experience with this is that on several occasions when I was getting familiar with the database, realising the limitations of self-report, it specifically became clear that some participants did not understand what was actually being asked. It is possible that the translation of the IPAQ to Spanish is not clear enough for the Mexican population and might need improvement or to include the participation of a facilitator who takes time to fully explain what is being asked. I understand this could have been a major task for a large sample like the one from ENSANUT (n= 2,880) but I wanted to avoid this issue with the data I was going to collect for Chapter 6. Therefore, I decided to investigate other self-report tools to measure the physical activity of adolescents. I found the YPAQ to be a convenient tool for the information I wanted to know and for the delivery of the questionnaire. Besides the acceptable reliability and validity of the questionnaire, the arrangement of the questions and their syntax is very straight forward and easy for the

participants to understand. This was going to prove to be an advantage when giving the questionnaire to complete to auditoriums full of students (over 200) and with not enough time to pay individual attention to any of the possible questions.

A further reflection on my experience in schools is that most of the times teachers and headmasters expressed their concerns about their students not being able to have the minimum requirements of physical activity and the possible ways to help them. Some of them even sought advice on how to address this issue with local authorities. This demonstrated that there is an undeniable interest in improving health through physical activity as a result of recent public health campaigns from the government but there is still a lack of information about the individual, or in this case school strategies, to improve health and wellbeing of people. I hope that findings from this thesis can contribute to addressing these questions and fill some gaps in missing knowledge.

8.6 Conclusions

The aim of this thesis was to study the association between urbanisation (measured as urbanicity and perception of safety) and adults' and adolescents' physical activity in Mexico. The findings demonstrate that some aspects of urbanisation are associated with some types or intensities of physical activity, but these are not uniform in their direction or strength and can be moderated by age, gender and geographical location. As such, the findings highlight the complexity in understanding these associations but the important role that urbanisation can plan in physical activity in Mexico.

Future research can rely on the use of urbanicity as a proxy measure for urbanisation, and a composite measure is advisable to capture the unique cultural and socioeconomical factors of a state. Moreover, it is recommended to use population density rather than population size in urbanicity-related studies, especially in areas where the variation of geographical area of studied municipalities or zones varies greatly.

Some of the current public health strategies at national and local level are reinforced by findings of this thesis. The need of adequate and functional infrastructure for physical activity, investing in street elements that increase perception of safety in women, the demand of walking and cycling paths, and the need of school campaigns promoting active commuting and moderation of electronic media should all be part of the current health policy in Mexico to increase physical activity on its population.

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List of Appendix

Appendix A Urbanicity Scale Manual

1. DEMOGRAPHIC

1.1. POPULATION SIZE

Description: How many people (including children) live in this locality?

1 – 500 ……..….. 1 point
501 – 1000 ……..... 2 points
1001 – 2000 ……..... 3 points
2001 – 4000 ……..... 4 points
4001 – 6000 ……..... 5 points
6001 – 8000 ……..... 6 points
8001 – 10,000 ……..... 7 points
10,001 – 15,000 ……..... 8 points
15,001 – 20,000 ……..... 9 points
> 20,000 ……..... 10 points

1.1. POPULATION DENSITY

Description: Number of people per unit area.

0 – 10 ..... 1 point
11 – 30 ..... 2 points
31 – 70..... 3 points
71 – 150 ..... 4 points
151 – 310 ..... 5 points
311 – 630 ..... 6 points
631 – 1,270 ..... 7 points
1,271 – 2,550 ..... 8 points
2,551 – 5,110 ..... 9 points
> 5,110 .....10 points

2. ECNONOMIC ACTIVITY

Description: Percentage of population involved in agriculture as a primary occupation (PIA%).

$$Economic\ Activity\ = \frac{100\% - PIA\%}{10}$$

Example:

42% of the population are involved in agriculture as primary occupation.

$$Economic\ Activity\ = \frac{100\% - 42\%}{10}$$

$$Economic\ Activity\ = 5.8$$

The score for "Economic Activity" is **5.8**

3. BUILT ENVIRONMENT

3.1.Paved Roads

Description: Overall blocks with paved roads (Pvdrd) in all roads.

If Pvdrd% > than 50% then 2 points
If Pvdrd% < than 50% then 1 point

3.2.Sewage Services

Description: Habited households with sewage (Hs).

If Hs% > than 90% then 2 points
If 40% < Hs% < 90% then 1 point
If Hs% < than 40% then 0 points

3.3.Availability of Flush Toilet

Description: Habited households with flush toilet (Hft).

$$Proportion\ of\ Hft\ = \frac{2(HFT\%)}{100}$$

3.4.Electricity Service

Description: Habited households with electricity service (Hes).

If Hes% > than 66.6% then 2 points
If 33.3% < Hes% < 66.6% then 1 point
If Hes% < than 33.3% then 0 points

3.5.Availability of electricity

Description: Habited households with electricity (He).

$$Proportion\ of\ He\ = \frac{2(He\%)}{100}$$

4. COMMUNICATION

4.1. TV availability

Description: Habited households with television (Htv).

$$Proportion\ of\ Htv\ = \frac{2(Htv\%)}{100}$$

4.2. Mobile phone availability

Description: Habited households with at least one mobile phone (Hmp).

$$Proportion\ of\ Htv\ = \frac{2(Hmp\%)}{100}$$

4.3. Internet availability

Description: Habited households with internet (Hi).

$$Proportion\ of\ Htv\ = \frac{2(Hi\%)}{100}$$

4.4. Public telephone

Description: Public telephones per block (Pt)

If Pt% > than 50% then 4 points
If Pt% < than 50% then 2 points

5. Education

5.1.Educational facilities in locality: Nursery and/or preschool (EFpresch)

Description: Number of nurseries and/or preschools in locality per borough.

$$EFpresch\ = \frac{number\ of\ localities\ with\ nursery * 2}{total\ of\ localities\ by\ borough}$$

5.2.Educational facilities in locality: Primary school (EFpsch)

Description: Number of primary schools in locality per borough.

$$EFpsch = \frac{number\ of\ localities\ with\ primary\ school * 2}{total\ of\ localities\ by\ borough}$$

5.3.Educational facilities in locality: Secondary school (EFssch)

Description: Number of secondary schools in locality per borough.

$$EFssch = \frac{number\ of\ localities\ with\ secondary\ school * 2}{total\ of\ localities\ by\ borough}$$

5.4.Educational facilities in locality: University (undergraduate and graduate) (EFuni)

Description: Number universities in locality per borough, including undergraduate and graduate centres.

$$EFuni = \frac{number\ of\ localities\ with\ university * 2}{total\ of\ localities\ by\ borough}$$

