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Lulu Tian Date

“SHIFTING” RISKS: THE ASSOCIATION BETWEEN RURAL-TO-URBAN MIGRATION AND DIABETES PREVALENCE IN CHENNAI, INDIA

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Master of Public Health

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Abstract

"SHIFTING" RISKS: THE ASSOCIATION BETWEEN RURAL-TO-URBAN MIGRATION AND DIABETES PREVALENCE IN CHENNAI, INDIA

By Lulu Tian

Background: Rural-to-urban migration is a key factor driving urban growth in developing countries. Urbanization may increase risk factors associated with non-communicable diseases such as type 2 diabetes (T2D).

Aims: To investigate the associations between migration status and diabetes risk factors and prevalence in southern India.

Methods: We analyzed data from a representative cross-sectional subsample of 546 adults from Chennai, India. We obtained a comprehensive history of places lived and classified individuals as migrants (lived in rural setting for at least one year before moving to Chennai). Self-reported demographic information, dietary patterns (food frequency questionnaire), and physical activity levels (International Physical Activity Questionnaire) were assessed. Clinical data was collected and anthropometric measurements were used to calculate body mass index (BMI) and waist-to-height-ratio (WHtR). Diabetes was defined through self-reported status or fasting plasma glucose ≥126 mg/dL or a 2-hour post-challenge blood glucose of ≥200 mg/dl or HbA1c ≥6.5%. We compared migrants and non-migrants in terms of risk factors for diabetes. Using logistic regression models, we evaluated the associations between migration status and high WHtR, BMI, physical activity, vegetable consumption, hypertension and high triglycerides, as well as the association between migration status and diabetes prevalence.

Results: Compared to non-migrants, migrants were slightly older and of lower socioeconomic status. Prevalence of diabetes was higher among migrants (30.2% vs. 26.1%) and migration status was associated with a two-fold higher T2D prevalence (OR: 2.1, 95% CI: 1.04-4.4) after adjusting for age, SES, sex, family history, BMI, WHtR, systolic blood pressure and triglycerides. In women, but not men, being a migrant was significantly associated with diabetes (OR: 3.0, 95% CI: 1.1-8.1); in particular, women of low SES were 3 times more likely to have T2D (OR: 3.1, 95% CI; 1.1-8.9).

Conclusion: Rural-to-urban migration was significantly associated with T2D prevalence in an urban subsample from Chennai. The effect of migration was more pronounced in women than men. Aside from migration status, age, BMI, family history of diabetes, systolic blood pressure and elevated triglyceride cholesterol were strong predictors for T2D.

Keywords: migration; diabetes; epidemiology; urbanization; risk factors

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ABBREVIATIONS

BMI	Body mass index
CARRS	Center for cArdiometabolic Risk Reduction in South Asia
CMD	Cardiometabolic disorders
DBP	Diastolic blood pressure
HbA1c	Glycosylated hemoglobin A1c
HBP	High blood pressure
HDL	High density lipoprotein (cholesterol)
HOMA	Homeostatis model assessment (score)
IGT	Impaired glucose tolerance
IFG	Impaired fasting glucose
IDF	International Diabetes Foundation
IPAQ	International physical activity questionnaire
LMIC	Low- and middle-income country
MET	Metabolic equivalent of task
MS	Metabolic syndrome
PAL	Physical activity level
WHR	Waist-to-hip ratio
WHtR	Waist-to-height ratio
WC	Waist circumference
SBP	Systolic blood pressure
SES	Socioeconomic status
T2D	Type 2 diabetes
LDL	Low density lipoprotein (cholesterol)

CHAPTER I

LITERATURE REVIEW

LITERATURE REVIEW

Outline

- Migration and Urbanization: an Overview
- Urbanization and T2D
- Pathophysiology of Type 2 Diabetes
- Migrant studies and traditional risk factors associated with type 2 diabetes
    - Diet
    - Physical activity
    - Metabolic risks (adiposity, hypertension, dyslipidemia)
    - Socioeconomic status
    - Age, gender
    - Family history
- Gaps in research

MIGRATION AND HEALTH

In recent decades, globalization has facilitated economic and lifestyle changes in many parts of the world, accelerating growth and development in the urban agglomerates in low- and middle-income countries (LMICs). A critical component of this changing landscape has been the influx of rural-to-urban migrants [1]. The United Nations Human Settlements Programme estimates that approximately 60% the world will reside in urban centers by the year 2030. For India, it is estimated that 4.9 out of 8.1 billion [2], or 46% of the country, will be urbanized by the year 2030[1].

Migration itself is a complex phenomenon—as a population to study, migrants are not a homogenous group, and their experience varies depending on geographic location; reasons for migrating which may include "pull factors" such as the draw of better education or economic opportunities, or "push factors" such as natural disasters and armed conflict[3]. In India, much of the rural-to-urban migration in the last decade is owed to the decline in profits for agricultural occupations, urban development resulting in displacement, and absence of educational and health facilitates in rural areas, driving migrants towards cities[3].

Two divergent hypotheses have been advanced to explain the health status of migrants in urban areas. At the crux of the 'healthy migrant effect' is the notion of positive self-selection: those who migrate inherently differ from those who have stayed behind because they are the healthiest and most likely to be able to physically migrate elsewhere and psychologically adjust to the new environment [4, 5]. In the United States, populations from Mexico who immigrate in search of work are typically healthier within the first few years of their lives in the U.S., and their health deteriorates over time [6]. Similarly, migrant selectivity from Puerto Rico into the mainland U.S. is one explanation for why mortality rates are lower among Puerto Ricans who are

living in the U.S., compared to those who stayed at home[4]. In LMICs, traditional rural lifestyles may be associated with a healthier diet, and more active lifestyles, which may impart some degree of protection for migrants in their shift into more urbanized environments.

Alternative theories propose that different reasons may compel migrants to leave their home in search for better opportunity, but that once arriving in the new environment, social changes or environmental factors impart added risk for disease. This may be as a result of fewer social contacts after adopting an urban life, increased stress, or other deleterious factors which may in fact render migrants more susceptible to diseases [5]. The two paradigms present conflicting images of how migration may manifest itself in health outcomes: on the one hand, migrants may be healthier than the host population into which they assimilate; on the other hand, migrants may be more vulnerable and at a higher risk, owing to various social factors and mediation through socioeconomic status (SES). Rural-to-urban migration was often associated with deleterious impacts on health due to crowding and poor urban living conditions leading to communicable diseases, but in recent years, there has been increasing evidence of a growing non-communicable diseases (NCD) burden in urban areas, and in the migrant population [5]

URBANIZATION AND T2D

Although cities have historically been cultural and economic epicenters, rapid urbanization in India has also paralleled dramatic changes in demography, lifestyle, and obesity, as well as widening differences in literacy, access to health care, and poverty [7]. The growth of type 2 diabetes (T2D) (also known as adult-onset diabetes), the predominant form of diabetes in LMICs, has been facilitated by rapid economic development and urbanization which have led to major changes in nutrition and physical activity patterns, and growing obesity [8].

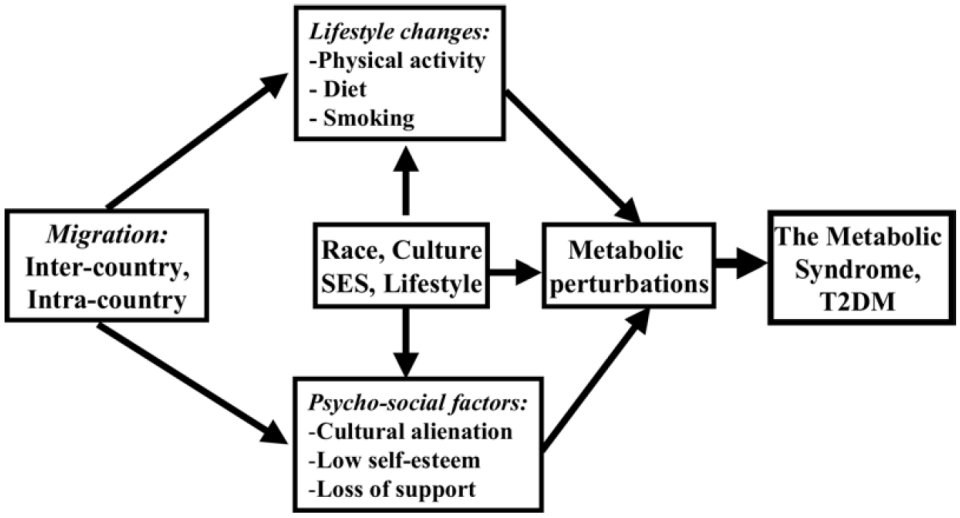
In 2011, the fifth edition of the Diabetes Atlas estimated that in India, there were 61.3 million individuals with diabetes in the 20-79 year old age group, with an estimated increase to 101.2 million by 2030 [7]. In Chennai, a burgeoning city in south India whose expansion has been driven by population growth and an influx of rural-to-urban migrants, the prevalence of T2D, impaired glucose tolerance (IGT), and associated cardiometabolic illnesses has been on the rise from 13.5% in 2000 to nearly 19% in 2006 [9] [10]. A recent study conducted in Chennai estimated an age-standardized prevalence of diabetes of 14.3% in the urban population, and 10.6% of IGT[11].

A number of studies characterizing prevalence across rural, urban, and semi-urban settings have begun to demonstrate the changing landscape of health in India by highlighting the burden of T2Ds and other non-communicable diseases (NCDs) in urban areas [1, 11, 12]. A recent nationally representative study in India estimated the prevalence of T2D in urban population in the states of Tamil Nadu, Maharashtra, Jharkhand and Chandigarh to be 5.2%, 7.2%, 5.1%, and 7.6% respectively[7]. T2D, and other related NCDs such as cardiovascular diseases, are closely associated with modifiable risk factors: in particular, exposure to the urban milieu appears to increase the burden of diabetes by facilitating access to the tenets of a "modern lifestyles"[13]: changes in dietary habits, decreased physical activity, and through the promotion of other co-morbid non-communicable diseases such as hypertension, dyslipidemia, tobacco, and alcohol consumption[14] although the exact mechanisms are currently poorly understood.

Rural to urban migration offers a unique opportunity to examine the interactions between environmental changes and the resulting health effects, and to provide some epidemiological clues to the causal pathways related to certain disease outcomes[3]. From a social science perspective, it is important to understand the health profiles of rural-to-urban migrants as a

doorway to understanding how cities in developing countries are changing, and how health needs may change accordingly, and the factors impacting health outcomes among rural-to-urban migrants.

Migration and risk factors for T2D: a Framework



Pathways linking migration, risk factors, and diabetes (adapted from Misra et al, 2007)[15]

Previous studies looking at prevalence of T2D across urban and rural populations have noted a marked increase in T2D and associated risk factors in urban environments. Many studies acknowledge "urban life factor" or urbanization as an important covariate in their analysis; similarly, an abundance of studies in India and elsewhere have compared the prevalence of diabetes and cardiovascular diseases across urban, semi-urban and rural regions to demonstrate the gradient in disease prevalence as environmental factors evolve [1, 16-18] with increasing urbanicity. Considering the patterning of these factors across rural and urban populations, it would be expected that in rural-to-migrant populations, who are transitioning from a low risk

rural environment into a high risk urban environment, risk factors would fall in a similar gradient.

However, such a simplistic conceptualization of disease prevalence across varying levels of urbanicity is not well supported by previous research. Across various populations, the patterning of risk factors is surprisingly heterogeneous, differing in unexpected ways for certain risk factors, and across gender and age groupings. In this literature review, we explore the etiology of T2D, and outline risk factors traditionally implicated in the development of T2D. We will then frame previous work on migration and risk factors for T2D to explore the relationships between migration and risk patterning for key risk factors, namely diet, physical activity level (PAL), obesity and central adiposity, blood pressure and cholesterol profiles.

PATHOPHYSIOLOGY

Type 2 Diabetes (T2D) is a metabolic condition characterized by acquired insulin resistance in target tissues, resulting in elevated blood glucose levels. In the early stages of the disease, there is an increase in insulin production as a response to decreased receptor sensitivity to the hormone. However, over time as the production of insulin is insufficient to overcome the underlying acquired resistance to this hormone, the production of insulin also decreases due to a failure of the insulin-producing beta cells in the pancreas [19]. As a consequence, T2D is typically characterized by hyperglycemia, insulin resistance, relative insulin deficiencies, and changes in metabolism [20].

T2D is a strong risk factor for cardiovascular diseases and is associated with a two-fold increased risk for stroke. Complications resulting from poor blood sugar, blood pressure, and cholesterol control include nephropathy (i.e. chronic kidney disease), neuropathy, foot and leg ulceration; and T2D is also the leading cause of visual impairment and blindness in developing countries[21, 22]. Although genetics may predispose individuals to T2D, many epidemiological studies have demonstrated that environmental factors, such as poor dietary habits and physical inactivity, can exacerbate the progression towards T2D. Obesity and central body fat deposition may be a consequence of these lifestyle habits and are strong precursors for T2D.

South Asian populations display a higher risk of developing T2D at lower obesity cut-offs relative to their Caucasian counterparts[15, 23]. Indeed, definitions of overweight and obesity have been lowered for South Asian populations, in recognition of the need for more accurate screening and identification of high risk individuals. Identifying a number of these

modifiable risk factors also offers opportunities for early lifestyle interventions to delay the onset of diabetes.

RURAL-TO-URBAN MIGRATION AND RISK FACTORS FOR TYPE II DIABETES

Diet and physical activity

Global dietary changes have resulted in issues of overnutrition, excess weight gain, and increased intake of particular types of fats. A recent analysis by the Food and Agricultural Organization (FAO) has demonstrated a steady increase in the amount of animal fats consumed in low and middle-countries, like India, where industrialization and overall economic development has driven a larger consumption of high fat, nutrient-dense food. Dietary changes favoring the consumption of high-energy foods, high in saturated fat, and depleted in non-starch polysaccharides (NSP) may be strongly associated with obesity [8]. Contributions to increased adiposity notwithstanding, poor diet contributes to increased insulin demand, dyslipidemia, and chronic inflammation which may be the link to increased cardiometabolic risk and T2D [8].

Hu et al, 2011 identified that excessive caloric intake is the main driver of the diabetes and obesity epidemic globally, but quality of diet also has a role [8]. Overnutrition, combined with a decrease in physical activity, synergistically work together to promote positive energy balance. In the Nurses' Health Study (NHS), quality of fats and carbohydrate intake were critical factors in the development of diabetes, independent of BMI and other risk factors. Furthermore, the study noted that those consuming the highest quartile of sugar-sweetened beverages (SSBs) had a 26% greater risk of developing T2D relative to those in the lowest quartile (relative risk [RR]: 1.26, 95% CI: 1.12-1.41). Dietary changes and migration may be closely linked together, and a recent prospective cohort study in Tanzania following migrants from their rural hometown in to

Dar es Salaam noted a marked increase in fat intake in male participants, 12 months following the migration.

Together with an increase in calorie-dense foods, changes in PAL have increased risk factors for T2D. The link between high physical activity and T2D risk is well established [8]. Biologically, physical activity has a strong effect on lipid and muscle metabolism, by decreasing the concentration of fatty acid metabolites which subsequently decreases the risk of fatty-acid induced insulin resistance [24]. Conversely, high levels of sedentary activities have been associated with increasing risks for T2D. Mohan et al noted the prevalence of diabetes was almost three times higher in those with light physical activity compared to those with moderate to high levels of activity (23.2% vs. 8.1%, $p < 0.001$)[9] and prevalence of metabolic syndrome was also significantly higher among those with light physical activity. In Sri Lanka, a nationally representative cross-sectional study utilized the International Physical Activity Questionnaire (IPAQ)-Short form to assess the association between activity level and metabolic syndrome (MS). The prevalence of MS was highest in those who were physically inactive (38.8%, 95% CI: 20.2-30.2), with decreasing prevalence with higher levels of physical activity [25]. Urbanicity also played strongly in the study's findings, with a notable observation that urban adults had a significantly higher prevalence of MS than their rural counterparts (prevalence = 34.8% [31.8-37.9] vs. 21.6 % [20.2 – 23.0]) vs. and that this effect was observed across genders[25] suggesting that there may also be a marked difference in PAL between rural and urban areas.

PAL may differ significantly from rural to urban environments as lifestyles in the cities tend to be more mechanized, and changes in occupation may decrease overall physical activity and increase sedentariness [26]. Additionally, certain energy-intensive chores associated with

agricultural lifestyles may be replaced with less-energy intensive chores in an urban environment. Specifically, there may be a higher prevalence of risk factors among rural-to-urban migrants as these changes may be more evident in populations who have migrated from a more low-risk environment.

