Understanding the obesity dynamics by socioeconomic status in Latin American contexts

Jose D. Meisel[1,2], Valentina Esguerra[1], Angie M. Ramirez[1], Felipe Montes[3], Ivana Stankov[4,5] Usama Bilal[4,6], Carolina Perez[7,8], Natalia Tumas[9,10], Juan A. Valdivia[11,12], Ana V. Diez Roux[4,6], Olga L. Sarmiento[13]

[1] Facultad de Ingeniería, Universidad de Ibagué, Ibagué, Colombia.
[2] Social and Health Complexity Center, Bogotá, Colombia
[3] Department of Industrial Engineering, Universidad de los Andes, Social and Health Complexity Center, Bogotá, Colombia.
[4] Urban Health Collaborative, Drexel Dornsife School of Public Health, Philadelphia, PA, USA
[5] UniSA Allied Health and Human Performance, University of South Australia, Adelaide, Australia
[6] Department of Epidemiology and Biostatistics, Drexel Dornsife School of Public Health, Philadelphia, PA, USA
[7] National Institute of Public Health, Cuernavaca, Mexico
[8] National Council for Science and Technology (CONACYT), Ciudad de Mexico, Mexico
[9] Centro de Investigaciones y Estudios sobre Cultura y Sociedad (CIECS), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) y Universidad Nacional de Córdoba, Córdoba, Argentina
[10] Universidad Pompeu Fabra, Barcelona, España.
[11] Departamento de Física, Facultad de Ciencias, Universidad de Chile, Santiago, Chile.
[12] Centro para el Desarrollo de la Nanociencia y la Nanotecnología, CEDENNA, Santiago, Chile.
[13] Department of Public Health, School of Medicine, Universidad de los Andes, Bogotá, Colombia.

wellcome

SALURBAL
Salud Urbana en América Latina

LAC-URBAN HEALTH
Urban Health Network for Latin America and the Caribbean

Universidad de Ibagué
Comprometidos con el desarrollo regional

Outline

1) Context
   - Obesity problem
   - Obesity transition by socioeconomic status (SES)
2) Purpose
3) Modeling the obesity dynamics of Colombian urban population at different levels
4) Discussion and future work
5) References

Context

High BMI, among 2010-2019, accounted for more than 1% of DALYs and were increasing in age-standardised SEVs by more than 1% per year.

Risk Factors (2019)

- High body mass index(BMI), was the fifth for females and the sixth for males risk factor for attributable deaths globally.[2]
- Low physical activity was the thirteenth for females and fifteenth for males risk factor for attributable deaths globally .[2]

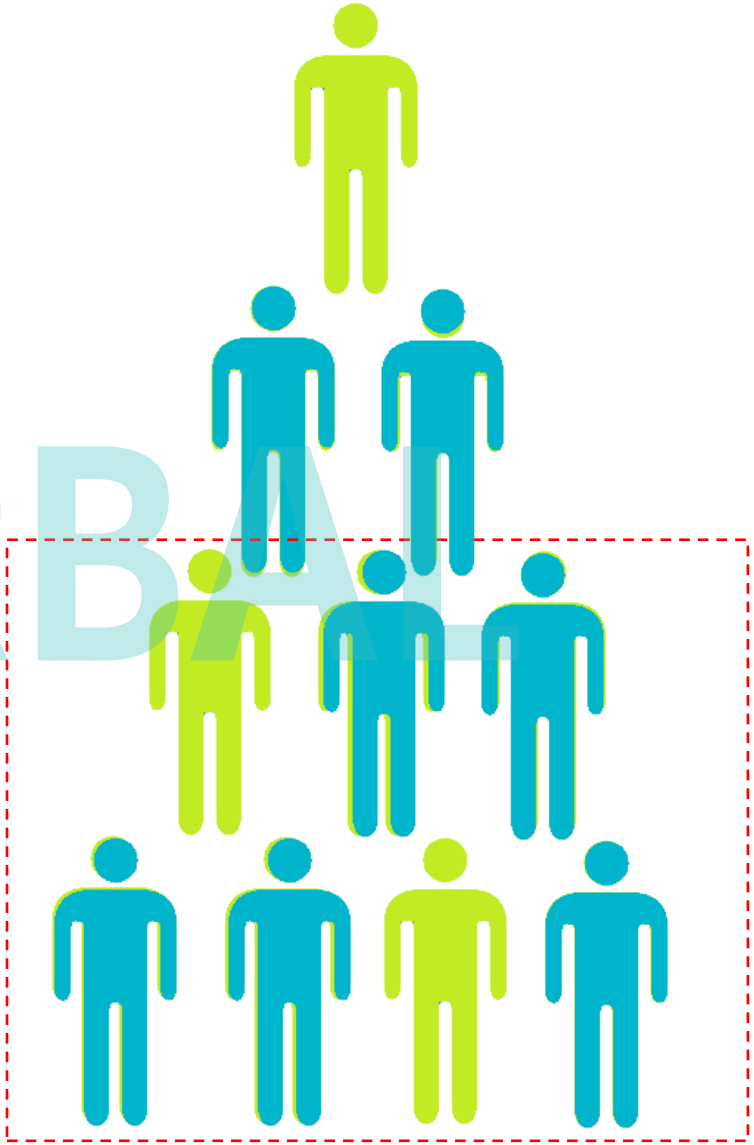
Low physical activity, among 2010-2019, was in the risk factor group that the annual rate of change was either statistically insignificant (p>0·05) or the annual rate of change was between –0·5% and 0·5% per year.[2]

