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an ecological study**

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The association between urbanisation and type 2 Diabetes: an ecological study

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Determinants, Socio-economic factors, Global Health.

Abbreviations:

AI: Agglomeration Index

DAGs: Directed Acyclic Graphs

GDP: Gross Domestic Product

HIC: Higher income countries

MIC: Middle-income countries

LIC: Lower-income countries

LMIC: Lower-middle-income countries

T2D: Type 2 diabetes

UMIC: Upper-middle income countries

UN: United Nation

UP: urbanisation percentage

WHO: World Health Organisation

Abstract:

Introduction: Previous studies have explored the effect of urbanisation on the prevalence of Type 2 Diabetes (T2D) at regional/national level. The aim of this study is to investigate the association between urbanisation and T2D at country level, worldwide, and to explore the role of intermediate variables (physical inactivity, sugar consumption and obesity). The potential effect modification of gross domestic product (GDP) was also assessed.

Methods: Data for 207 countries were collected from accessible datasets. Direct Acyclic Graphs were used to describe the association between urbanisation, T2D, and their intermediate variables (physical inactivity, sugar consumption and obesity). Urbanisation was measured as urban percentage (UP) and as Agglomeration Index (AI). Crude and multivariate linear regression analyses were conducted to explore selected associations. The interaction between urbanisation and T2D across levels of GDP per capita was investigated.

Results: The association between urbanisation and T2D diverged by exposure: AI was positively associated whilst UP negatively associated with T2D prevalence. Physical inactivity and obesity were statistically significantly associated with increased prevalence of T2D. In middle-income countries (MIC) UP, AI, and GDP were significantly associated with T2D prevalence, while in high-income countries (HIC) physical inactivity and obesity were the main determinant of T2D prevalence.

Conclusions: The type of urban growth, not urbanisation *per se*, predicted T2D prevalence at country level. In MIC, population density and GDP were the main determinant of diabetes, while in HIC these were physical inactivity and obesity. Globalisation is playing an important role in the rise of T2D worldwide.

What is already known about this topic

Urban environments are regarded as potentially obesogenic and diabetogenic. The majority of the studies investigating the association between urbanisation and diabetes found a positive association; however, it is not clear if this is a global trend, and if the mechanisms explaining the association are consistent across low and high income countries, and therefore across different stages of the epidemiological and nutritional transition.

What are the new findings

This worldwide ecological analysis investigates the association between urbanisation and prevalence of diabetes, exploring the role of potentially mediating factors, i.e. obesity, physical inactivity, and sugar consumption. The present data suggest that it is the uncontrolled growth of large urban agglomerates, rather than urbanisation *per se*, which is associated to a higher prevalence of diabetes worldwide. Agglomeration index and gross domestic product per capita are the determinant of diabetes in upper-middle income countries, while in high-income countries, obesity and physical inactivity explain its prevalence.

How might this influence practice

The effect of urbanisation on diabetes prevalence differs depending on the stage of the epidemiological and nutritional transition countries are going through. A controlled and effective urbanisation can confer an 'urban advantage', which mitigates the inequalities associated to the rapid expansion of urban agglomerates. This would also counteract the surge of risk factors for chronic diseases limiting the non-communicable disease epidemic.

Introduction

In 2015, the International Diabetes Federation reported that Type 2 diabetes (T2D) was the fourth leading causes of death worldwide, with 415 million people affected¹. Existing literature has examined the contextual effects of urbanisation on T2D risk^{2,3}. A structural change from agriculture to industrialisation has reduced the cost of calories through agricultural innovation and by producing and processing energy-dense foods⁴; a recent study has identified changes in obesity prevalence following alternations to agriculture in India⁵. Meanwhile, the cost of fruit and vegetables has increased due to the limited supply cultivated in less agriculturally productive land⁶. Internal migration contributes to changes in industrial practices, and has a role in changing health outcomes. As populations move towards a more urban environment, higher rates of obesity and T2D have been observed⁷, likely as a consequence of changes in lifestyles, and health behaviours (i.e. diet, physical activity)⁸⁻¹⁰, but perhaps also due to the changing socioeconomic make-up of these new urban populations.