5.5.Women's education score (WE)

Description: Overall years of women's education (aged 15-130).

$$WE = \frac{Overall\ years\ of\ women's\ education * 2}{17}$$

**Maximum amount of years of study*

6. Diversity

Habited households with floor made of ground

hh_fg: habited households with floor made of ground

If hh_fg% > than 25% then 1 point
If 5% < hh_fg% < 25% then 2 points
If hh_fg% < than 5% then 3 points

Habited households with floor made of a material different to ground (tiles, wood, concrete...) (%hh_fo)

If hh_fo% > than 70% then 3 points
If 50% < hh_fo% < 70% then 2 points
If hh_fo% < than 50% then 1 point
Habitants per room (HperR)

If HperR > than 2 then 1 point
If 1.5 < HperR < 2 then 2 points
If 1 < HperR < 1.5 then 3 points
If HperR < than 1 then 4 points

7. Health

7.1.Doctors per habitant (docperH)

If docperH > than 4 then 2 points
If 1 < docperH < 4 then 1 point
If docperH < 1 then 0 points

7.2.Medical units

Amount of hospitals, clinics, health centres per 100,000 habitants (Mu).
If Mu ≥ 2 then 4 points
If 1 ≤ MU < 2 then 3 points
If 0.7 ≤ MU < 1 then 2 points
If Mu < 0.7 then 1 point

7.3.Access to health services (4 pts)

$$\frac{\boldsymbol{Population\ size} * \mathbf{4}}{\boldsymbol{Population\ with\ access\ to\ health\ services}}$$

Appendix B Ethics Approval Letter

School for Policy Studies

University of BRISTOL

8 Priory Road
Bristol BS8 1TZ
Tel: +44 (0)117 954 6755
Fax: +44 (0)117 954 6756
bristol.ac.uk/sps

8 February 2016

School for Policy Studies
University of Bristol
8 Priory Road

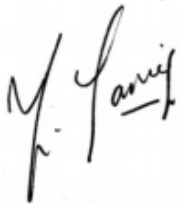
Dear Maria Hermosillo Gallardo

Title: Physical activity, sedentary behaviour and urbanisation in adolescents (SPSREC14-15.A55)

The School for Policy Studies Research Ethics Committee has reviewed your application with regard to this project and we have received your responses to our requests for clarification. As such I am happy to provide REC approval for this project.

Please do not hesitate to contact me if you have any queries.

Yours sincerely



(on behalf of)

Beth Tarleton
Chair of the SPS Research Ethics Committee

Appendix C Recruitment Letter to Schools

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road
Tel: +44 (0)117 954 6755
maria.hermosillo@bristol.ac.uk

PHYSICAL ACTIVITY, SEDENTARY BEHAVIOUR AND URBANISATION STUDY

Dear [name of school],

My name is Maria Hermosillo, I am a Mexican student funded by Conacyt to study for a PhD in The Centre for Exercise, Nutrition and Health Sciences in the School for Policy Studies at the University of Bristol in England. I am conducting research to better understand physical activity and sedentary behaviour study among older adolescents in Mexico City and the state of Oaxaca. We are inviting [name of the school] to take part in this research study.

This project will provide valuable information about adolescents' physical activity and sedentary behaviour and how they might be affected by where they live. Results from this study might be helpful for future research and for future urban planning.

The project is being carried out by Ms Maria Hermosillo, who is a PhD candidate in Health and Well-being at the University of Bristol. The project is supervised by Professor Russ Jago and Dr Simon Sebire and has received ethical approval from the School for Policy Studies Research Ethics Committee.

Please take time to read the attached information sheet which provides details of the study procedures and feel free to contact me if you require more information.

If you agree to participate, kindly sign the attached consent form and return it to me by e-mail (you can use an electronic signature), and also please provide me with the following information:

- How many students aged 16-18y does the school have?
- How do you normally communicate news or events to students (i.e. e-mail, newsletter, other)?
- Will you be willing to arrange groups of students to complete the questionnaire?

I will then send you details of how to proceed with the invitation for students to take part in the study.

If this email has not been sent to the appropriate person I would appreciate if you forwarded this message to the correct person or provide me with her or his details. Also please do not hesitate to contact me if you require more information.

Thank you very much in advance for your time and look forward to hearing from you.

Sincerely,

Ms. Maria Hermosillo

Centre for Exercise, Nutrition and Health Sciences

School for Policy Studies

8 Priory Road, BS8 1TZ

Bristol, England

Tel: +44 (0)117 954 6755

maria.hermosillo@bristol.ac.uk

Appendix D Information Sheet for Schools

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road
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maria.hermosillo@bristol.ac.uk

PHYSICAL ACTIVITY, SEDENTARY BEHAVIOUR AND URBANISATION STUDY

INFORMATION SHEET FOR SCHOOLS

My name is Maria Hermosillo, I am a Mexican student funded by Conacyt to study for a PhD in The Centre for Exercise, Nutrition and Health Sciences in the School for Policy Studies at the University of Bristol in England. I am conducting research to better understand physical activity and sedentary behaviour study among older adolescents in Mexico City and the state of Oaxaca. We are inviting [name of the school] to take part in this research study.

What is the purpose of the study?

This project is intended to provide valuable information about older adolescents' physical activity and sedentary behaviour with the aim of looking for an association with urbanisation. The study is being carried out by Ms. Maria Hermosillo, who is a PhD candidate in Health and Well-being at the University of Bristol. The project is supervised by Professor Russell Jago and Dr. Simon Sebire. Ethical approval has been granted from the School for Policy Studies Research Ethics Committee.

What will happen if [name of the school] takes part?

Before deciding to take part in this study is important to understand what the research will involve. Please read the following information carefully.

The study will take place from February to October 2016 and it will consist of a hand written survey to assess physical activity and sedentary behaviour of adolescents between 16 and 18 years old. We will also ask children their place of residency, gender and age as well as their weight and height. The questionnaire will take approximately 25 minutes to complete and the students can choose to withdraw at any moment during completion of it. After handing the questionnaire in it will not be possible for students to withdraw because we will not ask them to tell us their name.

If your school agrees to take part we will ask you to arrange classes of your 16-18 year old students where they can complete the questionnaire. We would also ask you to give students a

letter from the research team telling them about the study and giving them the option to take part or not.

What are the benefits of taking part in the study?

Once the data is analysed [Name of the school] will be given a report of their students' physical activity and sedentary behaviour and how this compares to the overall study results and recommendations from the World Health Organisation.

Are there any risks involved in taking part in the study?

The procedures of this study carry no risk of physical or psychological harm.

What happens to the information students at [name of the school] provide?