Analyses of dietary patterns and changes in migrant studies report strong differences between rural groups and the urban and migrant group. A cross-sectional study conducted in Guatemala compared the prevalence of cardiovascular risk factors across a rural, commuter, and a migrant (urban) group who had settled in Guatemala City. They noted that urban residents ate more meat, drank more sweetened beverage, and ate more vegetables than their rural or commuter counterpart[27], migration studies in India noted that the gradient dietary fat intake increased evenly from rural to migrant to urban, and in both men and women [12]. Migrant and urban men in this study had a higher proportion of energy intake from fat, saturated fats and protein than rural men, and a lower proportion from carbohydrates. In comparing food content, urban and migrant groups were similar in their consumption of fruit intake (148g and 146g), while vegetable, sugars, and dairy consumption, demonstrated a "gradient" pattern, increasing from rural to migrant to urban[28]. Together with the emerging pattern of rapidly increasing adiposity [29] and cholesterol profiles in migrants, this dietary change in migrants may be distally associated with increased risk factors for T2D.

Physical activities were analyzed in a number of studies and demonstrate consistent findings. Typically, rural men had more moderate and vigorous activity relative to urban and migrant populations ($p<0.001$) even after adjusting for BMI; conversely there was a trend of decreasing physical activity coinciding with increasing urbanicity in India[12]. In this comparison, however, urban and migrant groups were very similar in their overall MET hours

per day activities, suggesting that much of the difference is owed to the comparison to rural groups.[12]. In this population, physical activity levels were varied between men and women; whereas the pattern was clear for men, this pattern was not present in women. In Guatemala, where rural men had significantly higher physical activity levels than urban or commuter men ($p < 0.001$), only 17% of women reported being moderately active—even among rural women, the level of activity was light, and overall a significantly larger proportion of women reported very light PAL.

Obesity and adiposity

Obesity is a well-established risk factor for T2D, and the biological underpinnings of this association point to the accumulation of visceral fat as contributing to the release of free fatty acid, leading to insulin resistance and other metabolic disturbance closely associated with T2D[30] [15]. Obesity and T2D are closely linked in Chennai, as a large scale cohort study described prevalence of T2D closely mirroring the pattern of BMI; T2D prevalence increased by each increase in BMI class from overweight to obese, and obese II (from 16.7%, 18.4%, 23% from overweight to obese and obese II ($p < 0.0001$)[11]. These findings were consistent with a study conducted in a low-SES population in a slum in Northern India, where the overall prevalence was 13.9% (95% CI 11.1-17.2)[31]. The prevalence among men was 11.2% while the prevalence among women was 9.9%. Those who were classified as being centrally obese in the CUPS study in Chennai, based on a waist circumference greater than 0.5, had a significantly greater prevalence of diabetes (27.8% versus 9.0%, $p < 0.01$) relative to those who did not[11].

Despite its frequent use as an indicator for obesity, a number of studies have highlighted the limitations of BMI as an predictor for risk in the South Asian population, as this population tends to have an increased risk of diabetes at lower-cutoffs of overall obesity [23]. Waist

circumference (WC), waist-to-hip ratios (WHR) and, most recently, waist-to-height ratio (WHtR) have been increasingly used to assess central adiposity and risk for diabetes, in recognition of the fact that central adiposity may be a stronger predictor for T2D rather than overall overweight [30] [23]. Although WHtR and WC have strong predictive powers for increased diabetes risk (RR: 1.62 (95% CI: 1.48-1.78) and 1.63 (95%CI: 1.49-1.79, respectively) [30], some have argued that WHtR may be more appropriate than WC in discriminating central adiposity since WC is not standardized to differences in height and so may not be universally applicable across all populations[32]. In a cross-sectional study of 4,388 subjects in Sri Lanka, estimates for diabetes and prediabetes prevalence were regressed against standard anthropometric indicators, including BMI, WC, WHtR, and WHR. The authors noted that relative to the other indices, WHtR had the strongest correlation with biochemical parameters [2-hour post-prandial sugar, total cholesterol, LDL-cholesterol] and systolic and diastolic blood pressure. The area-under-the-curve (AUC) for WHtR was significantly higher relative to other indices [0.726 (95%CI: 0.71-0.75) compared to 0.711 (95% CI: 0.69-0.73) for WC, 0.69 (95%CI: 0.67 – 0.71) for WHR; and 0.67 (95%CI: 0.65-0.69) for BMI.] They found that high WHtR $\geq$ 0.5 was strongly associated with diabetes (odds ratio [OR]: 3.51, 95% CI: 2.77-4.43), hypertension (OR: 2.23, 95% CI: 1.89-2.64), and hypercholesterolemia (OR 1.70, 95% CI: 1.43-2.01) [32].

The associations between migration and obesity are complex, and delving into the literature to describe the anthropometric characteristics of rural- to-urban migrants yields conflicting evidence: anthropometric measurements, such as BMI, WC, WHR, vary greatly between groups and across gender, and across populations, and depending on the measure that was used to reflect adiposity and overweight. In a multi-site cross-sectional study conducted in

Peru, Miranda et al noted that migrants and urban residents had skinfold thicknesses which were 34.8 mm (29.5-40.1) and 45.8 mm (39.3-52.3) significantly higher than rural populations [33]. However, findings from a cohort study in Guatemala suggest the opposite: in a study of rural inhabitants, commuters and rural to urban migrants, Torun et al found that rural women had a higher prevalence of abdominal fat than their urban and migrant counterparts, as measured by waist-hip-ratio [27].

Findings from the Indian migration study suggest that there is the gradient of increasing BMI with urbanicity clearly observable in men but not in women. There was a significant difference in prevalence of obesity between urban and migrant women (p=0.05), but no notable differences between the male urban and migrant groups. Adjusted odds of obesity were also 3-4 times higher in migrants than in rural participants in both men and women.[12] and there was a clear trend for BMI for both men and women, increasing from rural to urban groups. In comparing differences between urban and migrants only, they also noted that migrant women had significantly lower odds of being obese, compared to urban women [OR: 3.86 (95%CI: 2.88-5.19) vs. 4.9 (95%CI: 3.56-6.72)] whereas this large difference was not noted when comparing migrant men and urban men's odds for obesity. Ebrahim noted that higher fat intake in migrants and reduced physical activity in both men and in women which may be likely to contribute to obesity in this population [12]. Similarly, evidence from a prospective study in Tanzania noted that both men and women had significantly higher anthropometric measurements 12 –months post-migration into a city, highlighting the drastic rate at which obesity can increase in rural-to-urban migrants.

Hypertension

Metabolic syndrome (MS) is a condition characterized by impaired glucose tolerance, impaired fasting glucose, dyslipidemia, and high blood pressure. Taken together, MS is a strong predictor for T2D [34]. High blood pressure and T2D may thus be strongly associated due to similar underlying risk factors. In a large study in China, the use of associated parameters from the definition of metabolic syndrome were helpful in predicting the occurrence of diabetes [35]. In an urban population in south India, those with a higher prevalence of hypertension and hypertriglycemia had an increased risk for IGT and T2D [11], suggesting that hypertension and abnormal cholesterol levels may reflect underlying risk factors that are also causally linked toT2D. In a study in northern India, the strongest risk factors for hypertension included low energy expenditure (OR: 1.35, 95%CI: 1.12-1.54), high dietary fat intake as measured through a seven-day food frequency (OR: 1.28, 95%CI: 1.06-1.43), and high BMI (OR: 1.08, 95%CI: 1.06-1.09)[36], risk factors which may also place individuals at risk for T2D. In a prospective study of 14 cohorts followed for 2.3 – 20 years, the RR for incident diabetes was significantly higher for those who met the criteria for MS (3.5-5.2)[34]. While there is less evidence to demonstrate that hypertension and dyslipidemia are causative of T2D, the shared risk factors among the three conditions warrant attention as they may be reflective of a state of shared risk factors[34].

Migration and hypertension have been well-documented in one of the earliest migration studies conducted in 1990s in China, which assessed the difference between farmers of Yi decent and their rural counterparts, against Han urban dwellers. The study population allowed for an indirect evaluation of changes in diet and lifestyle factors, as farmers of Yi decent were relatively isolated and had a consistently lower consumption of meat consumption, and a diet composed

primarily of potatoes, corn, rice and buckwheat, and oats [37]. In comparing individuals to their urban Han counterparts, the authors noted that complex patterns emerged: in men before the age of 45, SBP appeared to be similar across three groups, yet over the age of 45 there was a marked difference between the higher SBP in migrants and urban dwellers, and the lower SBP in Yi farmers. In men, they found that being a migrant was associated with a 1.96 odds of hypertension (95%CI: 1.52-2.52), and the risk ratio was 1.83 (95%CI: 1.14-2.93) [37].

Dyslipidemia

Together with high blood pressure, abnormal cholesterol levels make up a component of metabolic syndrome. In the South Asian population, abnormal lipoprotein levels commonly manifest as depressed levels of high-density lipoprotein cholesterol (HDL) and hypertriglyceridemia (elevated levels of triglycerides) [38] Cholesterol levels may be especially relevant in the context of rural-urban migration as illustrative of changes in dietary habits.

In the Guatemalan migration study, Torun et al noted that blood lipids, glucose, and hemoglobin followed a gradient, which was lowest in rural men and increased with increasing urbanicity[27]. In women, however, this pattern was reversed: women in rural areas tended to have higher serum lipids than migrant women, and commuters had a lower mean serum concentration than rural women[27]. Overall, they noted that adverse changes in body composition and lipid profiles were pronounced in men who had migrated to an urban area, compared to those who were still living in villages; interestingly, both men and women in rural area had a higher proportion of abdominal fat compared to the urban counterparts. In a prospective cohort study in Tanzania, following a 12-month follow-up after migration, the authors noted that serum triglycerides fell in men during the first 12 months (-0.31, 95%CI: -0.06 to -0.02); in women, there was a rapid fall in triglycerides level in the first six months, which

then leveled off towards the end of the 12 month follow-up period. The gender difference is consistent across migrants' cholesterol profiles: in the Indian migration study, female migrants more closely resembled their rural participants in their lower triglycerides, whereas in men, there was a clear and even gradient of increasing triglycerides from rural to migrant to urban (geometric mean = 1.29 (95% CI: 1.26-1.32) vs. 1.39 (95% CI: 1.35-1.43) vs. 1.41 (95% CI: 1.38-1.45) (p_{trend} <0.0001)[12].

Socioeconomic status (SES)

In the most recent edition of the Diabetes Atlas, the International Diabetes Federation (IDF) emphatically challenged the notion that NCDs are diseases restricted to high-income countries or high SES populations. Traditionally understood as "diseases of affluence", T2D and other cardiometabolic diseases have been gaining attention as health issues among those of lower socioeconomic status [39]. While the prevalence of T2D in middle income populations was twice as high as that of low-income brackets [7] emerging evidence from a number of studies indicates that even those of low SES may be at risk for T2D and other NCDs [26, 40, 41].

Using education as a proxy for low income and low occupational class, Gupta et al reported that tobacco use and stress were more prevalent in those of lower SES, while deleterious dietary habits such as increased fat intake were more prevalent in those of high educational attainment. In addition to differences in behavioral factors across education levels, anthropometric and clinical risk factors differed significantly too. Low educational status was strongly associated with a high waist-to-hip ratio (OR: 2.18, 95%CI: 1.65- 2.71) and low HDL cholesterol levels (OR: 1.51, 95% CI: 1.27-1.80). Furthermore, when assessing all relevant risk factors for vascular diseases like tobacco use, hypertension, hypercholesterolemia, diabetes, and metabolic syndrome, Gupta et al found that the prevalence of three or more risk factors was

significantly higher among low SES groups than those of middle SES and those of high SES (28.0% vs. 23.9%, p = 0.004; 28.0% vs. 22.1%, p<0.0001 respectively)[42].

Beyond just a measure of social positioning, SES may also be symptomatic of other underlying social factors that drive T2D. Consequently, social scientists have also suggested that SES may act on health through impacting social mobility, and reflecting social networks[5]. Studies involving slum populations in Northern India have reported that around 16% of men and 22% of women were overweight [10], while studies in Delhi reported obesity in 15.6% in females and 13.3% of men compared to city-wide estimates of around 28% [31]. In migrant studies, more drastic changes in body fat and overweight were noted across each decade of urban-life whereas the effect was not as pronounced in migrants from higher SES [29].

Migration, temporality, and T2D

Most notably, the effect of migration and risk factors for T2D appear to encompass a certain amount of temporality. In contrast to the patterning of risk factors in rural-to-urban migrants, the effect of urban-years is surprisingly consistent. In an analysis comparing total urban-years and risk for T2D and other cardiometabolic events, Kinra et al noted that the three parameters most associated with urban years lived were percentage of body fat, systolic blood pressure, and fasting glucose levels[29]. They found that overall there tended to be more risk factors among non-migrants than in migrants, but that within migrants, the risk tended to increase with increasing amount of time spent in an urban environment. Others have noted similar linear relationships between exposure to an urban environment and increased prevalence of BMI, blood glucose, and blood pressure ($\rho = 0.42$, $p < 0.0001$; $\rho = 0.23$, $p < 0.0001$; $\rho = 0.17$, $p < 0.0001$, respectively).

In the Indian migration study, stratifying on length of time spent in a study yielded differences across strata: migrants from lower socioeconomic positions were more 'susceptible' to the effects of increasing urban-years. Those who had not migrated had the lowest measures of adiposity, followed by an increase in those who had been exposed to 10 and 20 years of urban-life years, with a plateau for successive years[29]. Of particular note, the study found that between migrants and lifelong urban dwellers, blood pressure, fasting insulin levels, and homeostatis model assessment (HOMA) scores were higher in migrants than in non-migrants, and tended to increase with successive life years spent in an urban environment[29]. Similarly, Miranda and colleagues in Peru noted that among migrants who had migrated at the age of 12 or older, had a geometric mean ratio of blood glucose 3% higher and 2% higher of HbA1c, compared to those who migrated before the age of 12. These individuals also had a higher odds for diabetes (7.05 (0.9-55.5), IFG or diabetes (6.1, 1.36-27.06), and MS (OR: 1.66 (1.08-2.57). Together, these findings suggest that the effect of migration is not a static, but rather flexible one that might affect health in a "dosage-dependent" manner.

Age and gender

NCDs such as T2D, cancers, and other types of cardiovascular illnesses generally tend to follow an age gradient, as a result of interaction between multiple diseases processes as well as a loss of physiological functions[39]. Anthropometric measurements, for example, may be closely associated with increasing age as evidenced by higher prevalence of obesity among women in older age groups in a slum in Northern India [31]. Jayawardana and colleagues in Sri Lanka similarly found that WHtR progressively increased with age, and that central adiposity was higher in urban areas than in rural.

Across all migrant studies, gender-specific differences appear to be most consistent when evaluating the differences in adiposity and cholesterol. In comparing risk factors for metabolic syndrome, hypertension, and dyslipidemia between rural, migrant, and urban Peruvian participants, Barnabe-Oritz and colleagues noted that women had significantly higher prevalence of obesity as assessed by BMI, and had higher odds of metabolic syndrome (OR: 2.22, 95% CI: 1.39 – 3.55) [43]. Even after adjusting for factors indicative of acculturation and SES (income, education, language spoken at home) women were more likely to be centrally obese (OR: 5.97, 95%CI: 3.21-11.11), and were more likely to be only moderately active (43.6% vs. 28.2%, p <0.001) compared to their male counterparts. In women, but not in men, a steeper rise in WHR was observed after the age of 30 where 60% of women were classified as having high WHR. In contrast, only 15% of males of the same age group had a high WHR. Body fat percentages also tended to increase dramatically with age in women, whereas the percentage of body fat remained stable across age groups in men (P <0.0001)[29]. HOMA score patterns also differed between men and women: whereas HOMA scores followed an upward trend in men (from rural to migrant to urban), HOMA scores were relatively stable across groups in women.[29]

While a number of parameters correlated well with urban-life years in male migrants, body fat percentage and total cholesterol were significantly associated with increasing urban-life years in women[29]. Triglyceride levels among men and women responded differently in response to migration in a prospective cohort study in Tanzania. Differences in dietary pattern changes and physical activity may be insightful in linking together differences between male and female migrants in relation to risk factors for T2D.