Moreover, increasingly, urban sprawl replaces green space with densely populated buildings, reducing outdoor spaces suitable for physical activity¹¹. This also hampers proximity and connectivity, where the increase in distance and time to make journeys discouraged society from walking or cycling¹². Economic literature shows that urban sprawl is more common in higher income countries (HIC) and that it is a proxy for affluence¹³⁻¹⁵; living in urban environment might also facilitate access to health care and preventive programmes¹⁶. Few studies have examined the association between urbanisation and T2D at regional/national level finding mostly¹⁷⁻²⁰, but not always²¹, higher prevalence in higher urbanised areas.

It is not clear to what extent urban growth *per se* is associated with higher prevalence of T2D, or a rapidly increasing urban concentration might promote an obesogenic or diabetogenic environment. Most measures of urbanisation in relation to non-communicable diseases were previously found of limited value in measuring the urbanisation process²². The aim of this study is to investigate the association between urbanisation and T2D at country level, worldwide, and to examine the role of the

1 main potentially modifiable lifestyle risk factors (physical inactivity, sugar consumption and obesity)
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3 in mediating this association. The potential effect modification of gross domestic product was also
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5 explored.
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7 8 9 10 11 12 Methods

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15 Data on the exposure variable (urbanisation), the outcome variable (prevalence of T2D) and potential
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17 intermediate and interacting variables, or confounders (physical inactivity, prevalence of obesity,
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19 sugar consumption, and Gross Domestic Product (GDP) per capita) at country level, worldwide, were
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21 collected.
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23 24 25 Urbanisation

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28 There is no consensus on how to measure urbanisation at country level; few indicators have been
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30 suggested, providing different proxy measures. Data on urbanisation measured by urban percentage
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32 (UP), i.e. the proportion of a population living in urban areas as defined by national statistical offices,
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34 was collected for 207 countries from the 2015 World Bank Development Indicators ²³. UP despite
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36 being the most commonly used and widely available measure because of its simplicity, relies on
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38 country-specific definition of what it is urban, potentially leading to different ranks of urbanization
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40 when several countries are considered. As a consequence, also data on the Agglomeration Index (AI)
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42 in 2008 was obtained for 162 countries from The World Bank World Development Report ²⁴. AI is a
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44 composite measure of population density, size, and travel time to the nearest urban city. Population
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46 density is based on the average of two global gridded population data sources, Global Rural-Urban
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48 Mapping Project (GRUMP) and LandScan. Population size in a defined 'large' urban centre used for
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50 this analysis was 100,000 inhabitants. Travel time to the nearest urban city is calculated by a cost-
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52 distance model that estimates travel time to the city over the average travel speeds, based on GIS data,
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54 between the transport network and off road surfaces. These components are aggregated, with the
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56 proportion of this number to that country's total population being the agglomeration index. This
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58 measure is designed to quantify the degree of settlement concentration in order to capture the
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1 difference between large cities growing bigger from many small cities emerging²⁴. Also, AI includes
2 only locations that satisfy all three components, transcending country-specific and ad hoc definition
3 discrete entities, such as cities and administrative boundaries²⁵. However, AI is sensitive to the
4
5 chosen threshold values used to define the components.
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8 9 Type 2 Diabetes Mellitus (T2D) Prevalence

10 Prevalence of T2D was calculated using the 2015 World Bank Development Indicators²⁶ reporting
11 the percentage of people, aged 20 to 79 years, diagnosed with diabetes from 207 countries. These
12 figures aggregated type 1 and type 2 diabetes, however type 1 diabetes is, on average, a small
13 proportion (up to 10%) of prevalent cases²⁷, therefore it is possible to use the aggregate measure to
14 approximate T2D prevalence.
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24 Physical Inactivity

25 Physical inactivity was derived from The 2010 WHO Global Health Observatory Data Repository²⁸
26 for 143 countries as the proportion of a population, aged 20 to 79 years, achieving less than 150
27 minutes of moderate-intensity physical activity or less than 75 minutes of vigorous-intensity physical
28 activity per week, reflecting current recommendations.
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38 Obesity prevalence

39 Prevalence of obesity was collected for 187 countries from the 2014 Central Intelligence Agency
40 World Factbook²⁸ as age-adjusted measure of the proportion of the population, aged 20 to 79 years,
41 with a BMI of 30 kg/m² or higher.
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48 Sugar consumption

49 Sugar and sweeteners consumption (kg/capita/year) is obtained from The UN 2011 Food and
50 Agriculture Organisation Database²⁹ for 173 countries and measures the supply in kilograms, for
51 human consumption per year. This is calculated by dividing the annual sugar production by the mid-
52 year population.
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GDP per capita

GDP per capita is the GDP divided by the mid-year population, in US dollars. This was extracted from the World Bank ³⁰ 2015 for 183 countries and used as continuous variables (GDP per capita in \$/1000) in multivariate models. Countries were also stratified by income groups based on the World Bank's latest country classifications (2015) in low (<\$1025), lower middle (\$1026-\$4035) upper middle (\$4036-\$12,475), and high (\geq \$12,476) income countries ³¹.