All the collected information will be kept strictly confidential and will only be used by the research team. The data (not identifying your school or students individually will be written up in my PhD dissertation and for a peer –reviewed paper. You will be notified when results of this research get published and you will be able to obtain a copy of it if you wish.

What happens if [name of the school] wants to drop out of the study?

Your consent and participation are totally voluntary. This also applies to the consent your students give for completing the questionnaire. If you decide to participate in this study you may withdraw without giving any reason before one month of the completion of the survey.

Thank you for reading this Information Sheet. We hope that [name of the school] will be able to take part and if you have further queries please do not hesitate to contact us. If you decide to take part, please complete the attached Consent Form and return it to us by e-mail.

For further information please contact:

Ms. Maria Hermosillo
Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road, BS8 1TZ
Bristol, England
Tel: +44 (0)117 954 6755
maria.hermosillo@bristol.ac.uk

Appendix E Consent Form for Schools

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road
Tel: +44 (0)117 954 6755
maria.hermosillo@bristol.ac.uk

PHYSICAL ACTIVITY, SEDENTARY BEHAVIOUR AND URBANISATION STUDY

CONSENT FORM FOR SCHOOLS

Please read each statement and tick the box in the space provided if you agree:

- I confirm that I have read and understood the information sheet. ☐
- I confirm that I have had the opportunity to ask questions about this study and if so, I have received satisfactory answers to all my questions. ☐
- I understand that participation of the [name of the school] is voluntary and that we are free to withdraw from the study up to a month of completion without giving any reasons. ☐
- I understand that any files containing information about the school and its students will be made anonymous, will be treated as confidential and will be stored on password protected computers. At the end of the project, data will be stored for 10 years in appropriate storage facilities. ☐
- I agree to the University of Bristol processing this information and I understand that this information will be used only for the purposes of this study. My consent is conditional upon the University complying with its duties and obligations under the Data Protection Act. ☐
- I agree for the school to take part in the above study. ☐

Please sign and date here

_____

Name of School

_____ _____ _____

Name of School Representative **Signature** **Date**

Please return the signed form to maria.hermosillo@bristol.ac.uk. A copy will be sent back to you to keep.

Appendix F Participant Information Sheet

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road
Tel: +44 (0)117 954 6755
maria.hermosillo@bristol.ac.uk

YOUR DAILY ACTIVITIES AND SURROUNDINGS

PARTICIPANT INFORMATION SHEET

My name is Maria Hermosillo, I am a Mexican student funded by Conacyt to study for a PhD in The Centre for Exercise, Nutrition and Health Sciences in the School for Policy Studies at the University of Bristol in England. I am conducting research to better understand physical activity and sedentary behaviour study among older adolescents in Mexico City and the state of Oaxaca. We are inviting [name of the school] to take part in this research study.

What will I need to do if I want to take part in your study?

You will be asked to answer a pencil & paper questionnaire that will take about 25 minutes to complete.

The questionnaire will ask you:

1. Your age and school year
2. Where you live and for how long have you been living there
3. To tell us your height and weight
4. About your physical activity and other activities you do during the day, how often you do them and how long for

What happens to the information I give you?

The information you give will be anonymous (this means your name will not be recorded) and will be kept private; your teachers, parent/guardian or class mates will not see any of your answers. This information will be used by the research team only. You will not be able to be identified by your responses and all reports of this research will present group, not individual information. When the results of this research get written up your school will be told and sent a copy. At the end of the project data will be stored securely for 10.

What are the benefits of taking part in the study?

The results we get from this study will help us to understand better the impact of where you live on your physical activity and sedentary behaviour. This research might also lead to more research in the area and impact on future planning of the places people live

Are there any risks involved in taking part in the study?

The specific procedures of this study carry no risk of physical or psychological harm.

Do I have to take part in the study?

No, you do not have to take part. If you decide that you will complete the survey, you may stop completing it at any time without giving a reason. However, once you hand in the survey will not be able to withdraw your answers as the questionnaire does not ask for your name.

How do I take part in the study?

You just need to attend to the completion session arranged by your school on the

[day] at [time], [room/place].

Thank you for reading this Information Sheet. We hope that you will be able to take part in the study and if you have any further queries please do not hesitate to contact us.

Ms. Maria Hermosillo

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies
8 Priory Road, BS8 1TZ
Bristol, England
Tel: +44 (0)117 954 6755
maria.hermosillo@bristol.ac.uk

Appendix G Consent Form for Participants

Centre for Exercise, Nutrition and Health Sciences
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8 Priory Road
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maria.hermosillo@bristol.ac.uk

YOUR DAILY ACTIVITIES AND SURROUNDINGS

CONSENT FORM FOR PARTICIPANTS

Please read each statement and tick the box in the space provided if you agree:

- I confirm that I have read and understood the information sheet. ☐
- I confirm that I have had the opportunity to ask questions about this study and if so, I have received satisfactory answers to all my questions. ☐
- I understand my participation is voluntary. ☐
- I understand that I am free to withdraw from the study at any moment and without giving any reason before handing in my questionnaire. ☐
- I understand that any files containing information about myself will be made anonymous, will be treated as confidential and will be stored on password protected computers. At the end of the project, data will be stored for 10 years in appropriate storage facilities. ☐
- I agree to the University of Bristol processing this information and I understand that this information will be used only for the purposes of this study. My consent is based upon the University complying with its duties and obligations under the Data Protection Act. ☐
- I agree for the school to take part in the above study. ☐

Please sign and date here

_____ _____

_____

Name **Signature** **Date**

Appendix H English Version of the Questionnaire

Section 2. corresponds to Sections H and I form the NEWS-Y and Section 7 to the YPAQ.

University of BRISTOL

Centre for Exercise, Nutrition and Health Sciences
School for Policy Studies

URBANIZATION, PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR QUESTIONNAIRE

Section 1: General questions

First of all we would like you to answer some questions about yourself.

1. Are you a female or a male?

I am a _____.

2. How old are you?

I am _____ years old.

3. What is the educational level from your parents or guardians?

- ☐ Primary school
- ☐ Secondary school
- ☐ College
- ☐ Higher education (undergraduate)
- ☐ Postgraduate degree
- ☐ None

4. In which delegation do you live?

I live in: _____

5. What is the name of your street?

The name of my street is:

_____

6. What is your post code?

My post code is: _____

7. How much time have you been living there?

- ☐ Less than a year
- ☐ Between 1 and 3 years
- ☐ Between 4 and 10 years
- ☐ Between 10 and 15 years
- ☐ All my life

8. How tall are you?

I am _____ cm.

9. How much do you weight?

I weight _____ Kg.

Section 2. Getting Around in Your Neighbourhood

Please circle the answer that best applies to you and your local neighbourhood, which means within a 10-15 minutes walk from your home. Please circle one response for each item.