Migration and T2D

The majority of migration studies have focused on risk factors for cardiovascular disease, and few have looked at T2D as their outcome event. Nevertheless, IGT, IFG, and HOMA scores for the assessment of MS are considered across a number of studies. In India, the prevalence of diabetes as determined by doctor's diagnosis or fasting glucose >7.0 mmol/L was higher in urban and migrant groups compared to the rural group [12]. There was also a clear gradient, with urban populations having the highest prevalence, the rural group having the lowest, and the migrants having an intermediate prevalence of diabetes and obesity. Compared to rural populations, the odds of diabetes in the migrant population was 3-4 times greater than the rural population, even after adjusting for age, occupation, and the factory in which they worked[12]. Risk factors for T2D risk factors like HOME scores for MS fell along an expected gradient from lowest in rural men to highest in urban men, and with migrants in the middle. Clinical parameters associated with diabetes [fasting glucose, fasting insulin] in men were statistically different across the three groups; in contrast, estimates for these parameters were similar in women [12]. Interestingly, in the Peru study, migrants were found to more closely resemble rural participants in their HbA1c profiles, although their fasting insulin and insulin resistance more closely resembled that of urban participants.

GAPS IN RESEARCH

Conclusions drawn from a myriad of studies have shown that risk profiles are unique to regions, populations, and definitions of migration status. Studies from Peru, Guatemala, Tanzania, Cameroon, China, and India have underscored the variations in the effects of rural-to-urban migration on health: some have reported that risk factors for migrants are comparable to the urban population and risk factors accumulate over time [29], while others have noted that migrants seem to have an intermediary level of risk, sandwiched between their rural and urban counterparts[12]. Previous research on rural-to-urban migration, which used rural populations as the point of comparison, offers insights into how dietary habits, physical activity, and risk factors are different among rural, migrant, and urban populations. While these studies have been successful in demonstrating risk factors and how they vary across levels of urbanicity, there is still a paucity of data on the associations, and the mechanisms by which 'urbanization' affects health outcomes once individuals arrive in an urban environment. Although these studies have highlighted the timing and the patterning of risk factors according to gradients of urbanicity, utilizing rural participants as the point of comparison precludes gaining in-depth understanding of how environmental factors might facilitate changes in the health profile of rural-to-urban migrants.

Characterizing differences between migrants and lifelong urban dwellers may elucidate mechanisms associated with adaptation to city life: this comparison remains an important one, not only for the purposes of understanding risk factors and the mechanisms by which they accumulate, but as a means of redefining public health programs to target this population. Using a subsample of participants from a representative study from the city of Chennai, Tamil Nadu,

this study will examine the distribution of risk factors between migrant and non-migrant groups by comparing demographic, dietary, physical activity, obesity and other metabolic risks, with a particular focus on the impact of risk factors in men and women separately. We explore the relationship between gender, migration status, and health in an effort to elucidate risk factors which may impact migrant health differentially based on gender. The implications of rural-to-urban migration are many, considering that these phenomena will be relevant in many developing countries as one of the driving forces behind the expansion of urban agglomeration.

What this study adds to current literature

- Assessment of migration status as a determinant of intermediary risk factors for diabetes
- Evaluation of the associations between migration status and diabetes prevalence
    - The association between gender, migration, and risk factors for T2D
- Direct comparison of urban and migrant populations, as a means of understanding the differences, if any, in risk between the two groups in developing T2D
- Strengthening the evidence and data on migration and health in India

CHAPTER II

Manuscript

BACKGROUND

The growth of type 2 diabetes (T2D) (also known as adult-onset diabetes), the predominant form of diabetes in low- and middle-income countries (LMICs), has been facilitated by rapid economic development and urbanization which have accounted for major changes in nutrition and physical activity patterns, and growing obesity [8]. In 2011, the fifth edition of the Diabetes Atlas estimated that in India, there were 61.3 million individuals with diabetes in the age groups of 20-79, with an estimated increase to 101.2 million by 2030 [7]. Indeed, the rapid increase in diabetes prevalence in India parallels rapid changes in demography, lifestyles, as well as large differences in literacy, access to health care, and poverty[7].

In addition to globalization, which appears to facilitate many lifestyle changes in many low- and middle-income countries, urbanization and rural-to-urban migration have begun to receive attention for their role in driving in-country urban growth in many cities in LMICs [1]. The United Nations Human Settlements Programme estimates that approximately 60% the world will reside in urban centers by the year 2030, or 4.9 out of 8.1 billion [2] in India, 46% of the country will be urbanized by the year 2030[1]. As a burgeoning city in south India whose expansion has been fuelled by population growth and an influx of rural-to-urban migrants, Chennai is one of India's fastest growing cities and is now the country's fourth largest urban agglomeration[44, 45]. Driven by changes in demographics and lifestyles, the prevalence of impaired glucose tolerance (IGT) and T2D in Chennai has been on the rise [9] [10]. In particular, exposure to the urban milieu appears to increase the burden of diabetes through changes in dietary habits, physical activity, and through the promotion of other co-morbid non-communicable diseases such as hypertension, dyslipidemia, tobacco, and alcohol consumption[14].

While international migration has been examined in depth in literature, changes in health in post-migration countries reflect the changes in acculturation, rather than urbanization. Rural-to-urban migrants (henceforth referred to simply as migrants) are a unique population in that they offer a prism through which to understand the impacts of urbanization on health. A number of studies from Latin America, West and East Africa, and China have compared rural, migrant, and urban populations, and noted that risk factors for T2D, namely diet, obesity, physical activity, dyslipidemia, and high blood pressure (HBP) follow gradients of risk coinciding with the level of urbanicity that each population represents. Although these studies have highlighted the timing and the patterning of risk factors according to urbanicity, utilizing rural participants as the point of comparison precludes gaining in-depth understanding of what might drive these changes once individuals arrive in an urban environment. Recent work by Ebrahim and Kinra from the Indian migration group have placed a stronger emphasis on examining the changes within migrant populations themselves [12, 29], although there remains a paucity of data comparing migrant and urban populations directly. Focusing in on the contrast between these two populations may be critical in understanding the characteristics of migrants and the social factors which are associated with both migration and health outcomes.

Two divergent hypotheses have been advanced to explain the health status of migrants in urban areas. The healthy migrant effect hypothesizes that those who are healthiest will be the ones most apt to migrate elsewhere. In the United States, populations from Mexico who immigrate in search of work are typically healthier within the first few years of their lives in the U.S. and their health deteriorates over time [6]. Similarly, in LMICs, traditional rural lifestyles may be associated with a healthier diet, and more active lifestyles, which may impart some degree of protectiveness for migrants in their shift into more urbanized environments. On the other hand, migrants from rural areas in LMICs may be of lower socioeconomic status (SES),

owing to lower education attainment and upon arriving in a city, may be more likely to work in unskilled occupations. Framed in the context of health disparities mediated by SES, migrant populations may be more susceptible to non-communicable disease (NCD) risk factors relative to their lifetime urban counterparts.

In this study, we compare and describe the characteristics of a subsample of rural-to-urban migrants and lifelong urban dwellers in Chennai to evaluate the associations between migration and diabetes. We will assess the association between migration status and intermediary lifestyle risk factors such as diet, physical activity, and adiposity which may be strongly affected by SES. Our primary objective is to better understand the role of migration status in risk of T2D diabetes among this urban population in India.

METHODS

CARRS

The Center for cArdiometabolic Risk Reduction in South-Asia (CARRS) Surveillance study is a hybrid cohort-modeled multicenter surveillance study [46]. Participants were recruited from three cities in South Asia, namely Karachi, Pakistan and New Delhi and Chennai in India, and followed prospectively in order to ascertain and identify risk factors and incidence of morbidity and mortality associated with cardiometabolic disorders (CMD) in adults 20 years and above in urban environments[47]. Chennai, Delhi, and Karachi are home to 4.68 million, 16.3 million, and 13 million residents respectively[46]. Data for this report are from a subsample of the 2011 baseline cross-sectional survey data from Chennai in the South of India.

Study design

In 2011, a representative cross-sectional population sample was enrolled from each of the three cities. Participants in each urban center responded to a close-ended interviewer-administered questionnaire. Baseline information collected included sections on demographics, tobacco and alcohol use, dietary patterns (using a modified food frequency questionnaire), family history, and any current or previous personal history of any CMD illnesses. Anthropometric and clinical measurements and biological specimens were also collected using standardized tools. This study was approved by the Emory University, Public Health Foundation of India, and Madras Diabetes Research Foundation institutional ethics committees. Written informed consent was obtained from participating adults prior to any data collection.

Sampling

In each of the three cities, households were selected for sampling using multi-stage cluster random sampling techniques. Chennai is subdivided into municipal sub-divisions, municipal corporations, wards, and census enumeration blocks (CEBs) with each level representing a subsequent sampling frame. The primary sampling unit (PSU) for CARRS Chennai was wards. In Chennai, 100 CEBs were used as the sampling frames from which 20 households each were randomly sampled.

To be included as eligible participants, individuals had to be 20 years of age or older with permanent residence in the metropolitan area of Chennai. Pregnant women, bed ridden people, and those who were unable to comprehend the interview questionnaire were excluded from participation. One male and one female was selected from each household using the Health Information National Trends Study (HINT) and Kish methodology[47]. A total of 5,348 participants were enrolled in Chennai, with a response rate of 92.4%. .

Participants in this migration study were a subsample of the Chennai cohort and were recruited during their one-year follow-up visit. Every participant who had complete baseline data was eligible for the follow-up survey and the migration questionnaire. It is estimated that the attrition rates for the subsample mirror those of the one-year follow-up study. Participants responding to a follow-up questionnaire between May 2012 and August 2012 were invited to respond to an additional one page question detailing their migration history (*Figure 1)* from birth until present location. Consent was obtained at the time of baseline assessment.

Principal exposure variable

Migration status is a complex exposure to characterize and can be addressed in a number of ways. Migration status can be defined as a self-reported Y/N, or can be classified based on the location where the participant was born. Furthermore, it is important to distinguish in-country migration from international migration as the source population and reasons for migration may differ significantly between the two. For example, migrants who are selected for out of country migration may be well-educated or of a higher SES position. Additionally, the changes they encounter in their cardiovascular profiles may be more reflective of the process of acculturation, rather than urbanization alone. Migration can occur internationally, and even with within-country migration, there is a difference between individuals who move from one city to another city, from an urban environment to a rural environment, or a move from rural to urban.

In our study we examined in-country rural-to-urban migration. Participants were asked about their date and place of birth and moving forward chronologically, participants were asked to list their places of residence from birth until present residence in Chennai. In addition to listing the name and state of their place of residence, participants were asked to give the number of years lived in that place or the years during which they resided there. Lastly, participants were asked to self-classify each location as rural, urban, or semi-urban. Self-classification was preferred to categorization by the investigator because town designations may have changed over time, and self-classification may be more indicative of the size of the city and the lifestyle at the time of residence. In the rare event that the participants did not mention duration of time in a place, the 2010 Tamil Nadu census was used to categorize the town into rural, semi-urban, or urban. Lastly, participants were asked to document the reason for moving the area of residence. This was done to capture the common reasons for rural-to-urban migration to Chennai.

Participants were asked to choose from moving for work, for family, for education, or other. As an example, when women moved after marriage, this was classified as "for family". Lastly, participants were asked about their occupation during their stay in a given place. Migrants were defined as individuals who had spent at least one year in a rural environment before moving to an urban environment.

In addition to our primary exposure variable, we explored possible demographic (age, sex, socioeconomic status [SES]), clinical (systolic blood pressure [SBP], diastolic blood pressure [DBP], high-density lipoprotein [HDL], low-density lipoprotein [LDL] total cholesterol, triglycerides), and anthropometric covariates (body mass index [BMI], waist circumference [WC], waist-to-hip-ratio [WHR], waist-to-height ratio [WHtR]) which are also strongly associated with diabetes, and therefore could be potential confounders. At baseline, anthropometric measurements and clinical measurements were taken using instruments and methods that were standardized and validated in other epidemiological studies in South Asian populations. Data collection methods and definitions for each covariate are described below.

DATA COLLECTION

Clinical and anthropometric measurements

The following eight anthropometric measurements were taken: waist circumference (WC), hip circumference, weight, height (standing), and body composition analysis by bio-impedance[46]. Primary anthropometric measurements of interest considered for the analysis were BMI, WC, WHR, and WHtR.

Resting systolic and diastolic blood pressure were taken using electronic sphygmomanometer; Omron HEM-7080 and HEM-7080IT-E; Omron Corporation, Tokyo, Japan (certified by the British Hypertensive Society and the American association for the Advancement of Medical Instrumentation [AAMI] protocols). Systolic and diastolic blood pressure and pulse rates were measured twice using the right arm while the respondent was in a rested sitting position. If the second measurement differed significantly from the first, a third reading was taking. Non-stretch measuring tape (Gulick II, Country Technology, Gays Mills, WI) were used to measure body circumference. Standing height was measured using a portable Stadiometer (SECA Model 123, SecaGmbh Co, Hamburg, Germany). Lastly, weight and body composition was measured using Tanita-BC-418 bio-electrical impedance.

Biological sample collection and storage

Biological samples collected from participants included 5 milliliters (ml) of blood following an 8-10 hour fasting state. The samples were transported via cold chain from the field to the laboratory. Sample aliquots were prepared and stored in cryo-vials at -80 degrees Celsius. Detailed methods regarding CARRS study procedures have been published in detail elsewhere[46].

DEFINING VARIABLES

Socio-demographic

Participants' self-reported age, gender, and socioeconomic status were ascertained through the demographic section of the CARRS questionnaire. Participants responded to categorical questions regarding age, gender, education, and mean monthly household income.

Age

The age variable chosen for the analysis was the self-reported age from the CARRS questionnaire. Age groups were defined according to standard demographic groups of 20-29; 30-44; 45-59; and 60 years and older.

Education

Participants were asked the number of educational years completed, as well as the highest level of education level that they had attained. Education was categorized as: professional degree/post-graduate; graduate (university degree); secondary or intermediary schooling; high school; primary school; literate with no formal education; or illiterate. Due to the similarity in many of the strata of education, these seven levels were collapsed into four definitions: professional and graduate; secondary or high school; primary school and literate; or illiterate.

Occupation

Participants were asked their current employment status (yes or no). For those who were currently employed, they were categorized as working as a professional; trained clerical; skilled manual labor; or unskilled laborer. Those who were unemployed were further classified into students; housewife; retiree; or unemployed.

Income

Total monthly household income was reported in Indian rupees [Rs.] and income was categorized into bins of 10,000 Rs., with the lowest category being <3,000 Rs. a month [USD 56.14, according to the 2008-2012 World Bank Official Exchange] and the highest category being over 50,000 Rs. [USD 935.63] or more per month.

Socioeconomic status (SES)

Socioeconomic position in CARRS was characterized using a composite score that combined education, occupation, and household monthly income. The Kuppuswamy scale is a validated scale for South Asia which scores income, occupation, and education attainment to produce an overall score, which is later categorized into high, medium, and low SES according to total scores[48]. Detailed methods on the scoring methods have been published elsewhere [48]. For our study, the data on education and occupation was collected in congruence with the Kuppuswamy scoring criteria; however, the monthly household income was collected in a categorical format making direct classification not possible. Household income was classified into categorical variables and directly classification was not possible, a modified version of the Kuppuswamy scale was used to score our population. Respondents with monthly incomes anywhere in the range of 20,001-50,000 Rs. or more were given a score of 12, since this is the score associated with making over 28,215 Rs. on the Kuppuswamy scale. Those with incomes of 10,001-20,000 Rs. were scored 6; 3,001-10,000 was scored 4 and those with less than <3,000 Rs. a month were given a score of two.

Anthropometric measurements

Body Mass Index

Body mass index (BMI) was calculated by weight (measured in kilograms [kg]) divided by the height squared (standing height in meters [m]). Participants were classified into their respective BMI classes using the Asian BMI standards[49] where a BMI of $\leq$18.5 kg/m^2 was considered underweight, 18.6-22.9 kg/m^2 was normal, overweight was 23-27.4 kg/m^2 and a BMI of $\geq$27.5 kg/m^2 was considered obese.

Waist circumference, waist-to-hip, and waist-to-height ratio

In addition to traditional anthropometric measurements, WHR, WHtR, and WC were also examined to characterize central obesity status as this is a key predictor for diabetes. WHR was calculated using the waist and hip measurements. A high WHR was defined as > 0.9 for men and >0.8 for women[16],[42]. A high WC was defined as $\geq$ 90 cm for men and $\geq$80 cm for women, reflecting differing cut-offs for women and men as well as a lower-threshold for South Asian populations[42]. Lastly, a high WHtR indicating central adiposity was defined as $\geq$ 0.50 [32].