Statistical analysis

A conceptual framework for studying the interconnectedness of the variables included in this study was built using Directed Acyclic Graphs (DAGs) (Figure 1): measures of urbanisation are regarded as the main exposure variables; obesity, physical inactivity, and sugar consumption as intermediate variables; prevalence of T2D as the outcome variable. Accordingly, crude associations of each suitable variable (exposure or intermediate variables) with T2D and with intermediate variables were initially studied. Subsequently, few multivariate models were built to study the association between urbanisation (measured either as UP, or as AI) and intermediate variables, with GDP and other relevant variables (i.e. physical inactivity when studying obesity and vice versa) as potential confounders. Finally, a model including UP, the AI, and intermediate variables was built. Interaction of the association between urbanisation and T2D across income categories has been tested using the likelihood ratio test; the final model was repeated restricted to each of the income categories. All analyses were conducted using STATA 14.1. Statistical significance was set at $p < 0.05$.

Results

The age-adjusted prevalence of T2D at county level, the proportion of population living urban areas (or UP), and the AI at country level, worldwide, are shown in Figures 2 to 4. Statistical analyses include a maximum of 207 countries (crude association between urbanisation and T2D) and a minimum of 109 countries (multivariate analyses) allowing for missing values (Table 1).

1 Crude linear regression models assessing the association between the independent variables and T2D
2 prevalence are shown in table 1. Increasing urbanisation is associated with increasing T2D prevalence
3 regardless of the variable used: UP ($\beta=0\cdot048$, 95% C.I. 0·022 to 0·047) or AI ($\beta=0\cdot082$, 95% C.I.
4 0·058 to 0·105). Contrary to GDP, physical inactivity, obesity and sugar consumption are univariately
5 significantly associated with T2D.
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13 Urbanisation, obesity, and GDP were all positively associated with physical inactivity in a statistically
14 significant way. Similarly, urbanisation, physical inactivity, sugar consumption and GDP were
15 positively significantly associated with obesity. Urbanisation and GDP were also significantly
16 associated with sugar consumption (Table 1).
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23 In multivariate analyses, urbanisation measured either as UP or AI was found significantly and
24 positively associated with sugar consumption and physical inactivity, but not with obesity. In turn,
25 higher sugar consumption was significantly associated with higher obesity; and higher obesity with
26 higher physical inactivity (Table 1 and Figure 1, DAGs connectors in orange).
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31 When all the variables were included in a final model, higher obesity prevalence, higher levels of
32 physical inactivity and lower GDP were all significantly associated with higher prevalence of T2D,
33 entirely accounting for the association between UP and T2D. Nonetheless, when urbanisation was
34 measured by the AI, this remained positively statistically significantly associated with T2D in the
35 final model, and so did the intermediate variables (physical inactivity, obesity, and GDP) (Table 1).
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43 A statistically significant interaction was observed between urbanisation measured either as UP or AI
44 and T2D prevalence across categories of country income ($p=0\cdot04$ and $p<0\cdot001$, respectively). When
45 UP and AI were added to the same model, the former was estimated to be significantly negatively
46 associated with T2D ($\beta=-0\cdot047$, 95% C.I. -0·088 to -0·005), while latter was significantly positively
47 associated ($\beta=0\cdot066$, 95% C.I. 0·030 to 0·102) (Table 2). When stratified by income categories, these
48 associations were still significant only in middle-income countries (Table 2).
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1 The association between urbanisation, intermediate variables, and T2D varied across income
2 categories: while none of the variables is associated with T2D prevalence in lower-income countries
3 (LIC), the AI is the only variable significantly positively associated with T2D in lower-middle-
4 (LMIC), irrespective of intermediate variable levels. Upper-middle-countries with
5 higher prevalence of T2D have higher AI, lower UP and higher GDP. Finally, in HIC only high
6 prevalence of obesity and physical inactivity are associated with higher prevalence of T2D,
7 irrespective of GDP and urbanisation (Table 2).
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20 Discussion