1. The traffic makes it difficult or unpleasant for me to walk.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

2. The speed of traffic on most streets is usually slow (30 mph or less).

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

3. Most drivers go faster than the posted speed limits.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

4. I'm afraid of being taken or hurt by a stranger in a local park.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

5. Streets have good lighting at night.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

6. Walkers and bikers can be easily seen by people in their homes.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

7. There are crosswalks and signals on busy streets.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

8. There is a high crime rate.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

9. I'm afraid of being taken or hurt by a stranger on local streets.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

10. I'm afraid of being taken or hurt by a stranger in my yard, driveway or apartment common area.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

11. I'm afraid of being taken or hurt by a known "bad" person in my neighbourhood.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

12. I feel safe crossing the streets in my neighbourhood.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

Section 3. Barriers to Walking and Biking to School

Please circle the answer that best applies to you. Please circle one response for each item.

1. There are no sidewalks or bike lanes.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

2. The route is boring.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

3. The route does not have good lighting.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

4. There are one or more dangerous crossings.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

5. I get too hot and sweaty.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

6. No other teens walk or bike.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

7. It's not considered cool to walk or bike.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

8. I have too much stuff to carry.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

9. It's easier to drive or get driven there.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

10. It involves too much planning ahead.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

11. There is nowhere to leave a bike safely.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

12. There are stray dogs.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

13. It is too far.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

14. I would have to walk/bike through places that were unsafe because of crime or things sometimes related to crime (e.g. vandalism, graffiti, people drinking alcohol in public places).

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

15. I don't enjoy walking or biking to school.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

16. There are too many hills.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

17. There is too much traffic.

Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	2	3	4

Section 4. Places for Physical Activity Near Your Home

How often are you physically active in/at the following places?

1. Inside your home.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

2. In your yard or common area.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

3. In your driveway or alley.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

4. At a neighbour's house, yard or driveway.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

5. On a local street, sidewalk or vacant lot.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

6. In a nearby dead-end street.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

7. In a nearby park or open space.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

Section 5. Other Places for Physical Activity

How often are you physically active in/at the following locations?

1. Indoor recreation or exercise facility (public or private: YMCA/Boys & Girls Club, dance, martial arts).

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

2. Beach, lake, river or creek.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

3. Bike/hiking/walking trails, paths.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

4. Basketball court.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

5. Other playing fields/courts (like football, softball, tennis).

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

6. Indoor swimming pool.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

7. Small public park.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

8. Large public park.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

9. Public open space (like plaza, square or undeveloped land).

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

10. Friend’s or relative’s house.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

11. School grounds (during non-school hours).

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

12. School grounds (during school hours).

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

13. Skate-park.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

14. Swimming pool.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

15. Parking lot.

Never	Once a month or less	Once every other week	Once a week	2 or 3 times per week	4 or more times per week
0	1	2	3	4	5

Section 6. Proximity to parks and green areas.

Please circle the answer that best applies to you. Please circle one response for each item.

1. How close or far from your home is the nearest park?

Less than 5 mins walk	5 mins walk	10 mins walk	20 mins walk	30 mins walk	More than 30 mins walk
0	1	2	3	4	5

Section 7. Your physical activity.

Which of the following physical activities did you do in the past 7 days?

Did you do the following activities in the past 7 days?			Monday – Friday		Saturday - Sunday	
			How many times **Mon-Fri?**	**Total** hours/minutes **Mon-Fri?**	How many times **Sat-Sun?**	**Total** hours/minutes **Sat-sun?**
EXAMPLE: Bike riding	No	Yes	2	40 mins	1	15 mins
SPORTS ACTIVITIES						
Aerobics	No	Yes				
Baseball/softball	No	Yes				
Basketball/volleyball	No	Yes				
Cricket	No	Yes				
Dancing	No	Yes				
Football	No	Yes				
Gymnastics	No	Yes				
Hockey (field or ice)	No	Yes				
Martial arts	No	Yes				
Netball	No	Yes				
Rugby	No	Yes				
American Football	No	Yex				
Running or jogging	No	Yes				
Swimming lessons	No	Yes				
Swimming for fun	No	Yes				
Tennis/badminton/squash/other racquet sport	No	Yes				
LEISURE TIME ACTIVITIES	No	Yes				
Bike riding (not school travel)	No	Yes				
Trampolining	No	Yes				
Bowling	No	Yes				
Household chores	No	Yes				
Play on playground equipment	No	Yes				
Play with pets/horse riding	No	Yes				
Rollerblading/roller-skating	No	Yes				
Scooter	No	Yes				
Skateboarding	No	Yes				

Did you do the following activities in the past 7 days?			Monday – Friday		Saturday – Sunday	
			How many times **Mon-Fri?**	**Total** hours/minutes **Mon-Fri?**	How many times **Sat-Sun?**	**Total** hours/minutes **Sat-sun?**
Skiing, snowboarding, sledging	No	Yes				
Skipping rope	No	Yes				
Walk the dog	No	Yes				
Walk for exercise/hiking	No	Yes				
ACTIVITIES AT SCHOOL						
Physical education class	No	Yes				
Travel by walking to school (to and from school = 2 times)	No	Yes				
Travel by cycling to school (to and from school = 2 times)	No	Yes				
OTHER Please state: _____						

Section 8. Your free time.

Which of the following activities did you do in the past 7 days?

Did you do the following activities during your free time in the past 7 days?			Monday – Friday	Saturday – Sunday
			Total hours/minutes	**Total** hours/minutes
EXAMPLE: Watching TV/videos	No	Yes	15 hrs	6 hrs 30 mins
Art & craft (e.g. Pottery, sewing, drawing, painting)	No	Yes		
Doing homework	No	Yes		
Listen to music	No	Yes		
Play indoors with toys	No	Yes		
Playing board games/cards	No	Yes		
Playing computer games (e.g. playstation/gameboy)	No	Yes		
Playing musical instrument	No	Yes		
Reading	No	Yes		
Sitting talking	No	Yes		
Talk on the pone	No	Yes		
Travel by car / bus to school (to and from school)	No	Yes		
Using computer / internet	No	Yes		
Watching TV / videos	No	Yes		
OTHER Please state: _____				