Food frequency

To understand dietary patterns, a modified food frequency questionnaire was used to collect data from all CARRS baseline survey respondents. Participants were asked about their consumption of fruits, vegetables (cooked, raw, and other), sweets, meats, coffee and teas, grains, and dairy. Food frequencies were given as either monthly, weekly or daily values; for the

purposes of the analysis, all items and their frequencies were converted into weekly values, and then summed to give the total frequency of food consumed per participant per week.

The meat category encompassed any type of meat that the respondent reported consuming, as well as poultry and any organ meats that were consumed. Fruits consumed included both exotic and local fruits. Questions on vegetables, including cooked vegetables and raw and other types of vegetables were collapsed to calculate the total number of vegetables consumed daily. For the purposes of analysis, fruit and vegetable consumption were combined together and categorized as consuming two or more servings daily, and less than two servings daily. Sweetened beverages encompassed different types of sweetened drinks, including soft drinks, coffee, tea (commonly served with added sugar in Chennai), and fruit juices. If participants reported consuming Western desserts or *mithai* (South Asian desserts), these were all summed in the category for desserts. Lastly, frequency of dairy products and fish consumed were noted separately.

Physical activity

Information regarding weekly physical activity was collected using the International Physical Activity Questionnaire (IPAQ) short form[50]. The International Physical Activity Questionnaire is a standardized survey tool developed to assess physical activity patterns IPAQ assesses physical activity under four domains of exercise which include leisure time physical activity, domestic and gardening activities such as yard work, work-related physical activity, and transport-related activities[51].

Participants were asked to self-report the number of hours or minutes per day that they engage in vigorous and moderate physical activity and the number of hours and minutes that they

spent walking or sitting. Using the standardized method of calculation in the IPAQ Manual[52], the total number of minutes engaged in each type of activity per day was calculated. Total minutes of activity was calculated by summing self-reported minutes of physical activity and converting hour values into number of minutes for each reported activity, and weekly measurements for walking were converted into daily values by dividing all values by seven. (Metabolic equivalent of task) MET-minutes/week scores were calculated by multiplying together the average MET value for each type of activity by the number of minutes and the number of days of activity to produce a vigorous activity, moderate activity, and walking scores. These were then summed to produce the total physical activity (total PA) scores for each participant. MET values assigned to each activity are standardized, and their derivations described elsewhere[52].

In accordance with the IPAQ manual, total physical activity per week was the summation of vigorous activity, moderate activity, and walking scores. Although sedentary time was ascertained and calculated, these were not included in the total physical activity score, in accordance with the protocol for the IPAQ-Short questionnaire. Lastly, the total activity scores were used to classify participants into high, moderate, and low physical activity levels. High activity was defined as engaging in three or more days of vigorous physical activity resulting in a total physical score of at least 1500 per week, or seven or more days of combined vigorous, moderate or walking activity summing to a total physical score of at least 3,000 [52]. Moderate activity was classified through a composite definition which included as either having five or more days of combined moderate, vigorous or walking activity achieving a minimum total physical activity score of at least 600 MET-minutes weekly; three or more days of vigorous activity for at least 20 minutes daily; or five days or more of moderate intensity activity and/or

walking for at least 30 minutes daily[52]. Participants who did not meet the requirements for moderate or high physical activity were considered to be of low physical activity. While sedentary time is not a component of the total physical activity (total PA) score and was expressed as a continuous measure of sitting time per week, other studies using the IPAQ scoring have defined sedentary physical activity as less than 150 MET minutes in one week[33].

Dyslipidemia

Participants were defined as having abnormal lipid profiles or "dyslipidemia" based on their fasting levels of high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), triglycerides, and total cholesterol. Using the 2001 ATP III guidelines for screening and diagnosis of dyslipidemia and cholesterol, low levels of HDL cholesterol were defined as ≤ 40 mg/dL in men and ≤ 50 mg/dL in women and high LDL was classified as ≥ 130 mg/dL. High levels of triglycerides were defined as triglycerides ≥ 150 mg/dL and high levels of total cholesterol was defined as ≥ 200 mg/dL.

Hypertension

Systolic blood pressure (SBP) was calculated based on the average of two measurements recorded during clinical assessments. When the second measurement different significantly from the first, a third measurement was taken and averaged with the first. The same procedure was followed for diastolic blood pressure (DBP). For this analysis, participants were defined as hypertensive if they met any of the following criteria: self-reported hypertensive, on allopathic or traditional hypertension medication, or measured blood pressure ≥ 140/90mmHg.[53]

Primary outcome of interest: Diabetes prevalence

The overall population was classified into mutually exclusive groups that are affected by prediabetes, diabetes, or are normoglycemic.

Diabetes status was defined by a composite of self-reported status, taking allopathic or traditional diabetes medication, or meeting clinical cut-offs of fasting glucose ≥126 mg/dL or a 2-hour post-challenge blood glucose of ≥ 200 mg/dl or glycosylated hemoglobin A1c (HbA1c) ≥ 6.5%. Participants with undiagnosed diabetes were defined as individuals who did not self-report diabetes, or did not know their status, but who met the clinical cut-offs.

Prediabetes was defined as either impaired fasting glucose (IFG) fasting glucose level of ≥ 100 mg/dL and <126 mg/dl) or impaired glucose tolerance (IGT) 2 hour post-challenge glucose ≥ 140 mg/dl but <200 md/dL) or having combined IFG-IGT [16]. A participant was classified as dysglycemic if they had prediabetes or diabetes by any of the aforementioned definitions. All others were classified as normoglycemic.

ANALYSIS

The primary purpose of our study was to investigate the association between rural-to-urban migration and prevalence of T2D in this sample. Using the criteria of at spending at least one year in a rural area before moving to an urban area, migration status (yes/no) was defined as the primary exposure of interest. Descriptive statistics of all continuous and categorical variables were used to characterize the migrant, non-migrant, and total populations. For continuous variables, means and standard deviations were presented, and the unpaired t-test was used to evaluate differences in means between migrants and non-migrants. Frequencies were tabulated for categorical variables and the Pearson's chi-square test statistic was used to evaluate associations of independence between migration status and all strata of the variable. For variables where cells were missing more than 5% of the total, Fisher's exact test was used to assess differences between migrants and non-migrants. Furthermore, multi-level variables with an expected dose-response, such as socioeconomic status and educational status, were assessed using a one-sided Cochran-Armitage test of trend.

Implausible values and outliers were assessed using Jacknife and residual plots, and linearity assumptions were checked against the exposure variable. We also evaluated the appropriateness of keeping continuous variables versus categorizing them by using linearity assessments in scatter plots. Variables that were non-linear were transformed on the log scale. Data cleaning and analysis were conducted using STATA/SE (College Station, Texas) and SAS 9.3 (Cary, N.C.), and results were considered significant at the $\alpha = 0.05$ significance level.

Modeling strategy

Unadjusted and adjusted logistic regression models were constructed to evaluate the association between migration status and diabetes prevalence in the whole sample (N=546), using migration as a dichotomous variable (0= non-migrant, 1=migrant). Additional covariates of interest included demographic factors; anthropometric predictors (WHR, WHtR, WC, BMI); dietary factors (total vegetable consumption; total beverage consumption); physical activity (total sedentary time; physical activity level); and components of metabolic syndrome (hypertension and dyslipidemia).

Several modeling strategies were pursued to test the consistency of the findings. The first approach was based on the differences in the distribution of risk factors between the migrant and non-migrant groups. The second strategy aimed to develop an understanding of risk factors associated with diabetes that are well supported in the literature and whether these vary by migration status. Lastly, in addition to exploring the effects of risk factors and migration status among the overall sample, we examined the effects of these separately by gender.

Model I

Potential covariates were chosen from risk factors whose prevalence differed between migrants and non-migrants. In the demographic category and clinical variables entered into the model included age category, SES class and family history of diabetes. With respect to dietary risk factors, consumption of sweetened beverages was entered into the model. Fish consumption differed between the two groups, but was not selected into the model, due to little support from literature to support its relevance as a predictor for diabetes. Time spent conducting moderate activity and moderate activities score were close to being significantly different between the two groups, and thus were selected into the model. Lastly, hypertension (yes/no) was significantly different between the groups, as was elevated HDL levels in women.

Model II

With our second modeling strategy, variables were selected into the model based on their relevance in the literature and a stepwise regression modeling strategy was used to assess all possible subsets of covariates. Variables with non-significant associations were excluded from the model, unless their absence indicated a drastic change in the odds ratio for migration status. Variables which caused a marked difference of 10% or more in the odds ratio for the exposure variable were retained in the model, even if they were not independently significantly associated with diabetes.

Variables which were significantly associated with T2D through a univariate regression were screened into the model. In addition to these selection criteria, we included variables that differed significantly between the two groups. Groups of variables (such as demographic factors, dietary factors etc) were added into the model in a stepwise forward fashion. Variables that were strongly associated with diabetes or were strong confounders as assessed by a $\geq 10\%$ difference in the estimate of relationship between the exposure and diabetes (based on the odds ratio [OR]) were retained in the model. Associations between migration status and covariates to the outcome were reported using adjusted and unadjusted odds ratios.

For all modeling strategies, we evaluated any possible interaction and all remaining covariates with possible interaction were included with migration status to assess their role as potential effect modifiers. Collinearity diagnostics were conducted by assessing conditional indexes (CIs) and variance decomposition proportions (VDPs). CIs greater than 30 and VDPs greater than 0.7 were indicative of potential collinearity issues. Once a fully-adjusted model was determined, we fitted all possible subsets to see how estimates change.

Model III: Gender and migration

Research on risk factors associated with T2D strongly suggests that risk factors for diabetes may differ between men and women. Using the same variables selected through strategy II, we fitted two separate logistic regression models for males and females. In addition to unadjusted models for migration status and T2D risk, we built multivariate logistic models adjusting for other key demographic factors (age, SES, family history) and covariates (anthropometrics, SBP and triglycerides).

RESULTS

Demographic

Between May and August 2012, a total of 559 questionnaires ascertaining migration status were completed by CARRS participants living in Chennai. We estimate a response rate of around to 95%; all who were surveyed for a follow-up survey completed the migration survey, and non-respondents often included individuals who were not at home, or had moved. Out of the 559 surveys, complete CARRS data was available for 546 respondents. Mean participant age was 41.7 years of age, and the sample had a larger proportion of respondents (55%) that were women. In the sample, 78.8% (N=430) of the participants were identified as non-migrants; 116 (21.2%) of participants were classified as migrants *(Table 1).*

Migrants and non-migrants differed significantly in terms of their demographic composition *(Table 1).* A larger proportion of the migrant group were females, relative to the non-migrant group (63.8% vs. 52.8%; $p < 0.05$). In addition, the migrant group was slightly older, with a mean age of 45.2, compared to a mean age of 41.2 among non-migrants ($p < 0.0001$); this was also reflected in the distribution among age groups, with 38.8% of the migrant population in the 45-59 age group, compared to 23.7% among non-migrants. Around three quarters of participants in the whole sample came from households with monthly household income of Rs. 3,000-10,000, and there were no discernible differences between migrants and non-migrants. Twice as many migrants were illiterate compared to non-migrants (12.7% vs. 6.1%) and less than 10% of migrants had attained a professional or graduate education compared to 12.8% of non-migrants (overall $p_{trend} = 0.03$). Overall these differences were reflected in the calculated SES class as scored on the Kuppuswamy scale: 66.4% of migrants were of low socioeconomic

position, compared to only 51.2% of non-migrants who were of low-socioeconomic position ($p < 0.05$). Approximately 45% of the sample was employed, with most individuals working as skilled or semi-skilled manual laborers. Of those who self-reported being unemployed, being a housewife was the most common designation (82.67%)

Anthropometric factors and family history

Table 2 illustrates the anthropometric characteristics of migrants and non-migrants, and details the prevalence of family history among the overall sample. Migrants and non-migrants were of comparable heights, but differed significantly in their average weight with non-migrants weighing slightly more than migrants (63 kg vs. 60.7 kg, $p < 0.05$). Migrants and non-migrants had comparable body mass indexes (BMI) and measures for central obesity: around 50% of the sample had a high waist circumference and waist-to-height ratio, and 63.4% of the sample had a high waist-to-hip ratio. Non-migrants and migrants differed significantly in reporting a family history of diabetes and hypertension: 40% of non-migrants reported a family history of diabetes, compared to only 21.6% percent of migrants ($p = 0.0005$). Similarly, twice as many non-migrants had a familial history of high blood pressure compared to their migrant counterpart (24.2% vs. 12.9%; $p < 0.05$).

Dietary patterns

Dietary frequencies are described in Table 3. The highest reported frequency of food consumption was for sweetened beverages, followed by grains and vegetables. On average, non-migrants had a greater consumption of most food groups, except for vegetables. Non-migrants consumed almost 3.5 sweetened beverages (including coffee, sodas, and/or fruit juices) daily whereas migrants consumed an average of 2.7 drinks. Furthermore, the consumption of seafood

differed significantly between the two groups with non-migrants reporting fish consumption almost twice a week.

Physical activity

Table 4 shows the distribution of physical activity among participants. Overall, the reported average time spent in vigorous activities was 17 minutes per day, whereas participants reported an average of 349 minutes (almost 6 hours) of sedentary behavior a day. The majority of the sample (63.4%) had moderate levels of physical activity and 10% of participants had a low level of physical activity. Among migrants and non-migrants, the level of physical activity was comparable. More migrants had low levels of physical activity compared to non-migrants (29% vs. 24%), but this difference was not significant.

Hypertension and lipid profile

In the overall sample, the mean SBP was 125.8 mmHg (± 21.9) and the mean DBP was 83.4 mmHg (± 12.8); 15.8% of the sample had high blood pressure *(Table 5).* The mean SBP and DBP, and prevalence of high blood pressure did not differ significantly between migrants and non-migrants. However, more non-migrants self-reported having high blood pressure (19.8% vs. 10.2%, p= 0.02) and using the composite definition of hypertension (self-reported hypertension or meeting clinical cutoffs), the differences in prevalence between migrants and non-migrants approached significance (15.5% vs. 15.8%, p= 0.058).

Self-reported dyslipidemia was not common in the overall sample, with only 2.4% reporting being diagnosed with dyslipidemia. Lab measures of HDL, LDL, total cholesterol, and triglycerides showed abnormal cholesterol levels were more prevalent in non-migrants, with the exception of HDL levels in men, where 58.6% of non-migrants were classified has having low

HDL, compared to 61.9% of migrant men (p=0.107). In spite of low self-reported dyslipidemia, 85% of the sample was classified as having dyslipidemia.

Type 2 diabetes, prediabetes, and dysglycemia

Table 6 describes the prevalence of diabetes and prediabetes, as well as the overall distribution of normoglycemic and dysglycemic participants. Nearly two thirds of the sample was dysglycemic, where 44.5% of the sample was classified as having prediabetes through a combination of IFG, IGT, and elevated HbA1c levels, and 27% were classified as having diabetes. The mean fasting glucose values and two-hour post-prandial tests were 111.1 mg/dL (± 44.4) and 120.0 mg/dL(±68.3) respectively, while the mean HbA1c for the overall sample was 6.4%. The prevalence of both diabetes and prediabetes was higher in the migrant population although these differences were not statistically significant *(Figure 1).* Out of the 147 participants (27%) of the sample that met the clinical cutoffs for diabetes, approximately 45% were unaware of their status. Migrants had a higher prevalence of self-reported diabetes (17.2%) than in non-migrants (14.2%).

Modeling

Bivariate analysis of migration status and risk factors

Before assessing the associations between migration status with T2D, we considered relationships between migration status and key risk factors for T2D. In Table 7, we present the associations between migration status and potential intermediary risk factors, and we examined the effects of migration after adjustment by sex, SES, and family history. In the overall sample, we found that migration status was not strongly associated with any of the intermediary risk factors.

In adjusted models, we noted that sex, socioeconomic status, and age were strongly associated with high fruit and vegetable intake, high physical activity, high anthropometric measures, high SBP, and high triglycerides levels. Participants in the 30-44 and 45-59 age groups had a 1.6 and 1.8 higher likelihood of consuming more than two proportions of fruits and vegetables per day, compared to those between the ages of 20-29. Older age was also strongly and significantly associated with high WC, WHR, and WHtR. In adjusted models, being male was protective across a number of risk factors including level of physical activity (OR: 0.6, 95%CI: 0.4-0.8), a high WC (OR: 0.4, 95% CI: 0.2-0.6); a high WHtR (OR: 0.4, 95%CI: 0.4-0.8) but was associated with a 2.5 higher odds of having higher BMI (95% CI: 1.7-3.9). Similarly, being of low SES was protective against high WC (OR: 0.7, 95%CI: 0.4-0.9), high WHtR (OR: 0.5 95% CI: 0.3-1.0), high SBP (OR: 0.6, 95% CI: 0.3-1.0), and high triglycerides (OR: 0.6, 95% CI: 0.4-0.9) although these differences were just barely significant.