21 This is an ecological analysis investigating the determinants of the association between urbanisation
22 and T2D, globally. While the proportion of people living in urban settings (UP) is - if anything -
23 negatively associated with the prevalence of T2D, a measure of urban concentration (AI) is strongly
24 positively associated with T2D prevalence. These associations are mediated, though not entirely
25 explained, by the prevalence of some known risk factors for T2D (obesity and physical inactivity),
26 and by lower GDP. Sugar consumption at country level is a determinant of obesity prevalence, but is
27 not associated *per se* to T2D prevalence. In turn, obesity is associated with physical inactivity, and
28 both are then associated with increased prevalence of T2D.
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40 Notably, urbanisation measured as UP or as AI has inconsistent effects on the risk of T2D. UP is
41 based on member countries' existing definitions of what constitutes an urban or a rural area. Not only
42 do these definitions differ widely by country, in many places the traditional urban/rural dichotomy is
43 becoming increasingly inadequate³². The fact that this measure was negatively associated with T2D
44 prevalence in the final model might therefore reflect the 'urban advantage' paradigm, where economic
45 development, through urbanisation, improves social welfare³. Having urban communities better
46 spatial access to welfare facilities that offer preventative care contributes to increasing preventability
47 of chronic diseases such as T2D³³. On the other hand, the AI, distinguishing between large urban
48 cities which grow fast leading to highly densely populated areas, and the emergence of new,
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1 manageable urban agglomerates, accounts – at least partially - for the ‘urban advantage’ effect, and it
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3 is significantly positively associated with T2D prevalence.
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9 The analysis by income categories suggests how the socio-economic and lifestyle factors can prevail
10 in modulating the risk of T2D across different stages of the nutritional transition these countries are
11 going through. During the early phases of the transitions experienced by LMIC, agglomeration
12 density measured by the AI is the only factor found to be associated with increased T2D prevalence.
13 While the transition progresses, other socio-economic factors, including GDP, play an important role
14 in determining the risk of T2D, regardless of its lifestyle risk factor distribution (upper-middle income
15 countries (UMIC)). In HIC, by the end of the transition, lifestyle risk factors such as obesity and
16 physical inactivity are associated with T2D prevalence, regardless of the socioeconomic ones and
17 urbanisation. This suggest that during the transition, a plethora of complex risk factors cluster
18 according to socio-economic variables so strongly as to making the individual effect of some of them
19 negligible. Living in highly dense, overcrowded urban conditions that could increase the risk of T2D
20 and other non-communicable diseases reflects the ‘urban penalty’, where, historically, low socio-
21 economic groups are spatially situated in concentric zones, exposing them to poorer lifestyle habits as
22 well as poorer access to health care, sanitation and healthy nutritional options³⁴.
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40 Findings from individual studies mainly support this trend. Among LMIC, recent findings from India
41 showed a higher prevalence of T2D in low socio-economic groups living in the rapidly expanding
42 urban areas of the more economically developed states³⁵. Among UMIC, data from Peru show how
43 mortality and diabetes-specific mortality is higher in urban compared to rural context; internal
44 migrants from rural to urban areas maintain their lower mortality risk, probably reflecting a healthy
45 cohort effect³⁶. However, the longer migrants live in the new urban context, the higher their risk of
46 becoming obese³⁷. A multilevel analysis conducted in China, finding double diabetes prevalence in
47 highly urban areas compared to rural ones, suggests that community economic factors, modern
48 markets, communications and transportation infrastructure might responsible for the differences¹⁷. In
49 HIC, data coming from Oman, showed how diabetes, obesity, hypertension and high cholesterol were
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1 more prevalent in urban areas compared to rural ones¹⁹. In Greenland among Inuits, diabetes was
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3 more prevalent in small town than big cities despite people in small town were found to be exercising
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5 more, but also smoking more²⁰.
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9 The nutritional transition experienced at different levels by countries worldwide is strongly associated
10 with the process of globalisation. Globalisation is not only associated with changing incomes and
11 lifestyles, it also alters the quantity, type, cost and desirability of foods available for consumption by
12 altering the nature of agri-food systems³⁸. The ways globalisation impacts the nutritional transition
13 are multiple and interconnected: e.g. food trade and global sourcing, foreign direct investment, global
14 advertising, retail reconstructing. However, determining which are the specific mechanisms by which
15 globalisation alters diet quality and quantity is a challenge, and assessing their long-term health effect
16 is even more complicated^{39,40}. Urbanisation has a pivotal role in the effect of globalisation on the
17 nutritional transition, with the rise of multinational supermarkets and fast food chains expanding
18 beyond urbanised areas and into smaller cities and towns. This allows producers to mobilise the
19 supply of energy-dense foods and calorically sweetened beverages to new markets at cheap prices⁴¹.
20 Urbanisation is also associated with occupation-related physical inactivity in the administrative and
21 services sector that are incompatible with home food production and consumption, exacerbated by
22 increasing infrastructures and transport networks that limit land available for cultivation and
23 recreation⁴². However, the effects of urbanisation on lifestyle are not immediate; most studies explore
24 changes to health of rural to urban migrants over years to assess the impact of internal migration on
25 health behaviours⁷. Urban planning for increasing population health is becoming an emerging global
26 challenge; eight interventions designed to encourage walking, cycling, and public transport use, while
27 reducing private motor vehicle use were proposed, including equitable distribution of employment
28 across cities, designing pedestrian-friendly and cycling-friendly movement networks, reducing
29 distance to public transport and enhancing the desirability of active travel modes⁴³. However, this
30 needs to be coupled to an adequate access to healthcare and health education, and a minimised
31 westernisation of diet in countries undergoing the nutritional transition⁴⁴.
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1 The main limitation of this study is its ecological design, which does not allow generalisation of the
2 associations found at country level to an individual level (ecological fallacy)⁴⁵. However, the present
3 results are in line with previous ecological and observational study findings, indirectly arguing against
4 ecological fallacy. An ecological study investigating dietary patterns in association with diabetes
5 prevalence, found an increasing prevalence across agricultural/transitional/westernised nutrition
6 patterns, which, in turn, were associated with increasing urbanisation and decreasing physical activity
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The main limitation of this study is its ecological design, which does not allow generalisation of the associations found at country level to an individual level (ecological fallacy)⁴⁵. However, the present results are in line with previous ecological and observational study findings, indirectly arguing against ecological fallacy. An ecological study investigating dietary patterns in association with diabetes prevalence, found an increasing prevalence across agricultural/transitional/westernised nutrition patterns, which, in turn, were associated with increasing urbanisation and decreasing physical activity⁴⁸. A systematic review of individual-based studies in South East Asia was also highly coherent with the present ecological findings: point estimates of the associations between urbanisation and diabetes coming from single studies were not poolable due to high heterogeneity. However, the association was shown to be modified by per-capita Gross National Income of the country where the study took place being much stronger in countries with a lower Gross National Income⁴⁹.