Context

2015

71% of the deaths in the world due to non communicable chronic diseases (NCDs).[1]

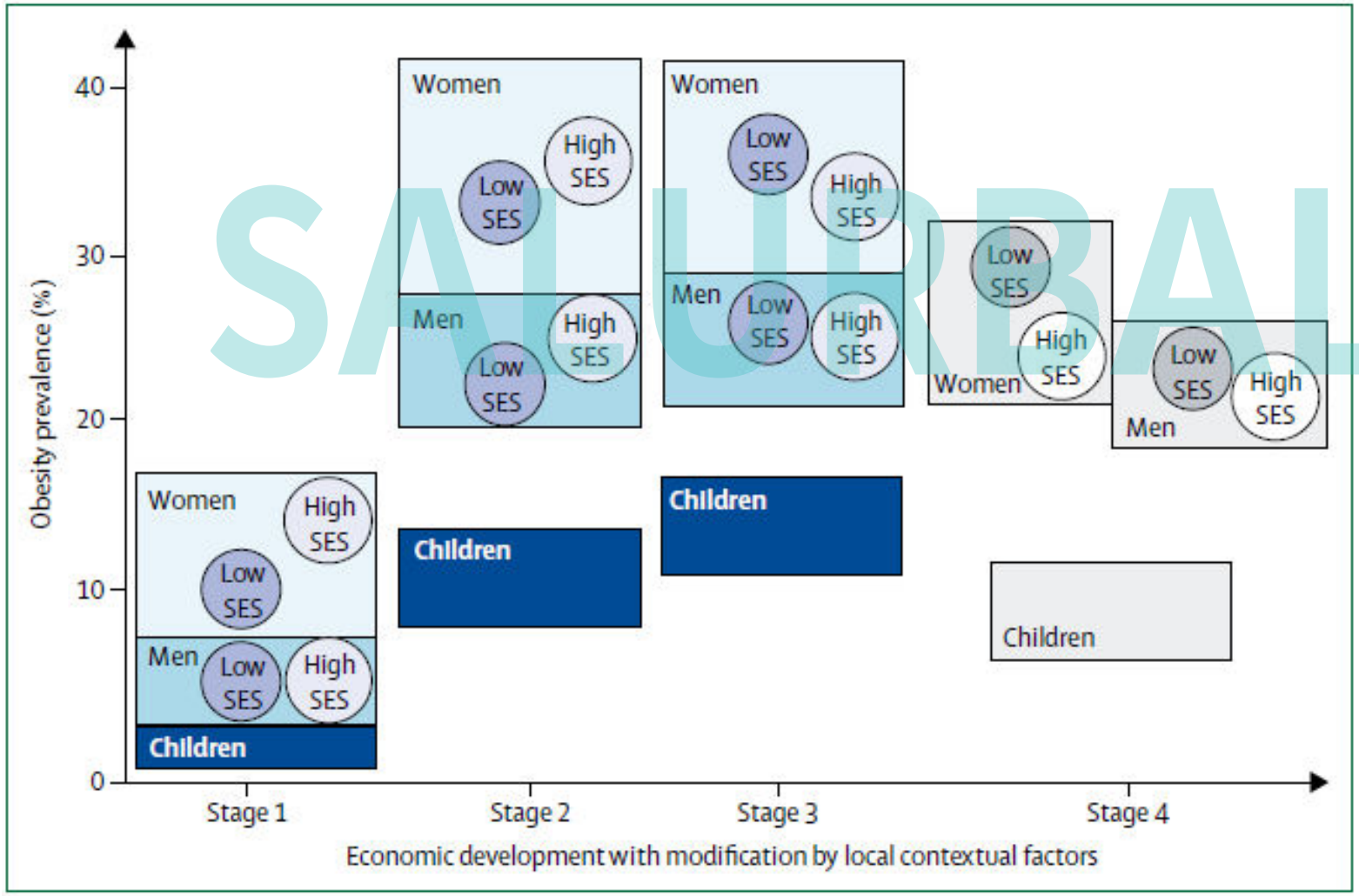
- **Over 77%**: Low and middle income countries



Overweight and obesity have represented among 2% and 9% of the total health care cost in different countries[4-7]

Context:

In a recent study, Jaacks et al. [8] proposed a conceptual model of the four stages of the obesity transition.