Bivariate analysis of risk factors and T2D prevalence

To assess the strength of the relationships between risk factors and T2D outcomes, we conducted a bivariate analysis of all relevant risk factors in a logistic regression with diabetes (Y/N) as the outcome variable. The unadjusted odds ratios are listed in Table 8. The strongest demographic predictor for diabetes was having a family history of diabetes, which was associated with a 2-fold higher prevalence of T2D (95% CI: 1.4-3.1). Age, sex and SES were not statistically associated with T2D in this unadjusted bivariate analysis. Diet and physical activity were only moderately associated with T2D prevalence. Increasing weekly consumption of vegetables was associated with a 1.2 increased odds of T2D (95% CI: 1.0-1.5), while increased weekly consumption of meat was protective (OR: 0.6, 95%CI: 0.4-0.9). With regards to physical activity, every minute of sedentary time was associated with a 2% increase in the risk for T2D, although this association was weakly significant (p= 0.03); no other strong observations were observed in other measures of physical activity.

Anthropometric parameters were uniformly positively associated with increased T2D risk; with the exception of those who were underweight, each increasing level of BMI class was significantly associated with a 3-fold increase in odds of T2D. Individuals with high WHR were more likely to have T2D (OR: 3.7, 95%CI: 2.1- 6.3); estimates for high WC show comparable associations (OR: 2.5, 95% CI: 1.7-3.9). The strongest effect size was observed for WHtR: individuals with a high WHtR were 5 times more likely to have T2D (95% CI: 2.5-11.6). The likelihood of having T2D was significantly higher among those identified as hypertensive (OR: 4.1, 95% CI: 2.6-6.2), and one unit increase in SBP and DBP were associated with modest increases in the risk of T2D. Elevated triglycerides and levels of total cholesterol were

associated with a four-fold increase and two-fold increase in the likelihood of having T2D, respectively.

Strategy I

Focusing on the differing risk factors between migrants and non-migrants, we built an associative multivariate model which included adjustment for age, socioeconomic status, gender, familial history of diabetes, and high LDL levels *(Table 9*). In the adjusted model, migration status was associated with 1.4 times the odds of diabetes compared to non-migrants but we did not have statistical power to detect this difference (95% CI: 0.82-2.432). An increasing trend in risk was observed in the relationship between diabetes and age. Relative to those in the 20-29 age group, those in the 30-44 age group were 6.1 times more likely to have diabetes (95%CI: 1.88-21.10) and this risk increased with increasing age. Those who were 60 years and older had 65 times the odds of diabetes (OR: 65.0, 95% CI: 17.4-242.7).

Strategy II

Using all possible relevant variables from the published literature, we noted that migration status, age, gender, socioeconomic status, BMI, family history of diabetes, waist-to-hip ratio, SBP, and triglycerides levels were all independently associated with diabetes. *(Table 10).* While migration status was not significantly associated with diabetes prevalence in an unadjusted bivariate regression, (OR: 1.2, 95% CI: 0.7-2.0), rural-to-urban migrants had a 2.1 greater odds of diabetes after adjusting for critical demographic, anthropometric, and clinical risk factors.

Age was a strong predictor for diabetes risk in both adjusted and unadjusted models. In crude associations between age and T2D, those between the ages of 30-45 years of age were 3.9

times more likely to have diabetes, relative to those who of 20-29 years of age (95% CI: 1.6-9.6). With increasing age, the odds of diabetes was 2-3 times higher (OR: 8.9, 95%CI: 3.7-21.8; and OR: 23.5, 95%CI: 8.6-63.2, respectively) for those who are in the 45-59 and over 60 age groups. In a fully adjusted model, the effects of age on migration status are accentuated and still remain strong predictors *(Table 10).* Similarly, family history of diabetes differed significantly between the two groups and remained a significant predictor for diabetes prevalence. In the overall group, those with a family history of diabetes had 3.7 times the odds of diabetes (95%CI: 1.8, 6.8).

Obesity and central adiposity were strong risk factors in the association with diabetes. Participants who were overweight had 3 times the risk of having T2D, compared to those who were of normal BMI (OR: 3.0, 95%CI: 1.1-7.8), although these effects were decreased in those who were obese (OR: 1.6, 95%CI: 0.68-4.5). High WHtR was a strong predictor for diabetes in the unadjusted analysis (OR: 5.4, 95%CI: 2.5-11.6) but this association was no longer significant after adjusting for demographics, BMI class, SBP, and triglycerides. In the multivariate model, SBP was weakly but significantly associated with diabetes; there was as 2% increase in diabetes prevalence for every mmHg increase in SBP (OR: 1.02, 95%CI: 1.0-1.0).

Among all indicators for lipoprotein control, triglycerides had the strongest influence on probability of T2D. In the multivariate regression model for the overall sample, high triglycerides levels was associated with a 4.0 odds of diabetes (95%CI: 2.1-7.5), after adjusting for all other confounders and covariates. We did not observe any interaction between risk factors and our exposure of interest, although the interaction between low HDL levels and migration status, and gender and migration status approached significance (data not shown).

Comparison of strategy I and strategy II

Comparing the consistency of our estimates using the two separate models, we noted that anthropometric measurements had a strong effect on the estimate of migration status on T2D. Model I, which included variables that were significantly different between migrants and non-migrants, gave a more modest estimate of migration status on T2D prevalence.

Gender and T2D

In model III, we examined the effects of migration and risk factors on T2D in men and women separately. After adjustment for age, family history of diabetes, BMI, WHtR, and SBP, among female participants being a migrant was associated with a 3-fold increase in diabetes risk (95%CI: 1.1-8.1). Similarly, SES in women was a stronger predictor for T2D; women of low SES had three times the risk of T2D (OR: 3.1, 95% CI: 1.1-8.9) *(Table 11).* Among men, the most significant predictors for T2D were positive family history of diabetes (OR: 3.0, 95% CI: 1.0-8.1) and being over the age of 60. In contrast to women, the strong effects of SES and migration were not observed in men (OR: 1.3; 95% CI: 0.4, 4.3).

DISCUSSION

Rural-to-urban migration is a complex phenomenon that is driving the expansion of cities in many developing countries. In our study, we examined the association between migration history and T2D prevalence among an urban population in Chennai. Overall, migrants did not differ significantly on dietary habits or physical activity, but were more likely to be older, and of lower SES. After accounting for age, SES, gender, BMI, WHtR, family history of diabetes, SBP, and high triglycerides, migrants were twice as likely to have T2D compared to their urban counterparts. The effect of migration on T2D was more pronounced in women compared to men, after adjusting for the same covariates and confounders. Furthermore, in the female sample, even after accounting for the similarities in age and other characteristics in women, SES and migration had a strong association with T2D.

Age

In both of our analyses, two groups of variables were highly influential in the estimate of migration status on diabetes. Demographic factors, predominantly age, was strongly associated with T2D risk; given that the migrant group tended to be slightly older, adjustment for age augmented the difference in risk between migrants and non-migrants. An unadjusted association between migration status and diabetes initially showed a protective effect (data not shown); however, adjustment for age increased the odds ratio estimate associated with migration status, likely as a result of the older age in the migrant group *(Table 1).* Both age and family history of diabetes is consistently a strong predictor within our overall sample and in gender-specific models.

Socioeconomic status and T2D

With the exception of two individuals, the remainder of our respondents were classified as either low or moderate-income, based on the Kuppuswamy scale [48]. In our study, migrants were consistently in a lower socioeconomic position with a large gap in the educational class attained between non-migrants and migrants. This may be indicative of differences in early life opportunities between migrants who grew up in rural areas, compared to those who grew up in an urbanized environment offering more opportunity for greater schooling advancement. In analyses of migration status and risk factors, low SES was somewhat protective against central adiposity *(Table 6),* a finding that is counter to a number of studies that demonstrated a strong correlation between lower education, SES, and higher likelihood for obesity and adiposity [42, 54]. Gupta et al found that SES, as measured by low education status was associated with high WHR (OR: 2.18, 95%CI: 1.65- 2.71) and low HDL cholesterol levels (OR: 1.51, 95% CI: 1.27-1.80), and that low SES groups had a greater prevalence of three or more risk factors, relative to those of middle and high SES (28.0% vs. 23.9%, $p = 0.004$; 28.0% vs. 22.1%, $p<0.0001$ respectively)[42]. This difference, however, may have been occluded by the distribution of SES between women and men.

In gender-separated models, we found that lower SES was strongly and positively associated with increasing T2D risk in women after adjusting for age, family history of diabetes, anthropometric factors, SBP and triglycerides. Given the similarities across all other risk factors among women, the pronounced effect of SES on T2D is consistent with findings from studies in Peru which found a marked difference in T2D prevalence between women of low, medium and high SES [(33% (27.8-38.7) vs. 9.3%, [7.0-12.2] vs. 8.3% [4.5-15.0], respectively, $p <0.01$). When we decomposed the differences resulting in SES in women, we noted that neither

education attainment nor occupation differed significantly between the two groups. In terms of household income, more migrant women were from households whose monthly income was 10,554 Rs. per month or less, whereas a number of non-migrant women came from households with higher incomes. SES may have a stronger effect on the health profiles of women.

Anthropometric indicators

Comparing measures of central obesity, we found that migrants and non-migrants were comparable in their average WC, WHR, and WHtR. It is unclear as to what WHtR cut-offs are useful for defining central obesity in South Asians, as this has not been extensively studied in this population. However, previous studies conducted in Asian populations in China and Japan have validated the utility of utilizing BMI together with a measure of central adiposity, such as WC or WHtR [55, 56] . In a clinic-based study of 5,947 male and female subjects, Takahashi and colleagues noted that combining BMI and WC increased the sensitivity of detecting metabolic syndrome to 82% for men and 89% for women from 68% in men and 75% in women when only WC was used[55]. Combining BMI and WC also improved specificity from 69% and 71%, to 86% and 98% in men and women, respectively. For our study, we utilized BMI in combination with WHtR as our indicator of adiposity due to each of the predictors' strong association T2D among all possible anthropometric measurements. Although our study found a strong effect for migration status after adjusting for BMI and WHtR together, we also noted that the effect of each predictor was attenuated after adjustment by other factors in the multivariate model. For example, while we demonstrated WHtR to be strongly associated with T2D in bivariate analyses, this association was no longer significant in the fully adjusted model *(Table 10b).* This attenuation in effect is likely due to the strong association between familial history of

diabetes and T2D outcomes. These findings are similar to those found by Kodama et al noted that there is a strong influence of familial history on the prediction of diabetes—that although WHR, WC, and WHTR were all significantly associated with the risk of diabetes, these effects disappeared after adjusting for family history[30], suggesting that anthropometric measurements were not as critical as family history of diabetes.

Food and physical activity

Migrants and non-migrants were remarkably similar in their dietary habits and physical activity. Migrants and non-migrants differed significantly across their consumption of sweetened beverages, a finding consistent with previous migration studies in India and Guatemala which noted significant differences in the consumption of dairy and sugars between migrant and urban participants[27, 28]. Similar to the dietary profile in our study population, previous studies also noted similarities in fruit and vegetable consumption between migrants and non-migrants, and reported that rural to urban migration was associated with increased intake of fruits and vegetables[28, 57]. Among remarkable dietary findings, Unwin et al noted the increase in both vegetables and fruits in migrants was also positively associated with triglycerides and HDL cholesterol[57], a counter-intuitive finding which is in line with our findings that increasing vegetable consumption was associated with 1.2 increased odds of T2D. These findings may be understood in the context of the traditional diet in Southern India, which is predominantly vegetarian. Thus, an absolute increase in vegetable and fruit consumption may not be the most sensitive indicator for discriminate between a good and poor diet and associated risk factors.

Lipid profiles

Despite low self-reported dyslipidemia, a large proportion of individuals were classified as having an abnormal lipid profile and 97% of identified participants were undiagnosed. Around one third of the entire sample had elevated LDL, total cholesterol, or triglyceride levels and the prevalence of low HDL was especially high in both women and men. Elevated levels of cholesterol may be congruent with the high prevalence of central adiposity that was observed in the population.

Another explanation could be that lipoprotein profiles, closely associated with diet, may evolve over time, depending on length of time spent in an urban area. In a study examining the prevalence of risk factors across decades of urban years, levels of triglycerides and HDL appeared to remain relatively constant with each successive increase in decade [29]. The geometric mean for triglyceride in both men and women remained stable around 1.30 and 1.20, respectively, over the course of each successive decade indicating that triglyceride levels remain stable after the initial jump in the first decade of urban-life. Recent migrants (<15 years in an urban setting) comprised a small proportion of our overall sample, so triglyceride levels may have become similar to those of urban dwellers [29]. In patients with T2D, the more prevalent pattern of cholesterol associated with dysglycemia include low levels of HDL cholesterol and elevated triglycerides [53]; in our study, this strong association was noted in all multivariate models and across genders.

Sex-specific differences

A notable finding in our analysis was the interaction between migration status and sex, suggesting that the socio-behavioral changes associated with migration may exert a stronger effect on the health of migrant women. Overall, we found evidence of effect modification of migration status by gender on diabetes prevalence. In women, migration status was highly associated with increased T2D, with a three-fold increase in the likelihood of T2D, compared to a 1.5 risk in men.

In the assessment for interaction, we did not detect any statistically significant effect modification of migration status by gender, yet gender-stratified models demonstrated an appreciable difference in the effect of risk factors for T2D. While the association of migration and T2D for women was significant, we did not have sufficient power to detect this effect in men. The difference between the sexes may have explained why interaction was not detected using the chunk test when we fit a final model. We also noted that missing values for predictors, such as height, were more prevalent in males than females, thereby introducing greater variance for the point estimates in the model for males.

Interestingly, while there was a large difference in age distribution for the sample overall, there was no statistically significant difference of age distribution in the female migrant group; the mean age for migrant women was 42.1 (39.2-44.5) compared to 40.8 (39.2-42.4) in non-migrant women ($p = 0.722$) suggesting that, unlike in the overall model, in the women-only model the effect estimate for migration and T2D was not skewed by uneven distribution of age between the two comparison groups.

Our findings on gender effects on migration and T2D risk are consistent with the work by the Kinra and Ebrahim from the Indian Migration group, who also noted that odds of risk factors, such as obesity and blood pressure, differed between the genders and across migration status[12, 29]. Most notably, the patterning of risk factors was significant among men, but not women, with fasting glucose levels and HOMA scores values increasing from rural, to migrant, to urban, to migrant [12]. Another large-scale migration study in Peru noted that the odds of metabolic syndrome, abdominal obesity, and low HDL levels are higher in women than in men, while there were no discernible differences in fasting glucose, hypertension or hypertriglycemia in men [43].

MISSING DATA

Height was the variable with the most amount of missing, which may have impacted the calculation of certain variables, such as BMI and waist-for-height ratio. However, since some missing BMI values were supplemented from BMIs calculated in the field, we were able to have more complete BMI values than WHtR. In order to assess the impact that these missing values may have had on our analysis, we examined the distribution of the key covariates (age, SES, family history of diabetes, WC, WHR, SBP, triglycerides) and our outcome, diabetes, across migration status. The distribution of T2D was not significantly different across migrants and non-migrants with missing WHtR values. Additionally, in those missing WHtR, migrants and non-migrants were similar across gender, WHR, WC, high blood pressure, high DBP, HDL, LDL and triglycerides. Missing WHtR values were greater in non-migrants with family history of diabetes; in migrants, missing WHtR was more common among those who were older (ages 45-59), of low SES, and with high SBP.

Given the strong effect of age and SES on estimated odds ratios for T2D, it is likely that our analysis actually underestimates the effects of migration status in the fully adjusted model.