Other limitations include genetic population stratification, which could confound the results, with some ethnic groups (e.g. South Asians) at higher genetic risk of T2D^{46,47}. Ethnicity-specific cut-offs of BMI were not used and therefore may underestimate obesity prevalence in some populations. A residual confounding effect could also be due to diet or other unmeasured variables. Finally, the analysis did not take directly into account access to health care, internal and external migration, literacy levels and education, which might account for some of the differences in T2D prevalence. The role of some of these factors might be particularly difficult to explore as they might lay on the causal pathway linking urbanisation with T2D prevalence (i.e. migration or access to health care).

Conclusion

The uncontrolled rapid growth of highly densely populated urban agglomerates is associated with an increased prevalence of T2D, worldwide. In UMIC, which have nearly completed the epidemiological and nutritional transition, more densely urbanised and relatively richer economies have higher prevalence of T2D. In HIC, the prevalence of T2D is not associated with wealth nor urbanisation, but with a more diabetogenic environment characterised by higher prevalence of obesity and physical

1 inactivity. An urbanisation process effectively targeting urban planning, including access to
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3 healthcare; health inequalities associated to the rapid expansion of urban agglomerates; and the risks
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5 associated to the westernisation of the diet might be effective in limiting the non-communicable
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7 disease epidemic in countries undergoing the epidemiological and nutritional transition.
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Author statement and Acknowledgments