Appendix I YPAQ Questionnaire with METs and PA Classification

LIST OF ACTIVITIES	MET VALUES CLASSIFICATION*			PHYSICAL ACTIVITY CLASSIFICATION				
	CODE	METS	OBSERVATIONS	MVPA	SPORT ACTIVITIES	LEISURE PA	PE CLASS	ACTITVE COMMUTING
SPORTS ACTIVITIES								
Aerobics	03015	6.5		X	X			
Baseball/softball	15620	5.0		X	X			
Basketball/volleyball	15050	6.0	Basketball, non-game, general	X	X			
Cricket	15150	5.0		X	X			
Dancing	03025	4.5	General, Greek, Middle Eastern, hoola, flamenco, belly, swing	X	X			
Football	15610	7.0	Casual, general soccer	X	X			
Gymnastics	15300	4.0		X	X			
Hockey (field or ice)	15350	8.0		X	X			
Martial arts	15430	10.0		X	X			
Netball	15070	4.5	Basketball, shooting baskets	X	X			
Rugby	15560	10.0		X	X			
American Football	15560	10.0	Same as rugby	X	X			
Running or jogging	12020	7.0	Jogging, general	X	X			
Swimming lessons	18320	8.0	Swimming sidestroke, general	X	X			
Swimming for fun	18310	6.0	Swimming, leisurely, not lap swimming, general	X	X			
Tennis/badminton/squash/other racquet sport	15675	7.0	General	X	X			
LEISURE TIME ACTIVITIES								
Bike riding (not school travel)	01015	8.0	Bicycling, general	X		X		
Trampolining	15700	3.5				X		
Bowling	15090	3.0				X		
Household chores	05030	3.0	Cleaning, house or cabin, general			X		
Play on playground equipment	15135	5.0	Children's games (dodge ball, hopscotch, 4-square, playground apparatus, t-ball, tetherball, marbles, arcade games)	X		X		
Play with pets/horse riding	05193 15370	4.0 4.0	Walk/run, playing with animals, moderate, only active periods Horseback riding, general	X		X		
Rollerblading/roller-skating	15590	7.0	Skating, roller	X		X		
Scooter	15580	5.0	Same as skateboarding	X		X		
Skateboarding	15580	5.0		X		X		
Skiing, snowboarding, sledging	19075	7.0	Skiing, general, sledding	X		X		
Skipping rope	15552	8.0	Rope jumping, slow	X		X		
Walk the dog	17165	3.0				X		

Walk for exercise/hiking	17200 17080	3.8 6.0	Walking 3.5 mphg, brisk, firm surface, walking for exercise. Hiking, cross country			X		
ACTIVITIES AT SCHOOL								
Physical education class	11876	6.5	Teach physical education, exercise, sports classes (participate in the class)	X			X	
Travel by walking to school (to and from school = 2 times)	17270	4.0	Walking, to work or class	X			X	X
Travel by cycling to school (to and from school = 2 times)	01010	4.0	Bicycling <10 mpg, leisure, to work or for pleasure.	X			X	X
OTHER Please state: _____	MET values and physical activity classification was done according to each stated answer.							

MET: Metabolic Equivalent of Task
MVPA: Moderate-to-vigorous physical activity
PA: Physical Activity
PE: Physical Education

** MET values from The Compendium of PA: and update of activity codes and MET intensities http://www.juststand.org/portals/3/literature/compendium-of-physical-activities.pdf*

Appendix J Confirmatory Factor Analysis

Confirmatory Factor Analysis for the adolescent version of the Neighbourhood Environment Walkability Scale-youth (NEWS-Y) in a Mexican population.

Method

The CFA was performed on the complete case data for the NEWS-Y (n = 3,737) in STATA (Version 13), College Station, TX. A measurement model was specified in which the 11 measured items loaded onto their hypothesised latent variables (Pedestrian Safety and Crime Safety).

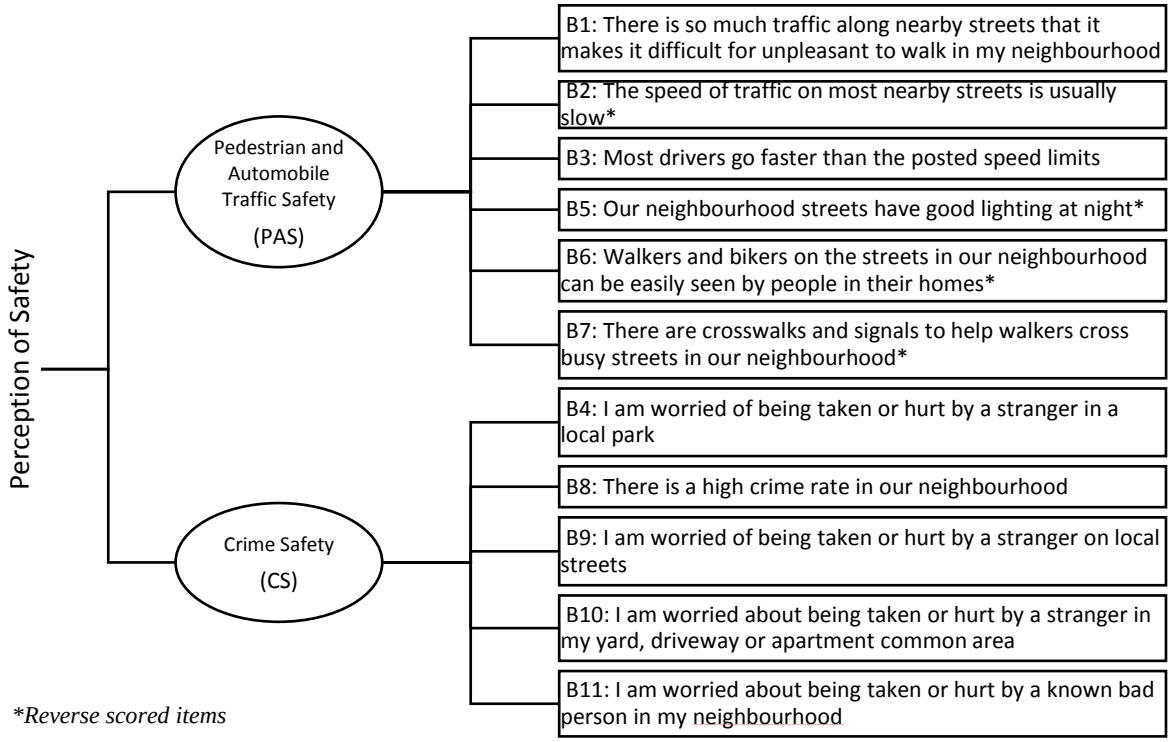


Fig 1. Latent variables and observed variables for Perception of Safety prior to CFA.

Model fit was assessed using Goodness of Fit indicators (Comparative fit index [CFI, where values of 0.90 or 0.95 indicate good fit], Standardized root mean squared residual [SRMR, where values <0.08 indicate good fit], and Root mean squared error of approximation [RMSEA, where values ≤0.05 indicate good fit and values between 0.05 and 0.08 indicate a reasonably close fit])[158]. In addition to model fit, factor loadings (both their magnitude and potential cross-loadings) were examined and modification indices were examined to identify

potential model misspecification. This quantitative data were combined with examination of the item wording to ensure modification decisions were based on a balance of data and theory driven approaches.