STRENGTHS

The randomly selected population from the city of Chennai is an organic sample of the population in the city of Chennai. In contrast to case-control studies employed by other migration studies, using a sample drawn from a representative surveillance study allows for stronger inferences about the prevalence of risk factors and diabetes status at the population level. Ebrahim et al matched migrant workers with siblings who are living in rural areas and urban areas, to control for the effect of familial history and to better isolate the effect of environmental factors brought on by urbanization [12, 29]. Selection of migrant workers, however, may introduce some degree of selection bias. Studies from the social sciences have highlighted the intrinsic differences in skills and capabilities between migrant workers and those who are able to migrate to cities for work [58]. The outcome variable was defined through a combination of laboratory values and self-reported status, thereby increasing the likelihood of correctly classifying participants as having diabetes, prediabetes, or nomoglycemia compared to self-report alone, as rates of undiagnosed diabetes may be high [7]. Similarly, documenting migration status as a series of chronological time points with duration of residence for each place allowed us to control misclassification bias [59]. Given the importance of SES as a possible confounder, using an integrated scale combining educational attainment, income, and occupation more accurately reflects an individuals' social status than education alone. Lastly, the plethora of clinical, anthropometric, and lifestyle factors collected in the CARRS survey allowed for an in-depth analysis of many possible variables which contribute to diabetes prevalence.

LIMITATIONS

The cross-sectional nature of the study did not allow us to make any inferences about the causal nature of the relationship between rural-to-urban migration and T2D. While the comparison between the migrant and urban group allows us to make conclusions about health risks associated with migration or adaptation to an urban life, we are not able to assess baseline rates of T2D in the rural population[59] and therefore, are not able to estimate the exact amount of risk attributable to urban living. A larger sample size would have allowed us to better detect differences between migrants and non-migrants, as many risk factors and interaction terms approached significance. A larger and more balanced sample size composed of equal part migrants and non-migrants may have been more conducive to examining not only differences across migration status, but also differences across sexes and any additional gender-specific interactions.

A key limitation of this study is the lack of power to assess differences in dietary habits between migrants and non-migrants, and women and men. We were largely unable to include dietary factors into the model because of insufficient variation in key risk factors, such as vegetable consumption. Also, in a predominantly vegetarian population, as it is the case in Chennai, vegetable intake may not discriminate well between a healthy or unhealthy diet. Stronger indicators, such as quantitative measures of fat, protein, fiber intake would have been better for elucidating any links between dietary factors and migration status.

Similarly, although the IPAQ information was complete for all 546 respondents, we did not have enough granularity to explore the differences in physical activities and were unable to meaningfully assess the role of physical activity in T2D in our multivariate models.

Lastly, completeness of anthropometric data may limit the interpretation of the data. We found that a sizeable proportion of individuals were missing height measurements, which was necessary for the calculation of WHtR and BMI. Our chi-square statistics took into consideration the distribution of missingness between groups; therefore, the non-significance between the two groups shows that the differences between the two groups are not appreciable. However, since those with missing WHtR and BMI values were excluded from the model, this may have resulted in an overestimation of the strength of association between migration status and T2D. Assessment of all possible subsets and inclusion of WC and WHR in lieu of BMI and WHtR demonstrated that there was still a strong effect of these factors on overall diabetes prevalence *(Table 10 b)* but weakened the certainty of our point estimates. Lastly, respondents sampled for this survey represented low- to moderate- SES, with only two individuals being from high SES. For the purposes of analysis, these two individuals were added to the moderate SES group and we used this dichotomous categorization. Without representation of migrants and non-migrants in the upper strata of SES, it is difficult to observe the strength of associations of migration status and relevant risk factors across the full spectrum of SES. As a result, this may have resulted in an overestimation of the effect of low SES on outcomes.

In our study, we noted that migration status has a sizeable effect on the likelihood of T2D, after taking into account several critical risk factors such as family history and central adiposity. Our finding that migration status exerts a larger effect in women is an important one, considering the health inequalities that exist along gender lines. Llacer and colleagues stress the importance of integrating a gender perspective when considering the impact of migration and health, given that in many LMICs, women may lack financial autonomy, have

less access to education, and less likely to access healthcare services[60], thus rendering them more vulnerable to risk factors for NCDs.

CONCLUSION

In a comparison of rural-to-urban migrants and life-long city dwellers in a cross-sectional sample of 20-90 year olds in Chennai, Tamil Nadu, we found that rural-to-urban migration was associated with T2D prevalence and this effect was more pronounced in women than in men. Other strong predictors for T2D prevalence included high BMI, WHtR, increasing age, elevated triglycerides and positive family history. In female participants, SES class was an especially strong predictor for T2D. Rural-to-urban migration is associated with rapid changes in lifestyle, possibly mediated through social factors such as education, income, occupation, stress, and other environmental factors. Migrants are not homogenous as a group, yet the common exposure to an increasingly urbanized lifestyle may provide an avenue for understanding the effects of urbanization and environmental factors associated with T2D. That the effect of migration status on probability of T2D is not immediately apparent, and is observable only after adjusting for a number of intermediate factors suggests that social factors, central adiposity and co-existing conditions such as dyslipidemia are strong mediators of this effect. The findings from this study may have implications for screening of diabetes in an urban environment by urging primary healthcare to consider risk factors such as migration history, in additional to traditional risk factors for diabetes[61].

Given that urbanization is an increasing phenomenon in low- and middle-income countries, research in migration is especially relevant in understanding how to improve urban health. While clinical parameters are critical in screening and early detection of T2D,

macrosocial determinants of health such as migration status must play a stronger role in our understanding of health and risk factors for non-communicable diseases. These findings also highlight the need for targeting public health and social interventions to reach vulnerable populations such as rural-to-urban migrants.

CHAPTER III

PUBLIC HEALTH IMPLICATIONS

In 2010, the World Health Organization commissioned report "Our Cities, Our Health" unpacked the complexity and interconnectedness of social factors, economic factors, and health aspects of urbanization. The implications of urbanization were examined in the context of economic development, environmental protection, and health, reflecting the reality that urbanization is a multi-faceted phenomena that requires an integrated approach to understand.

Rural-to-urban migration will be increasingly common in LMICs in the future; by comparing migrants to urban populations, the scope of this study was not solely to understand the way in which urbanization may drive changes in health in the migrant population, but also to highlight key intermediary factors that might have different effects on health in migrants and non-migrants.

Going forward, there are still many unanswered questions. Given the heterogeneity of the populations and the cultural make-up of 'an urban lifestyle' across Cameroon, China, Peru, Tanzania, and India, converging findings deserve further attention to understand what common threads run through them. Conversely, when differences in risk patterning are observed, further efforts should be taken to understand not only what these differences are, but what works upstream to facilitate these changes. For example, in considering the differential effects of migration status on women and men, what factors are associated with this sex difference? Are these solely related to behavioral changes and adaptations among men and women, and how do these vary across different race/ethnic or geographic populations? For example, if diet and physical activity, strong risk factors for T2D, differ so significantly between women and men, what accounts for these differences, and do these occur differently in different race/ethnicities or geographic locations? What structures or

norms govern these changes, and how does the experience of stress impact health outcomes among migrants? These questions are difficult, but not trivial, as they help explain the relationships between epidemiological findings and health impacts.

From a methodological perspective, future studies focusing on migrant health should consider longitudinal designs to provide stronger evidence for a pre- and post- migration comparison. The challenge lies in keeping track of these populations as they may be more mobile than long-time dwellers of one location. To gain more depth and richness about the changes that might facilitate increased risk for NCDs, future studies should also investigate the psychosocial aspects of the migration experience. Aside from being a fascinating demographic phenomenon migration is, ultimately, a real and lived human experience and should be studied as such. Rigorous qualitative research methods have been employed in maternal health and nutrition and have elucidated a complex web of factors affecting maternal feeding practices and health-seeking behavior, in a way that surveys and laboratory measurements may not. Along these lines, innovative approaches can be employed to unravel the determinants, and the health consequences of, acculturation and adaptation in new environments.

Cities can be engines for tremendous growth and innovation, but in order to harness the potential of this growth and mitigate the negative health consequences of urbanization, we must also understand the social, structural, and behavioral factors which contribute to behavior change and adaptation among rural-to-urban populations. Doing so will require that epidemiologists and public health practioners to think creatively beyond the field of health and biomedicine. Making linkages across disciplines—economics, sociology, environmental science, to name a few—will not only shed more understanding on the

context in which health unfolds, but also ensure that research can, and is, effectively translated towards improving human health. In particular, by identifying and starting to explore the various health and psychosocial risks experienced by migrants, health care providers, public health professionals, and city administrators can develop policies and programs that facilitate transitions into urban life that preserve health and wellbeing.

Appendix

Tables and Figures

Table 1. Demographics of migrants and non-migrants in a cross-sectional subsample of adults ages 20-90 in Chennai, Tamil Nadu

	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value**
	n	(%)	n	(%)	n	(%)	
Gender							
Female	301	(55.1)	227	(52.8)	74	(63.8)	**0.035**
Male	245	(44.9)	203	(47.2)	42	(36.2)	
Age							
20-29	95	(17.4)	74	(17.4)	20	(17.4)	
30-44	247	(45.3)	212	(49.3)	35	(30.4)	**0.001**
45-59	147	(26.9)	102	(23.7)	45	(38.8)	
60+	57	(10.5)	41	(9.5)	16	(13.9)	
Mean age	41.8	(12.8)	40.9	(12.3)	45.2	(13.9)	**0.001***
Socioeconomic status							
Low	297	(54.4)	220	(51.2)	77	(66.4)	
Middle	247	(45.2)	209	(48.6)	38	(32.8)	**0.003ǂ**
High	2	(0.4)	1	(0.2)	1	(0.9)	
Household monthly income							
<3,000	42	(7.7)	34	(7.9)	8	(6.9)	
3,001-10,000	417	(76.4)	327	(76.1)	90	(77.6)	
10,001-20,000	67	(12.3)	53	(12.3)	14	(12.2)	
20,001-30,000	10	(1.8)	9	(2.1)	1	(0.9)	0.381 §
30,001-40,000-	5	(0.9)	3	(0.7)	2	(1.7)	
40,001-50,000	1	(0.2)	1	(0.2)	0	(0.0)	
>50,000	2	(0.4)	2	(0.5)	0	(0.0)	
Don't know	2	(0.4)	1	(0.2)	1	(0.9)	
Education							
Professional graduate	66	(12.1)	55	(12.8)	11	(9.6)	
High school	404	(74.0)	319	(74.2)	85	(73.3)	**0.030§**
Primary school	36	(6.6)	30	(7.0)	6	(5.2)	
Illiterate	40	(7.3)	26	(6.1)	14	(12.2)	
Number of years of education	8.4	(4.2)	8.6	(4.1)	7.8	(4.4)	0.0703*

	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value**
Occupation							
Professional graduate	6	(1.1)	5	(1.2)	1	(0.9)	
Trained clerical	55	(10.1)	41	(9.5)	14	(12.1)	
Skilled manual labor	68	(12.5)	58	(13.5)	10	(8.6)	0.053 §
Semi-skilled labourer	74	(13.5)	66	(15.4)	8	(6.9)	
Unskilled labourer	43	(7.9)	36	(8.4)	7	(6.0)	
Unemployed	300	(55.0)	224	(52.1)	76	(65.5)	
Student	9	(3.0)	8	(3.6)	1	(1.3)	
Housewife	248	(82.7)	186	(83.0)	62	(81.6)	
Retired	18	(6.0)	13	(5.8)	5	(6.6)	0.674 ǂ
Unemployed	25	(8.3)	17	(7.6)	8	(10.5)	

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

** Pooled t-test*

ǂ*Fisher's exact*

***Pearson's* $\chi 2$ test

§ Cochran-Armitage trend test (one sided)

Table 2. Prevalence of risk factors associated with type II diabetes, in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value**
	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
Anthropometric							
Height (cm)	156.4	(9.4)	156.7	(9.5)	155.4	(9.0)	0.262*
Weight (kg)	63.0	(13.2)	63.7	(13.4)	60.7	(12.5)	0.037*
	N	(%)	N	(%)	N	(%)	
Body mass index							
Underweight	32	(5.9)	24	(5.6)	8	(6.9)	
Normal	101	(18.5)	73	(17.0)	28	(24.1)	0.243ǂ
Overweight	150	(27.5)	122	(28.4)	28	(24.1)	
Obese	145	(26.6)	112	(26.1)	33	(28.5)	
Central obesity							
WHR	346	(63.4)	269	(62.6)	77	(66.4)	0.245
WC	277	(50.7)	213	(49.5)	64	(55.2)	0.209
WHTR	270	(49.5)	213	(49.5)	57	(49.1)	0.539
Family history							
Diabetes	197	(36.1)	172	(40.0)	25	(21.6)	**<0.001**
Heart disease	25	(4.6)	22	(5.1)	3	(2.6)	0.338
Stroke	3	(0.6)	2	(0.5)	1	(0.9)	0.505ǂ
High blood pressure	119	(21.8)	104	(24.2)	15	(12.9)	**0.019**

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

Waist-to-hip ratio (WHR); waist circumference (WC); waist-to-height ratio (WHTR)

** Pooled t-test*

ǂ*Fisher's exact*

***Chi-square*

§ Trend test

Table 3. Weekly consumption of meats, fruits and vegetables, grains, and beverages in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value*
	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
Weekly consumption							
Meat	0.6	(0.6)	0.633	(0.6)	0.540	(0.5)	0.121
Meat							
Poultry							
Organ meats							
Fish	0.2	(0.2)	0.254	(0.3)	0.195	(0.2)	**0.018**
Fish							
Shellfish							
Fruits	0.3	(0.5)	0.336	(0.5)	0.295	(0.4)	0.362
Exotic fruits							
Other fruits							
Vegetables	1.9	(1.0)	1.901	(1.0)	1.9265	(0.9)	0.813
Leafy greens							
Legumes							
Cooked vegetables							
Other raw vegetables							
Grains	2.9	(0.9)	2.926	(0.9)	2.8787	(0.9)	0.620
Refined cereal							
Whole grain							
Dairy	0.4	(0.5)	0.3681	(0.5)	0.335	(0.4)	0.530
Milk							
Desserts	0.3	(0.5)	0.275	(0.5)	0.296	(0.6)	0.718 •
Desi style							
Western style							
Sweetened beverages	3.2	(2.3)	3.332	(2.4)	2.7152	(1.9)	**0.004** •
Tea							
Coffee							
Cold beverages							
Fruit juice							

Fried foods	0.1	(0.2)	0.101	(0.2)	0.090	(0.2)	0.587
Deep fried, desi food							
Deep fried, Western food							

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

** Pairwise pooled t-test*

• *Unpooled t-test of unequal variances*

Table 4. Physical activity and IPAQ scores in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

	Overall N= 546		Non-Migrant N= 430		Migrant N=116		p-value*
	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
Minutes per day							
Vigorous	17.1	(66.3)	17.8	(68.4)	14.7	(58.3)	0.631•
Moderate	34.1	(22.7)	35.0	(22.7)	30.6	(22.6)	**0.067**
Walking	48.1	(54.9)	48.4	(55.0)	47.2	(54.5)	0.842
Sedentary	349.1	(156.0)	344.9	(155.2)	364.9	(158.8)	0.220
IPAQ Scores							
Vigorous activity score	879.9	(3560.1)	935.9	(3745.4)	672.4	(2771.2)	0.480•
Moderate activity score	909.1	(621.3)	933.3	(623.6)	819.4	(607.1)	**0.080**
Walking activity score	1080.1	(1269.3)	1085.1	(1270.5)	1061.4	(1270.1)	0.859
Total physical activity score	2869.1	(3733.5)	2954.3	(3906.7)	2553.2	(2999.6)	0.305•
	n	%	n	%	n	%	
Activity Level							
High physical activity level	146	(26.7)	115	(26.7)	31	(26.7)	
Moderate physical activity level	346	(63.4)	277	(64.4)	69	(59.5)	0.270**
Low physical activity level	54	(9.9)	38	(8.8)	16	(13.8)	

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

* Pairwise pooled t-test

• Unpooled t-test of unequal variances

** Chi-square test

Table 5. Hypertension and dyslipidemia in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value*
	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
SBP	125.8	(21.9)	125.5	(21.4)	126.9	(23.9)	0.557
DBP	83.4	(12.8)	83.5	(82.2)	83.1	(80.8)	0.778
	n	%	n	%	n	%	
Blood pressure							
Self-reported	67	(12.3)	44	(10.2)	23	(19.8)	**0.002ǂ**
Traditional medicine	5	(7.5)	3	(6.8)	2	(8.7)	0.564ǂ
Allopathic medicine	53	(79.1)	36	(81.8)	17	(73.9)	0.858ǂ
High SBP	106	(19.4)	82	(19.1)	24	(20.7)	0.243**
High DBP	126	(23.1)	99	(23.0)	27	(23.3)	0.135**
HBP	86	(15.8)	68	(15.8)	18	(15.5)	0.234**
Hypertension	120	(22.0)	87	(20.2)	33	(28.5)	0.058**
Undiagnosed	53	(44.2)	43	(49.4)	10	(30.3)	0.060