Author Contributions: V Gallo has full access to all data in the study and takes responsibility for their integrity and the accuracy of the data analysis. She declares that this manuscript is honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted. All co-authors had full access to the data (including statistical reports and tables), and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: V Gallo

Analysis and interpretation of data: Z Gassasse, V Gallo, S Finer, D Smith

Drafting of the manuscript: Z Gassasse

Data collection: Z Gassasse

Critical revision of the manuscript for important intellectual content: all

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Table 1: Linear regression coefficients and relative 95% Confidence Intervals coming from crude models and from multivariate models investigating the association of independent variables in relation to T2D and intermediate variables (N = number of countries)

Variates	Crude β coefficient (95% CI)		Adjusted (urban percentage) β coefficient (95% CI)		Adjusted (Agglomeration Index) β coefficient (95% CI)	
	N	T2D	N	T2D	N	T2D
Urban percentage	207	0.048* [0.022 / 0.074]	126	-0.024 [-0.058 / 0.009]	-	-
Agglomeration Index	162	0.082* [0.058 / 0.105]	-	-	109	0.054* [0.019 / 0.089]
Obesity	187	0.281* [0.233 / 0.329]	126	0.233* [0.149 / 0.317]	109	0.148* [0.052 / 0.244]
Physical inactivity	143	0.204* [0.142 / 0.265]	126	0.142* [0.085 / 0.199]	109	0.106* [0.045 / 0.167]
Sugar consumption	173	0.114* [0.075 / 0.152]	126	0.016 [-0.044 / 0.076]	109	0.011 [-0.056 / 0.078]
GDP per capita	183	0.020 [-0.018 / 0.057]	126	-0.060 [-0.103 / -0.017]	109	-0.069 [-0.108 / -0.031]
	N	Physical inactivity	N	Physical inactivity	N	Physical inactivity
Urban percentage	143	0.210* [0.136 / 0.283]	136	0.128* [0.033 / 0.224]	-	-
Agglomeration Index	118	0.261* [0.185 / 0.336]	-	-	112	0.203* [0.111 / 0.295]
Obesity	141	0.461* [0.305 / 0.617]	136	0.359* [0.185 / 0.532]	112	0.216 [-0.006 / 0.437]
GDP per capita	138	0.182* [0.080 / 0.285]	136	-0.007 [-0.126 / 0.111]	112	0.025 [-0.082 / 0.132]
	N	Obesity	N	Obesity	N	Obesity
Urban percentage	187	0.229* [0.170 / 0.288]	126	0.045 [-0.027 / 0.117]	-	-
Agglomeration Index	153	0.234* [0.177 / 0.290]	-	-	109	0.040 [-0.031 / 0.110]
Physical inactivity	141	0.429* [0.284 / 0.574]	126	0.112 [-0.008 / 0.233]	109	0.109 [-0.012 / 0.231]
Sugar consumption	166	0.457* [0.388 / 0.525]	126	0.432* [0.328 / 0.535]	109	0.426* [0.317 / 0.534]
GDP per capita	178	0.236* [0.151 / 0.321]	126	-0.015 [-0.107 / 0.077]	109	0.020 [-0.059 / 0.981]
	N	Sugar consumption	N	Sugar consumption	N	Sugar consumption
Urban percentage	173	0.370* [0.283 / 0.457]	165	0.242* [0.136 / 0.347]	-	-
Agglomeration Index	148	0.375* [0.282 / 0.468]	-	-	143	0.280* [0.186 / 0.373]
GDP per capita	165	0.451* [0.339 / 0.563]	165	0.273* [0.141 / 0.404]	143	0.305* [0.193 / 0.417]

*p-value <0.005

Table 2: Linear regression coefficients and relative 95% Confidence Intervals coming from multivariate models across the four categories of GDP (N = number of countries)