Results

The baseline model was not a good fit to the data (Chi2 = 1694.761 (43), $p < 0.001$, CFI = 0.796, SRMR = 0.089, RMSEA = 0.099), with internal consistency estimates $\alpha = 0.329$ for Pedestrian Safety and $\alpha = 0.794$ for Crime Safety. Modification indices suggested the removal of items B1, B2 & B3 which resulted in improved fit (Chi2 = 720.391 (19), $p < 0.001$, CFI = 0.906, SRMR = 0.048, RMSEA = 0.098) with internal consistency for Pedestrian Safety of $\alpha = 0.583$ and for Crime Safety of $\alpha = 0.794$. Item B2 related to speed of traffic was included as a separate dependent variable in the regression. From the three erased items, B2 was the one with the least weak loading (B2 = 0.14 compared to B1=0.07 and B3=0.10) to perception of pedestrian and automobile traffic safety that was related to "transit and driving" as such, keeping it as an independent variable outside of the CFA model could contribute to understanding the association of perception of safety and physical activity in adolescents.

Appendix K Complete Case Analysis for Chapter 6

Table 1. Descriptive Statistics of Participants' Physical Activity by sex.

	Men			Women		
	Mean	SD	Range	Mean	SD	Range
BMI(Kg/m^2) by age:						
15	22.28	3.57	15.03-41.35	21.75	3.30	15.43-35.55
16	22.34	3.57	15.42-43.11	22.24	3.08	15.23-34.69
17	22.81	3.41	15.14-35.15	22.27	3.06	15.43-34.71
18	23.38	3.66	15.03-46.29	22.76	3.39	15.62-43.11
Moderate to Vigorous Physical Activity (min/week)*	917.26	795.78	10.00-3360.00	771.47	706.11	10.00-3360.00
Sports Activities (min/week)*	682.68	679.30	0.00-3360.00	422.24	457.40	0.00-3360.00
Leisure Activities (min/week)*	491.50	581.48	0.00-3360.00	593.07	586.42	0.00-3360.00
PE Class (min/weekday)*	13.34	59.72	0.00-900.00	12.25	48.64	0.00-700.00
Active Commuting (min/weekday)*	84.56	171.59	0.00-1020.00	81.60	157.97	0.00-960.00

* p-value=0.00

Table 2. Descriptive Statistics of Participants' Physical Activity by state.

	Mexico City			Oaxaca		
	Mean	SD	Range	Mean	SD	Range
BMI(Kg/m^2) by age:						
15	22.59	3.78	15.03-41.35	21.74	3.26	15.23-34.02
16	22.16	3.21	15.23-34.23	22.40	3.41	15.42-43.11
17	22.52	3.17	15.14-33.20	22.58	3.31	15.43-35.15
18	22.99	3.30	15.62-36.22	23.24	3.80	15.03-46.29
Moderate to Vigorous Physical Activity (min/week)*	938.32	863.20	10.00-3360.00	847.14	751.400	10.00-3360.00
Sports Activities (min/week)*	555.54	607.32	0.00-3360.00	535.19	540.79	0.00-3360.00
Leisure Activities (min/week)*	608.34	625.89	0.00-3360.00	495.22	552.63	0.00-3360.00
PE Class (min/weekday)*	5.19	29.09	0.00-450.00	18.30	64.25	0.00-900.00
Active Commuting (min/weekday)*	112.23	183.96	0.00-940.00	61.73	145.10	0.00-1020.00

* p-value=0.00

Table 3. Descriptive Statistics of Urbanicity Variables in men and women. Unstandardized values.

	Men			Women		
	Mean	SD	Range	Mean	SD	Range
Demographic*	4.32	1.62	1.00-10.00	4.20	1.55	1.00-10.00
Economic Activity*	4.32	0.47	1.87-5.99	4.35	0.47	1.87-7.09
Built Environment*	8.7	0.86	5.5-10.00	8.76	0.88	1.00-10.00
Communication*	4.10	1.57	0.33-7.80	4.09	1.67	0.30-8.64
Education*	6.9	0.66	4.68-9.14	7.00	0.70	5.25-9.22
Health*	6.12	0.94	0.63-9.54	6.16	0.96	0.00-9.75
Overall*	38.66	3.37	26.73-47.94	38.71	3.42	26.73-47.94

[a] Sub-score values range from 0 to 10 and overall from 0 to 60.
*p-value<0.05

Table 4. Descriptive Statistics of Urbanicity Variables in Mexico City and Oaxaca. Unstandardized values.

	Mexico City			Oaxaca		
	Mean	SD	Range	Mean	SD	Range
Demographic*	5.01	1.42	1.00-10.00	3.59	1.20	1.00-10.00
Economic Activity*	4.55	0.40	2.76-7.09	4.17	0.45	1.87-5.62
Built Environment*	8.96	0.56	7.00-10.00	8.59	1.02	1.00-10.00
Communication	2.86	1.10	0.30-6.65	5.14	1.20	0.44-8.64
Education*	7.26	0.71	5.75-9.22	6.75	0.56	4.68-9.14
Health*	6.22	0.79	0.00-9.75	6.09	1.05	0.63-9.54
Overall	41.10	2.35	30.66-47.94	36.60	2.71	26.73-42.33

[a] Sub-score values range from 0 to 10 and overall from 0 to 60.
*p-value<0.05

Table 5. Linear Regression Models: Associations Between Urbanicity (Z-scores), Moderato to Vigorous Physical Activity, Sports Activities, Leisure Activities, Physical Education Class and Active Commuting. By sex.