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012
Systolic blood pressure (SBP); diastolic blood pressure (DBP); high blood pressure (HBP); high density lipoprotein (HDL); low-density lipoprotein (LDL)
** Unpaired pooled t-test*

• Unpaired Satterthwaite t-test of unequal variances

ǂFisher's exact

***Chi-square*

§ Trend test

Table 5 (Contd) Hypertension and dyslipidemia in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

	Overall		Non-Migrant		Migrant		p-value*
	N=546		N=430		N=116		
	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
LDL	114.9	(30.5)	116.0	(30.2)	110.8	(31.3)	0.110
HDL							
Women	43.3	(7.8)	43.0	(7.4)	44.4	(8.7)	0.162
Men	39.9	(9.9)	39.8	(10.0)	40.5	(9.3)	0.688
Total cholesterol	184.2	(39.1)	185.5	(39.5)	179.6	(37.6)	0.151
Triglycerides	161.8	(151.1)	166.3	(160.4)	145.5	(110.3)	0.108•
	n	%	n	%	n	%	
Cholesterol							
Self-reported	13	(2.4)	10	(2.3)	3	(2.6)	0.545‡
Traditional medicine	1	(7.7)	1	(100.0)	0	(0.0)	1.00‡
Allopathic medicine	8	(61.5)	6	(60.0)	2	(66.7)	0.685‡
High LDL	147	(26.9)	121	(28.1)	26	(22.4)	**0.05****
Low HDL							
Women	246	(81.7)	190	(83.7)	55	(75.7)	0.107‡
Men	145	(59.2)	119	(58.6)	26	(61.9)	0.851**
High total cholesterol	169	(31.0)	136	(31.6)	33	(28.5)	0.156**
High triglycerides	188	(34.4)	153	(35.6)	35	(30.2)	0.098**
Dyslipidemia	464	(85.0)	368	(85.6)	96	(82.8)	0.450**
Undiagnosed	451	(97.2)	358	(97.3)	93	(96.9)	0.829‡

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

Systolic blood pressure (SBP); diastolic blood pressure (DBP); high blood pressure (HBP); high density lipoprotein (HDL); low-density lipoprotein (LDL)

** Unpaired pooled t-test; • Unpaired Satterthwaite t-test of unequal variances; ‡Fisher's exact; **Chi-square*

Table 6. Prevalence of diabetes and prediabetes in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

Diabetes	Overall N=546		Non-Migrant N=430		Migrant N=116		p-value**
Lab values	Mean	± Std. dev.	Mean	± Std. dev.	Mean	± Std. dev.	
Fasting glucose	111.1	(44.4)	110.2	(43.8)	114.3	(46.5)	0.384*
HbA1c	6.4	(1.6)	6.4	(1.6)	6.5	(1.7)	0.360*
Post-prandial	120.0	(68.3)	120.8	(70.8)	117.2	(58.0)	0.700*
	n	%	n	%	n	%	
Self-reported	81	(14.8)	61	(14.2)	20	(17.2)	0.260‡
Traditional medication	5	(6.2)	4	(6.6)	1	(5.0)	0.6405‡
Allopathic medicine	71	(87.7)	53	(86.9)	18	(90.0)	0.767‡
Fasting glucose	94	(17.2)	69	(16.1)	25	(21.6)	0.226‡
Hba1c	133	(24.4)	100	(23.3)	33	(28.5)	0.131
Post-prandial test	24	(4.4)	20	(4.7)	4	(3.5)	0.855
Diabetes	147	(26.9)	112	(26.1)	35	(30.2)	0.217
Undiagnosed	66	(44.9)	51	(45.5)	15	(42.9)	0.781

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012
Impaired fasting glucose (IFG); impaired glucose tolerance (IGT)

***Chi-square*

‡Fisher's exact

** Unpaired pooled t-test*

Table 6. (Contd) Prevalence of diabetes and prediabetes in a cross-sectional sample of adults ages 20-90 in an urban population in Chennai, Tamil Nadu

Prediabetes	Overall N=545		Non-Migrant N = 430		Migrant N=116		p-value**
	n	%	n	%	n	%	
IFG	120	(22.0)	95	(22.1)	25	(21.6)	0.530
IGT	30	(5.5)	21	(4.9)	9	(7.8)	0.425‡
Combined IFG and IGT	20	(3.7)	14	(3.3)	6	(5.2)	0.348‡
HbA1c	231	(42.3)	180	(41.9)	51	(44.0)	0.216
Prediabetes	243	(44.5)	0	(44.2)	53	(45.7)	0.289
Dysglycemia	390	(71.4)	302	(70.2)	88	(75.9)	0.234

Overall	Overall N=545		Non-Migrant N = 430		Migrant N=116		p-value**
	n	%	n	%	n	%	
Diabetes	147	(26.9)	112	(26.1)	35	(30.2)	
Prediabetes	243	(44.5)	190	(44.2)	53	(45.7)	0.105
Normoglycemic	156	(28.6)	128	(29.8)	28	(24.1)	

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

Impaired fasting glucose (IFG); impaired glucose tolerance (IGT)

***Chi-square*

‡*Fisher's exact*

** Unpaired pooled t-test*

Table 7. Unadjusted and adjusted models for the association between migration status and risk factors for diabetes in an urban population aged 20-80 in Chennai, India

	Dietary		Physical activity		Anthropometric							
	≥ 2 Portions of fruits and vegetables per day		Activity level		BMI class		WC		WHtR		WHR	
Unadjusted model												
Migration	1.0	(0.7, 1.5)	1.2	(0.8, 1.8)	1.2	(0.8, 1.8)	1.1	(0.74, 1.74)	0.8	(0.5, 1.4)	1.0	(0.6, 1.6)
Adjusted model ǂ												
Migration	1.0	(0.6, 1.5)	1.0	(0.7, 1.6)	1.1	(0.7, 1.7)	1.2	(0.7, 1.9)	0.8	(0.5, 1.5)	1.0	(0.6, 1.5)
Age												
20-29*												
30-44	1.6	**(1.0, 2.6)**	0.6	(0.4, 1.0)	0.4	(0.3, 0.7)	**2.3**	**(1.3, 3.8)**	**2.8**	**(1.5, 5.0)**	**2.7**	**(1.6, 4.5)**
45-59	1.8	**(1.1, 3.1)**	0.7	(0.4, 1.1)	0.6	(0.3, 1.0)	**2.0**	**(1.1, 3.5)**	**3.4**	**(1.7, 7.0)**	**3.9**	**(2.1, 7.1)**
60+	1.4	(0.7, 2.7)	1.5	(0.7, 3.0)	0.5	(0.2, 0.9)	**3.4**	**(1.6, 7.3)**	**7.2**	**(2.5, 20.5)**	**5.2**	**(2.3, 11.9)**
Sex												
Female*												
Male	1.0	(0.7, 2.7)	**0.6**	**(0.4, 0.8)**	**2.5**	**(1.7, 3.9)**	**0.4**	**(0.2, 0.6)**	**0.4**	**(0.2, 0.8)**	1.0	(0.6, 1.7)
Socioeconomic status												
Moderate												
Low	0.8	(0.5, 1.2)	1.0	(0.7, 1.5)	1.4	(0.9, 2.1)	**0.7**	**(0.4, 1.0)**	**0.5**	**(0.3, 0.9)**	0.8	(0.5, 1.3)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

*Referent group; ǂ Model adjusted for age, sex, SES

Table 7. (contd) Unadjusted and adjusted models for the association between migration status and risk factors for diabetes in an urban population aged 20-90 in Chennai, India

	Blood pressure		Cholesterol	
	Systolic blood pressure		High triglyceride cholesterol	
Unadjusted model				
Migration	1.0	(0.6, 1.7)	0.8	(0.5, 1.2)
Adjusted model ǂ				
Migration	0.8	(0.5, 1.5)	0.8	(0.4, 1.2)
Age				
20-29*				
30-44	**4.8**	**(1.4, 16.1)**	**2.2**	**(1.2, 3.9)**
45-59	**13.3**	**(43.9, 44.7)**	**3.4**	**(1.9, 6.3)**
60+	**38.9**	**(10.6, 142.8)**	**2.3**	**(1.1, 5.1)**
Sex				
Female*				
Male	1.1	(0.6, 1.8)	1.3	(0.8, 1.9)
Socioeconomic status				
Moderate				
Low	**0.6**	**(0.3, 1.0)**	**0.6**	**(0.4, 0.9)**

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

*Referent group; ǂ Model adjusted for age, sex, SES

Table 8: Bivariate regression of risk factors and T2D, in an urban population aged 20-79 in urban population in Chennai, Tamil Nadu

	Unadjusted OR	95% Confidence Interval		P-value
Demographic				
Sex	1.1	(0.8 -	1.7)	0.486
Socioeconomic position (low vs. med)	1.0	(0.7 -	1.5)	0.839
Family history				
Family history yes vs. no	**2.1**	**(1.4 -**	**3.1)**	**0.0003**
Age categories				
30-44	**3.9**	**(1.6 -**	**9.4)**	**0.0027**
45-59	**8.9**	**(3.7 -**	**21.8)**	**<.0001**
60+	**23.5**	**(8.7 -**	**63.2)**	**<.0001**
Diet				
Weekly vegetable consumption	**1.2**	**(1.0 -**	**1.5)**	**0.019**
Weekly fruit consumption	0.7	(0.4 -	1.1)	0.123
Combined Weekly fruit and vegetable consumption	1.1	(1.0 -	1.3)	0.169
Weekly consumption of meat	**0.6**	**(0.4 -**	**0.9)**	**0.0201**
Weekly consumption of fried foods	0.5	(0.2 -	1.5)	0.2154
Weekly consumption of fish	1.3	(0.6 -	2.8)	0.464
Weekly consumption of sweetened beverages	0.9	(0.9 -	1.0)	0.237
Weekly grain consumption	1.0	(0.8 -	1.3)	0.752
Physical activity				
Vigorous	1.0	(1.0 -	1.0)	0.961
Moderate	1.0	(1.0 -	1.0)	0.290
Walk time	1.0	(1.0 -	1.0)	0.153
Sitting time	**1.02**	**(1.0 -**	**1.0)**	**0.031**
Total physical activity score	1.0	(1.0 -	1.0)	0.371

Activity level 1 vs. 0	1.0	(0.7 -	1.6)	0.917
Activity level 2 vs. 0	0.9	(0.4 -	2.1)	0.790
Anthropometric				
BMI				
Underweight vs. normal	0.4	(0.1 -	1.8)	0.224
Overweight vs. normal	**2.9**	**(1.5 -**	**5.5)**	**0.0015**
Obese vs. normal	**3.1**	**(1.6 -**	**5.9)**	**0.0007**
Waist to hip ratio	**3.7**	**(2.1 -**	**6.3)**	**<.0001**
Waist to height ratio	**5.4**	**(2.5 -**	**11.6)**	**<.0001**
Waist circumference	**2.5**	**(1.7 -**	**3.9)**	**<.0001**
Comorbidities				
Hypertension	**4.1**	**(2.6 -**	**6.2)**	**<.0001**
SBP	**1.0**	**(1.02-**	**1.04)**	**<.0001**
DBP	**1.1**	**(1.03-**	**1.06)**	**<.0001**
Dyslipidemia	1.5	(0.8 -	2.8)	0.162
HDL	0.9	(0.6 -	1.3)	0.458
LDL	1.4	(0.9 -	2.2)	0.106
Triglycerides	**4.1**	**(2.8 -**	**6.1)**	**<.0001**
Total cholesterol	**2.0**	**(1.3 -**	**2.9)**	**0.0008**

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

Table 9. Crude and adjusted OR (95%CI) for diabetes prevalence among migrants and non-migrants in a cross-sectional subsample of adults ages 20-90 in Chennai, Tamil Nadu, with a focus on risk factors that are different between the two groups (Strategy I)

Parameter	Crude OR**	95% CI	Adjusted OR ǂ	95% CI
Migration status	1.7	(1.0, 2.7)	1.4	(0.8, 2.4)
Age				
20-29*				
30-44	3.9	(1.6, 9.6)	**6.3**	**(1.9, 21.1)**
45-59	8.9	(3.7, 21.8)	**19.9**	**(5.8, 67.9)**
60+	23.5	(8.7, 63.2)	**65.0**	**(17.4, 242.7)**
Socioeconomic status				
Moderate*				
Low	1.0	(0.7, 1.5)	0.9	(0.5, 1.5)
Sex	1.1	(0.8, 1.7)		
Female*				
Male	1.1	(0.8, 1.7)	1.0	(0.6, 1.7)
Family history				
No*				
Yes	2.1	(1.4, 3.1)	**3.4**	**(2.1, 5.7)**
High LDL cholesterol	1.4	(0.9, 2.2)	1.2	(0.8, 2.0)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

**Univariate models

*Referent group

ǂ Adjusted for age, SES class, gender, family history of diabetes, high triglyceride cholesterol

Table 10 a. Crude and adjusted OR (95%CI) for the association between migration status and diabetes prevalence in a cross-sectional subsample of adults ages 20-90 in Chennai, Tamil Nadu

Parameter	Crude OR	95% CI	Adjusted OR ǂ	95% CI
Migration status	1.7	(1.04, 2.71)	**2.1**	**(1.04,4.43)**
Age				
20-29*				
30-44	3.9	(1.60, 9.63)	**4.8**	**(1.04, 22.29)**
45-59	8.9	(3.66, 21.77)	**13.7**	**(2.82,66.80)**
60+	23.5	(8.72, 63.18)	**58.5**	**(9.61, 356.33)**
Socioeconomic class				
Moderate*				
Low	1.0	(0.71, 1.52)	1.5	(0.72, 2.95)
Sex				
Female*				
Male	1.1	(0.78, 1.68)	0.7	(0.35,1.43)
Family history of diabetes				
No*				
Yes	2.1	(1.40, 3.06)	**3.7**	**(1.8, 6.8)**
BMI				
Underweight*	0.4	(0.083, 1.79)	0.4	(0.04, 3.70)
Overweight*	2.9	(1.50, 5.45)	**3.0**	**(1.12, 7.78)**
Obese*	3.1	(1.61, 5.86)	1.6	(0.60, 4.49)
Central obesity				
High waist to height ratio	5.4	(2.50, 11.58)	1.5	(0.52, 4.35)
Comorbidities				
Systolic blood pressure	1.0	(1.02, 1.04)	**1.0**	**(1.00, 1.03)**
High triglycerides	4.1	(2.76, 6.15)	**4.0**	**(2.10, 7.45)**

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012
**Univariate models

*Referent group

ǂ Model adjusted for age, SES class, gender, family history of diabetes, BMI, waist-to-height ratio, SBP, high triglyceride cholesterol

Table 10 b . Evaluation of all possible subsets: assessing changes in estimates by risk factor groups: demographic parameters

		GOLD STANDARD: Migration status, adjusted for SES, age, sex, family history, BMI, WHtR , SBP, trigly		Model 0. Age, SES, sex, family history of diabetes, BMI, WHtR, SBP, triglycerides (without migration)		Model 1. Migration status, adjusted for BMI, WHtR, SBP, triglycerides	
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
	Migration status	**2.1**	**(1.0, 4.4)**			**2.0**	**(1.1, 3.8)**
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Demographic	30-44	4.8	(1.0, 22.3)	4.5	(1.0, 20.7)		
	45-59	13.7	(2.8, 66.8)	13.6	(2.8, 66.4)		
	60+	58.5	(9.6, 356.3)	57.6	(9.6, 346.2)		
	Low vs. non-low socioeconomic position	1.5	(0.7, 3.0)	1.5	(0.7, 2.9)		
	Male vs. female	0.7	(0.4, 1.4)	0.7	(0.04, 1.4)		
Family history	Family history of diabetes	3.5	(1.8, 6.8)	3.2	(1.7, 6.1)		
Anthropometric	Underweight	0.4	(0.04, 3.7)	0.4	(0.04, 3.8)	0.5	(0.06, 4.72)
	Overweight	3.0	(1.1, 7.8)	2.7	(1.1, 6.8)	1.6	(0.70, 3.9)
	Obese	1.6	(0.6, 4.5)	1.6	(0.6, 4.2)	1.2	(0.5, 2.9)
	High waist-to-height ratio	1.5	(0.5, 4.3)	1.5	(0.5, 4.2)	2.6	(1.0, 6.8)
Hypertension	SBP	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)
Dyslipidemia	High triglyceride cholesterol	4.0	(2.1, 7.5)	3.9	(2.1, 7.3)	2.9	(1.7, 5.0)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