	All countries β coefficient (95% CI) N=126	Low income β coefficient (95% CI) N=21	Lower middle income β coefficient (95% CI) N=32	Upper middle income β coefficient (95% CI) N=29	High income β coefficient (95% CI) N=44
Diabetes prevalence, median % (IQR)	6.6 (4.4-9.8)	3.4 (2.2-4.1)	6.5 (3.7-8.2)	9.9 (8.8-11.7)	7.1 (5.4-10.0)
Urban percentage	-0.047* [-0.088 / -0.005]	0.038 [-0.086 / 0.163]	-0.078 [-0.158 / 0.002]	-0.140* [-0.241 / -0.039]	-0.018 [-0.077 / 0.041]
Agglomeration Index	0.066* [0.030 / 0.102]	-0.031 [-0.185 / 0.123]	0.087* [0.008 / 0.166]	0.108* [0.032 / 0.184]	0.028 [-0.025 / 0.082]
Obesity	0.177* [0.079 / 0.275]	-0.606 [-1.535 / 0.323]	0.071 [-0.115 / 0.258]	-0.004 [-0.261 / 0.253]	0.247* [0.091 / 0.402]
Physical inactivity	0.115* [0.054 / 0.175]	0.011 [-0.098 / 0.119]	0.109 [-0.078 / 0.297]	-0.009 [-0.121 / 0.102]	0.200* [0.097 / 0.302]
Sugar consumption	0.014 [-0.052 / 0.080]	0.137 [-0.089 / 0.364]	0.104 [-0.009 / 0.218]	0.081 [-0.055 / 0.216]	-0.063 [-0.171 / 0.046]
GDP	-0.051* [-0.093 / -0.010]	-0.202 [-5.974 / 5.571]	0.310 [-0.765 / 1.385]	0.776* [0.041 / 1.512]	-0.015 [-0.071 / 0.400]

*p-values <0.005

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Figure 1: A conceptual framework disentangling the reciprocal associations of the variables used in the analysis, using the Directed Acyclic Graph (DAGs). In orange, the association that were found significant statistically in the multivariate models (Table 1). UP: Urban Percentage; AI: Agglomeration Index

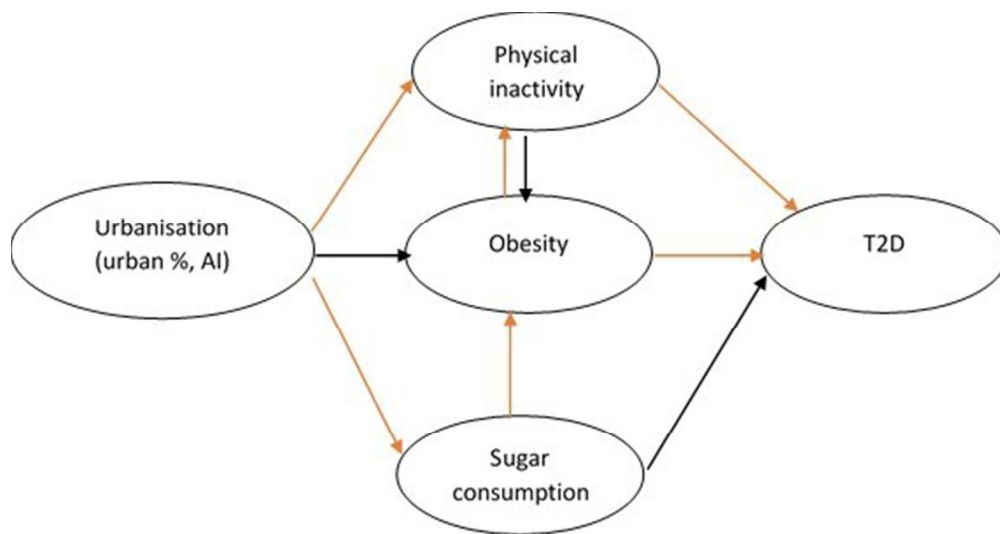
Figure 2: Maps showing the age-adjusted prevalence of T2D as proportion of the total population aged 20 to 79 years in 2015, worldwide (a); urban proportion, as proportion of total population at country level living in urban areas, worldwide (b); Agglomeration index at country levels, worldwide (c)

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All the authors declare to have no competing interests

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A conceptual framework disentangling the reciprocal associations of the variables used in the analysis, using the Directed Acyclic Graph (DAGs). In orange, the association that were found significant statistically in the multivariate models (Table 1). UP: Urban Percentage; AI: Agglomeration Index

151x79mm (96 x 96 DPI)

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(a)



(b)



(c)

Maps showing the age-adjusted prevalence of T2D as proportion of the total population aged 20 to 79 years in 2015, worldwide (a); urban proportion, as proportion of total population at country level living in urban areas, worldwide (b); Agglomeration index at country levels, worldwide (c)

583x825mm (72 x 72 DPI)