		MVPA				Sports				Leisure Activities				PE Class				Active commuting			
		Min/wk				Min/wk				Min/wk				Min/wk				Min/wk			
Linear regression	Score/subscore	Coef,	95% CI		P>|t|	Coef,	95% CI		P>|t|	Coef,	95% CI		P>|t|	Coef,	95% CI		P>|t|	Coef,	95% CI		P>|t|
Men	Overall urbanicity	-0.12	-0.19	-0.05	0.00	-0.26	-0.40	-0.12	0.00	0.12	-0.12	0.38	0.27	0.10	0.04	0.21	0.02	0.41	0.28	0.55	0.00
Simple		-0.03	-0.12	0.05	0.36	-0.04	-0.26	0.17	0.63	0.00	-0.26	0.27	0.97	0.00	-0.10	0.11	0.90	0.26	0.05	0.48	0.01
Multivariable	Demographic																				
	Economic Activity	0.03	-0.03	0.10	0.33	-0.03	-0.23	0.16	0.68	0.05	-0.21	0.32	0.66	0.12	-0.02	0.28	0.09	-0.16	-0.36	0.04	0.11
	Built Environment	-0.08	-0.16	-0.00	0.03	0.01	-0.11	0.15	0.79	-0.08	-0.25	0.07	0.25	0.04	-0.00	0.10	0.08	0.12	-0.03	0.28	0.11
	Communication	0.07	-0.06	0.21	0.23	0.34	0.09	0.58	0.01	-0.33	-0.73	0.06	0.08	0.12	-0.24	0.48	0.47	-0.46	-0.94	-0.06	0.05
	Education	0.00	-0.05	0.06	0.91	0.08	-0.05	0.21	0.21	0.03	-0.30	0.37	0.81	-0.10	-0.31	0.11	0.30	0.00	-0.27	0.28	0.95
	Health	-0.04	-0.13	0.04	0.25	0.00	-0.22	0.23	0.97	-0.32	-0.53	-0.11	0.00	0.16	0.01	0.31	0.03	-0.11	-0.40	0.17	0.39
Women		0.03	0.02	0.09	0.02	-0.10	-0.20	-0.00	0.04	0.18	-0.06	0.44	0.12	0.06	-0.14	0.26	0.50	0.33	0.10	0.56	0.01
Simple	Overall urbanicity	0.02	0.01	0.05	0.00	-0.13	-0.25	-0.00	0.04	0.02	0.00	0.20	0.05	0.01	-0.06	0.09	0.75	0.21	0.12	0.45	0.04
Multivariable	Demographic																				
	Economic Activity	0.00	-0.07	0.08	0.98	0.05	-0.08	0.19	0.36	-0.22	-0.39	-0.05	0.01	0.03	-0.17	0.24	0.73	-0.03	-0.25	0.18	0.74
	Built Environment	-0.09	-0.14	-0.04	0.00	-0.13	-0.23	-0.02	0.01	-0.08	-0.18	0.02	0.11	0.09	0.01	0.17	0.03	-0.03	-0.16	0.10	0.613
	Communication	-0.07	-0.23	0.08	0.30	-0.01	-0.25	0.21	0.86	-0.39	-0.66	-0.13	0.00	0.13	-0.21	0.49	0.40	-0.29	-0.86	0.27	0.27
	Education	-0.00	-0.10	0.10	0.99	-0.06	-0.22	0.10	0.41	0.14	-0.16	0.45	0.32	-0.04	-0.21	0.11	0.54	0.08	-0.17	0.35	0.46
	Health	0.00	-0.07	0.09	0.81	0.07	-0.07	0.21	0.30	-0.16	-0.36	0.03	0.09	0.31	0.01	0.61	0.03	-0.15	-0.46	0.14	0.26

[a]Adjusted by parents' education level and participants' age

Table 6. Linear Regression Models: Associations Between Urbanicity (Z-scores) and Sports Activities. By state.

		Sports Min/wk			
Linear regression	**Score/subscore**	**Coef,**	**95% CI**		**P>|t|**
Mexico City		0.10	0.02	0.42	0.04
Simple	Overall urbanicity	0.02	-0.01	0.06	0.06
Multivariable	Demographic				
	Economic Activity	-0.11	-0.24	0.02	0.08
	Built Environment	0.10	-0.23	0.44	0.48
	Communication	-0.14	-0.46	0.17	0.30
	Education	-0.14	-0.27	-0.01	0.03
	Health	0.25	0.03	0.43	0.02
Oaxaca		-0.12	-0.24	-0.00	0.04
Simple	Overall urbanicity	-0.11	-0.21	-0.01	0.03
Multivariable	Demographic				
	Economic Activity	0.12	0.10	0.14	0.00
	Built Environment	-0.11	-0.20	-0.03	0.02
	Communication	-0.06	-0.39	0.26	0.61
	Education	-0.08	-0.27	0.09	0.25
	Health	-0.06	-0.10	-0.02	0.00

*Adjusted by parents' education level and participants' age.

Appendix L Complete Case Analysis for Chapter 7

Table 1. Descriptive Statistics of Participants' Physical Activity by gender.

	Males (n=1613)			Females (n=1576)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
BMI(Kg/m^2)[a] by age:						
15	22.28	3.57	15.03-41.35	21.75	3.30	15.43-35.55
16	22.34	3.57	15.42-43.11	22.24	3.08	15.23-34.69
17	22.81	3.41	15.14-35.15	22.27	3.06	15.43-34.71
18	23.38	3.66	15.03-46.29	22.76	3.39	15.62-43.11
High Speed of Traffic*	2.38	0.77	1.00-4.00	2.41	0.71	1.00-4.00
Pedestrian Safety*	2.55	0.54	1.00-4.00	2.62	0.53	1.00-4.00
Crime Safety*	2.22	0.60	1.00-4.00	2.47	0.59	1.00-4.00
Moderate to Vigorous Physical Activity (min/week)	817.26	695.78	10.00-3360.00	671.472	60611	10.00-3360.00
Sports Activities (min/week)	582.68	579.30	0.00-3360.00	422.24	457.40	0.00-3360.00
Leisure Activities (min/week)	491.50	581.48	0.00-3360.00	593.07	586.44	0.00-3360.00
PE Class (min/weekday)	13.34	56.72	0.00-900.00	12.25	48.64	0.00-700.00
Active Commuting (min/weekday)	84.56	171.59	0.00-1020.00	81.60	157.97	0.00-960.00

[a] According to WHO's BMI cut-off points for each age group and gender, 40% of male participants had overweight and 9.41% obesity; 31.32% of female participants had overweight and 4.38% obesity.

* Items scored from 1(safe) to 4(unsafe).