ǂ Adjusted for age, SES class, gender, family history of diabetes, BMI, waist-to-height ratio, SBP, high triglyceride cholesterol

Table 10 b . (Cont'd) Evaluation of all possible subsets: assessing changes in estimates by risk factor groups: anthropometric parameters

		GOLD STANDARD: Migration status, adjusted for SES, age, sex, family history, BMI, WHtR , SBP, trigly		Model 2 a): Migration status, adjusted for age, SES, gender, family history, SBP, and triglycerides		Model 2b): Migration status, adjusted for age, SES, gender, family history, WHtR, SBP, trigly		Model 2c): Migration status, adjusted for age, SES, gender, family history, BMI, SBP, trigly	
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
	Migration status	**2.1**	**(1.0, 4.4)**	1.3	(0.7, 2.4)	1.8	(0.9, 3.7)	1.5	(0.8, 3.0)
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Demographic	30-44	4.8	(1.0, 22.3)	3.0	(1.1, 8.1)	4.8	(1.0, 21.8)	5.5	(1.2, 24.8)
	45-59	13.7	(2.8, 66.8)	6.8	(2.4, 19.1)	12.5	(2.6, 59.5)	16.4	(3.5, 76.4)
	60+	58.5	(9.6, 356.3)	25.0	(7.5, 83.3)	43.5	(7.7, 244.0)	50.3	(9.0, 279.9)
	Low vs. non-low socioeconomic position	1.5	(0.7, 3.0)	1.1	(0.6, 2.0)	1.3	(0.6, 2.5)	1.3	(0.7, 2.5)
	Male vs. female	0.7	(0.4, 1.4)	0.8	(0.4, 1.3)	0.7	(0.4, 1.4)	0.8	(0.4, 1.5)
Family history	Family history of diabetes	3.5	(1.8, 6.8)	3.0	(1.8, 5.0)	3.0	(1.6, 5.7)	2.7	(1.5, 4.8)
Anthropometric	Underweight	0.4	(0.04, 3.7)					0.3	(0.04, 3.1)
	Overweight	3.0	(1.1, 7.8)					3.4	(1.5, 7.6)
	Obese	1.6	(0.6, 4.5)					2.6	(1.2, 5.8)
	High waist-to-height ratio	1.5	(0.5, 4.3)			2.7	(1. 1, 6.5)		
Hypertension	SBP	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)
Dyslipidemia	High triglyceride cholesterol	4.0	(2.1, 7.5)	4.0	(2.5, 6.6)	3.5	(1.9, 6.4)	3.6	(2.1, 6.4)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

ǂ Adjusted for age, SES class, gender, family history of diabetes, BMI, waist-to-height ratio, SBP, high triglyceride cholesterol

Table 10 b. (Cont'd) Evaluation of all possible subsets: assessing changes in estimates by risk factor groups: hypertension, dyslipidemia

		GOLD STANDARD: Migration status, adjusted for SES, age, sex, family history, BMI, WHtR , SBP, trigly		Model 3. Migration status, adjusted for age, SES, gender, family history, BMI, WHtR, trigly		Model 4. Migration status, adjusted for age, SES, gender, family history, BMI, WHtR, SBP		Model 5. Sensitivity analysis: Using WHR instead of WHtR	
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
	Migration status	**2.1**	**(1.0, 4.4)**	**2.0**	**(1.0, 4.1)**	**2.1**	**(1.1, 4.2)**	1.7	(0.9, 3.3)
		OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Demographic	30-44	4.8	(1.0, 22.3)	5.8	(1.3, 26.5)	4.5	(1.0, 20.0)	5.5	(1.2, 24.7)
	45-59	13.7	(2.8, 66.8)	18.6	(3.9, 88.6)	12.3	(2.6, 57.4)	17.1	(2.6, 80.0)
	60+	58.5	(9.6, 356.3)	88.4	(15.5, 504.1)	38.5	(7.0, 213.0)	49.6	(8.8, 279.9)
	Low vs. non-low socioeconomic position	1.5	(0.7, 3.0)	1.3	(0.7, 2.7)	1.4	(0.7, 2.8)	1.4	(0.7, 2.6)
	Male vs. female	0.7	(0.4, 1.4)	0.7	(0.3, 1.4)	0.8	(0.4, 1.6)	0.8	(0.4, 1.5)
Family history	Family history of diabetes	3.5	(1.8, 6.8)	3.5	(1.8, 6.7)	3.1	(1.7, 5.9)	2.9	(16, 5.3)
Anthropometric	Underweight	0.4	(0.04, 3.7)	0.4	(0.04, 3.5)	0.3	(0.04, 2.8)	0.4	(0.04, 3.7)
	Overweight	3.0	(1.1, 7.8)	2.9	(1.1, 7.6)	2.5	(1.0, 6.4)	3.5	(1.5, 8.0)
	Obese	1.6	(0.6, 4.5)	1.7	(0.6, 4.4)	1.8	(0.7, 4.7)	2.5	(1.1, 5.7)
	High waist-to-height ratio	1.5	(0.5, 4.3)	1.5	(0.5, 4.4)	1.9	(0.7, 5.2)		
Hypertension	SBP	1.0	(1.0, 1.0)			1.0	(1.0, 1.0)	1.0	(1.0, 1.0)
Dyslipidemia	High triglyceride cholesterol	4.0	(2.1, 7.5)	4.6	(2.5, 8.5)			3.7	(2.0, 6.7)
	High waist-hip-ratio							1.2	(0.6, 2.7)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012

ǂ Adjusted for age, SES class, gender, family history of diabetes, BMI, waist-to-height ratio, SBP, high triglyceride cholesterol

Table 11. Adjusted logistic regression model‡ for the effect of migration status and risk factors on diabetes prevalence in men and women aged 20-90 in Chennai, Tamil Nadu

Parameter	Women		Men	
	OR	95% CI	OR	95% CI
Migration	**3.0**	**(1.1, 8.1)**	1.3	(0.4, 4.3)
Age				
20-29*				
30-44	6.7	(0.8, 58.3)	2.7	(0.3, 26.0)
45-59	**24.5**	**(2.6, 226.3)**	6.5	(0.6, 69.4)
60+	-		**38.0**	**(1.9, 742.0)**
Socioeconomic class				
Moderate*				
Low	**3.1**	**(1.1, 8.9)**	0.6	(0.2, 2.2)
Family history of diabetes				
No*				
Yes	**3.9**	**(1.6, 9.9)**	**3.0**	**(1.0, 9.1)**
BMI				
Normal*				
Underweight	0.7	(0.05, 9.0)	-	
Overweight	3.8	(0.9, 16.8)	2.3	(0.6, 9.1)
Obese	1.7	(0.4, 7.6)	1.6	(0.4, 7.0)
Central obesity				
High waist to height ratio	1.4	(0.3, 5.7)	2.3	(0.4, 14.9)
Comorbidities				
Systolic blood pressure	1.0	(1.0, 1.0)	1.0	(1.0, 1.0)
High triglycerides	**4.7**	**(2.0, 11.2)**	2.6	(0.9, 7.3)

Source: Center for Cardiometabolic Risk Reduction Surveillance Study, 2011; Center for Cardiometabolic Risk Reduction Surveillance Study—Migration Instrument 2012
*Referent group

NB: In women, the age group 60+ contained few observations; these were collapsed into the 40-59 age group. Similarly, due to small sample size, there were too few respondents in the underweight category; these were collapsed into the normal BMI group

ǂ Adjusted for age, SES class, family history of diabetes, BMI, waist-to-height ratio, SBP, high triglyceride cholesterol

Figure 1. Overall prevalence of diabetes, prediabetes, and normoglycemia in migrants and non-migrants

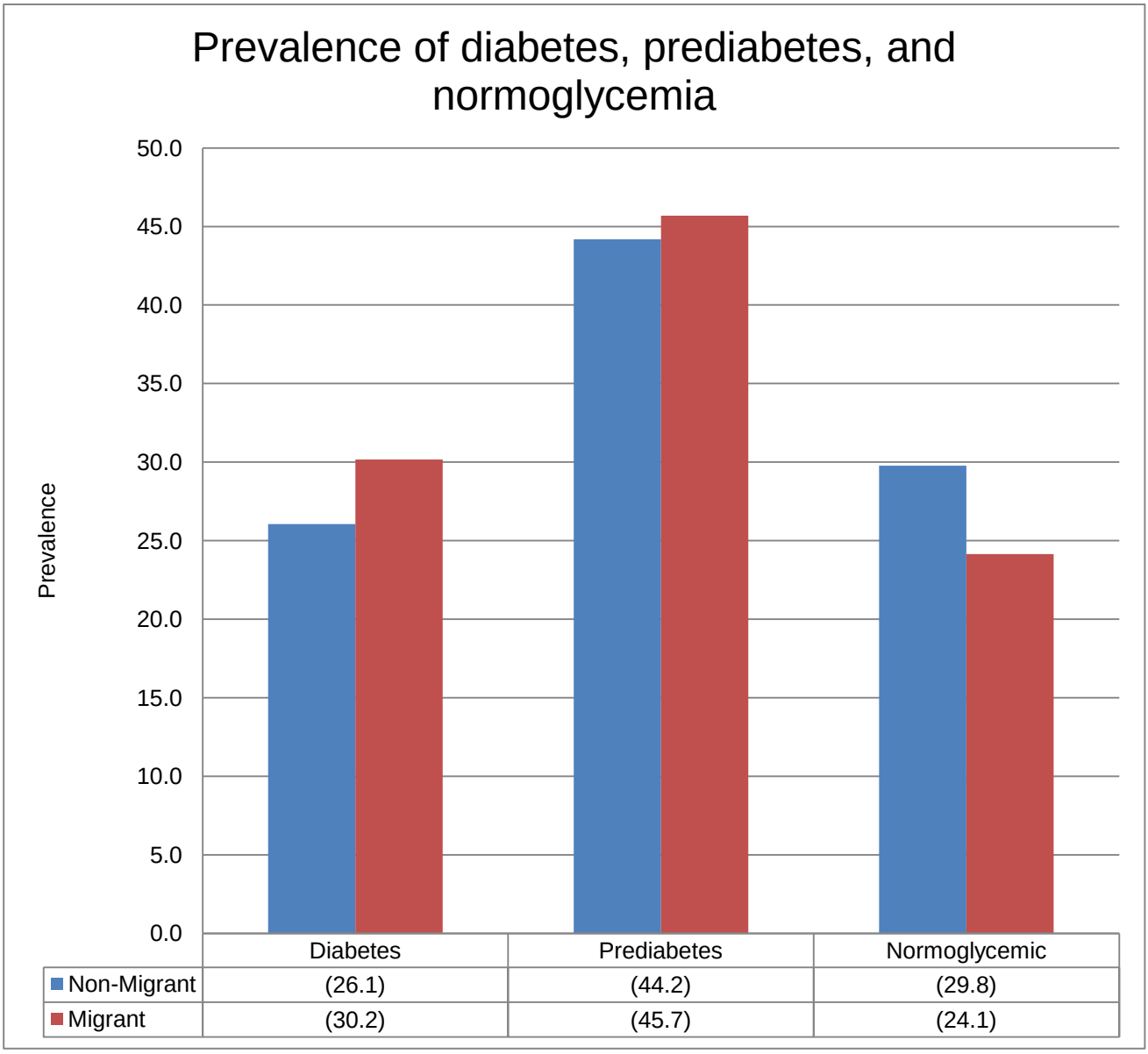


Figure 2. Prediabetes: IGT, IFG, and elevated HbA1cs in migrants and non-migrants

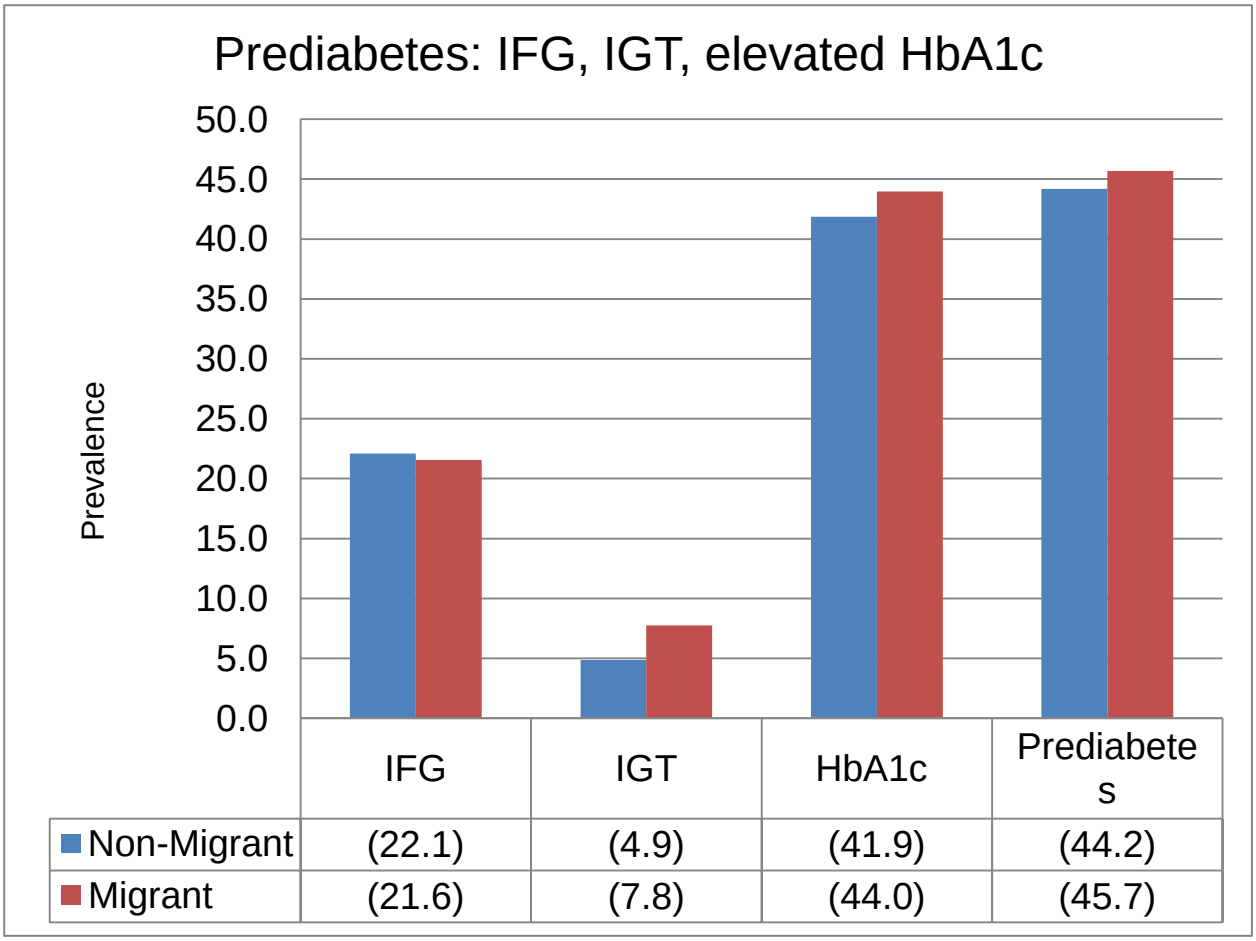


Figure 3. Migration Survey

***C**entre for c**A**rdiometabolic **R**isk **R**eduction for **S**outh-Asia **(CARRS)** – Surveillance Study* Date_____ Study ID_____

1. Date of Birth	__ __ __/__ __/ __ __ __ __ DD/MM/YYYY	__ __ __ Age

Please tell us the places you have lived starting with where you were born

Town/village name	District	State/Province	Urban--1 Semi-urban—2 Rural—3	From (yyyy)	To (yyyy)	How many years did you live here?	Reason for shifting? (Select One) 1—Family 2—Employment 3—Education 4--Other	Occupation
1. Place of birth			____	__ __ __ __	__ __ __ __	__ __ __	____	
2.			____	__ __ __ __	__ __ __ __	__ __ __	____	
3.			____	__ __ __ __	__ __ __ __	__ __ __	____	
4.			____	__ __ __ __	__ __ __ __	__ __ __	____	
5.			____	__ __ __ __	__ __ __ __	__ __ __	____	
6.			____	__ __ __ __	__ __ __ __	__ __ __	____	
7.			____	__ __ __ __	__ __ __ __	__ __ __	____	

8.			_____	_ _ _ _	_ _ _ _	_ _ _	____	
9.			_____	_ _ _ _	_ _ _ _	_ _ _	____	
10.			_____	_ _ _ _	_ _ _ _	_ _ _	____	

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