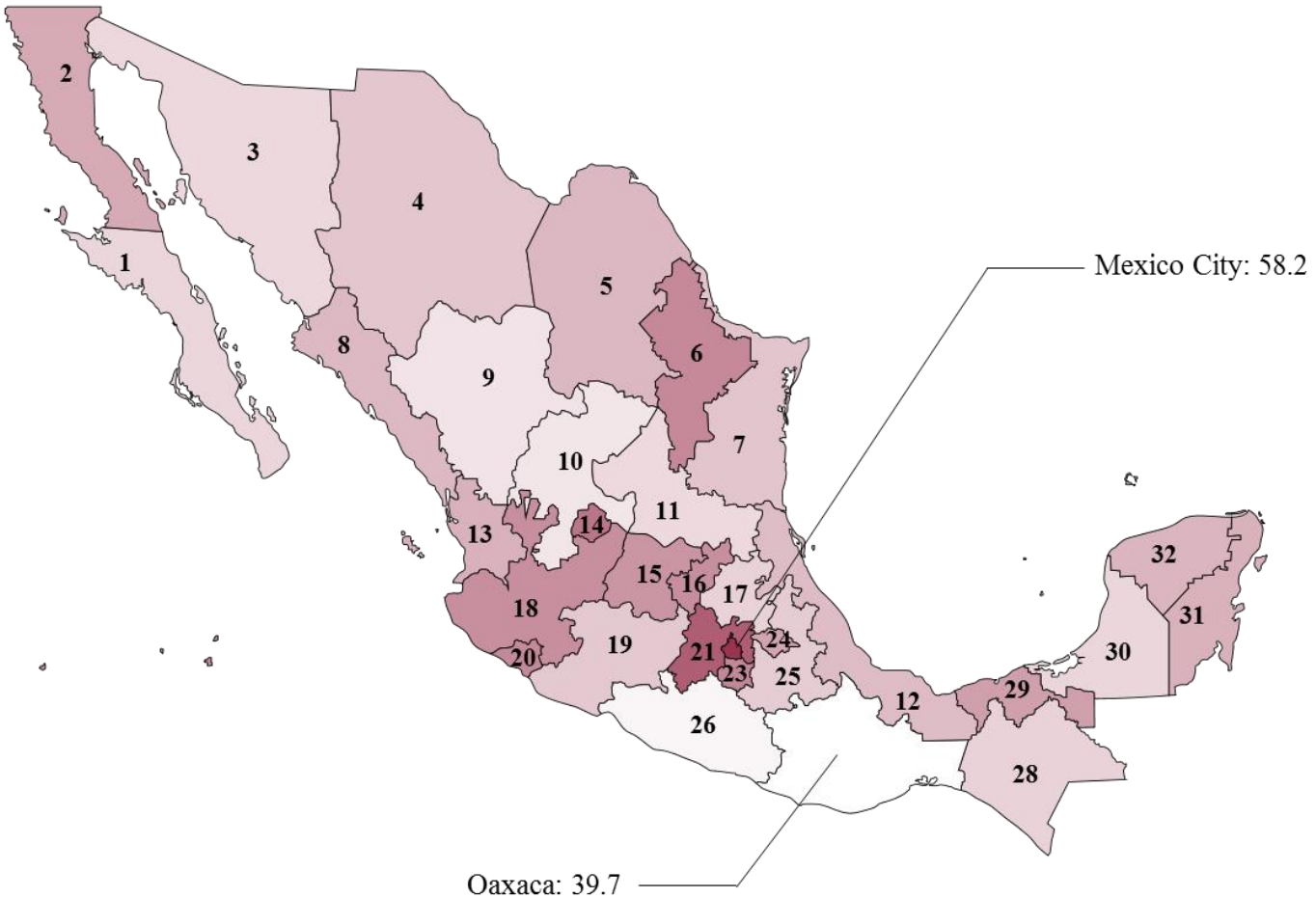
Table 2. Linear Regression Models: Associations between Perceived Safety and Moderate to Vigorous Physical Activity, Sports Activities, Leisure Activities, Physical Education Class and Active Commuting. By gender.

	Males (n=1613)			**Females (n=1576)**		
	High Speed of Traffic	**Pedestrian Safety**	**Crime Safety**	**High Speed of Traffic**	**Pedestrian Safety**	**Crime Safety**
MVPA						
min/week						
Coef	0.00	-0.07	0.00	0.03	-0.10	0.19
(95% CI)	(-0.05 to 0.07)	(-0.19 to 0.04)	(-0.12 to 0.13)	(-0.03 to 0.09)	(-0.16 to -0.05)	(-0.07 to 0.11)
P>|t|	*0.795*	*0.198*	*0.894*	*0.314*	*0.001*	*0.657*
Sports						
min/week						
Coef;	0.05	0.12	0.04	-0.00	-0.21	0.03
(95% CI)	(-0.11 to 0.23)	(-0.28 to 0.31)	(-0.11 to 0.20)	(-0.08 to 0.07)	(-0.34 to -0.08)	(-0.16 to 0.23)
P>|t|	*0.470*	*0.926*	*0.513*	*0.836*	*0.004*	*0.696*
Leisure Activities						
min/week						
Coef;	-0.01	-0.11	-0.01	-0.12	-011	-0.24
(95% CI)	(-0.18 to 0.15)	(-0.34 to 0.12)	(-0.28 to 0.25)	(-0.30 to 0.05)	(-0.28 to 0.06)	(-0.46 to -0.01)
P>|t|	*0.835*	*0.305*	*0.909*	*0.143*	*0.183*	*0.038*
PE Class						
min/week						
Coef;	-0.00	-0.03	0.10	0.03	0.05	0.03
(95% CI)	(-0.14 to 0.13)	(-0.14 to 0.07)	(-0.01 to 0.22)	(-0.07 to 0.14)	(-0.11 to 0.23)	(-0.02 to 0.09)
P>|t|	*0.906*	*0.442*	*0.085*	*0.452*	*0.454*	*0.180*
Active Commuting						
min/week						
Coef;	0.05	-0.05	-0.14	-0.06	-0.01	0.04
(95% CI)	(-0.08 to 0.18)	(-0.37 to 0.26)	(-0.32 to 0.03)	(-0.23 to 0.11)	(-0.21 to 0.19)	(-0.12 to 0.21)
P>|t|	*0.421*	*0.701*	*0.098*	*0.441*	*0.899*	*0.577*

*Adjusted by parents' education level, age, state.

Appendix M Map of urbanicity scores of the states in Mexico

Number	State	Urbanicity Level
1	Baja California Sur	43.52
2	Baja California	47.37
3	Sonora	43.32
4	Chihuahua	44.94
5	Coahuila	46.19
6	Nuevo Leon	50.46
7	Tamaulipas	44.98
8	Sinaloa	46.05
9	Durango	42.29
10	Zacatecas	42.03
11	San Luis Potosi	43.17
12	Veracruz	45.71
13	Nayarit	46.71
14	Aguascalientes	52.23
15	Guanajuato	49.26
16	Queretaro	49.83
17	Hidalgo	43.73
18	Jalisco	49.86
19	Michoacan	44.66
20	Colima	50.33
21	Estado de Mexico	54.38
23	Morelos	50.49
24	Tlaxcala	47.95
25	Puebla	44.32
26	Guerrero	40.69
28	Chiapas	43.77
29	Tabasco	48.39
30	Campeche	43.51
31	Quintana Roo	46.78
32	Yucatan	46.41



Appendix N Examples of places in Mexico with low, medium and high urbanicity