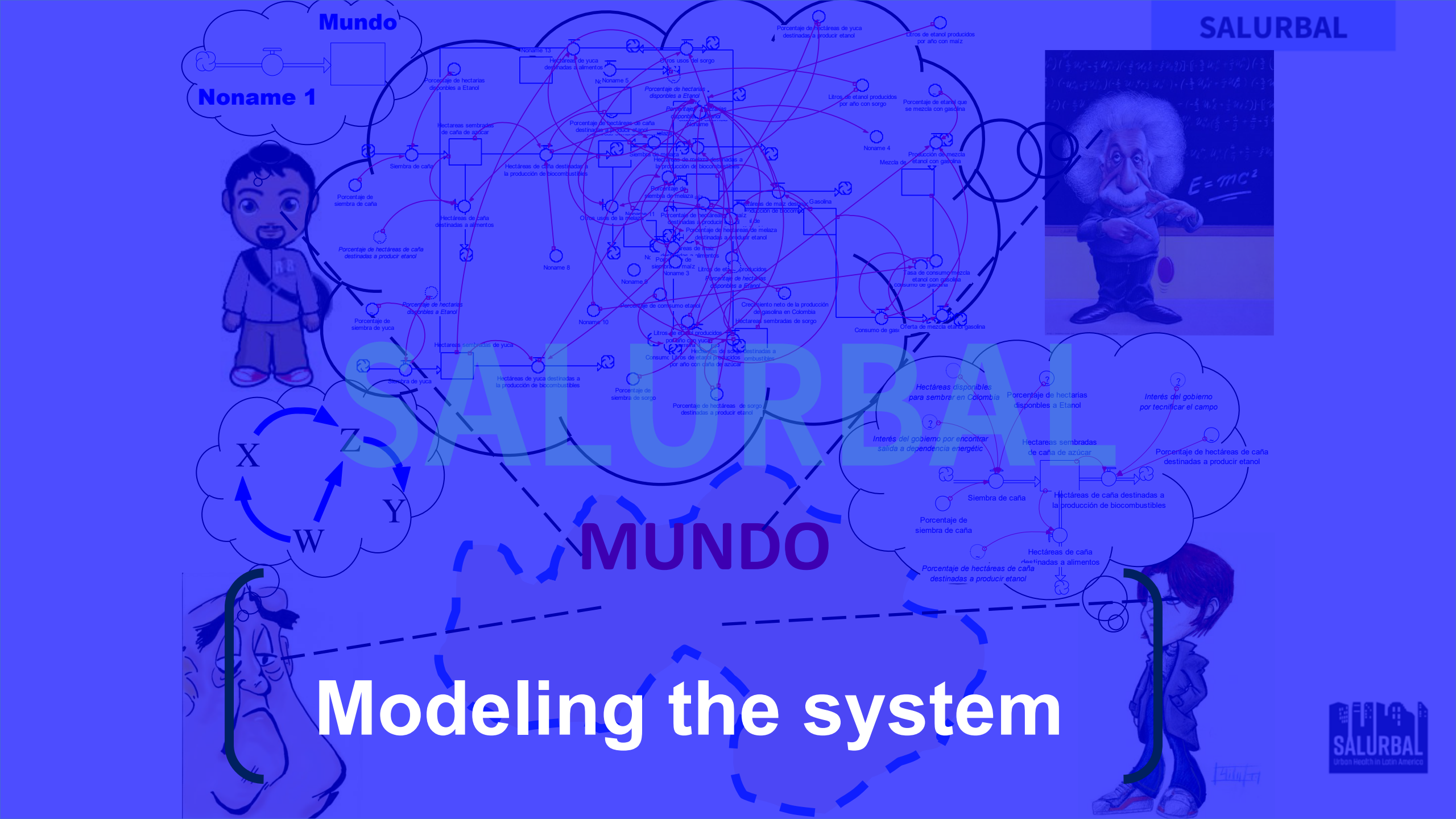


Purpose

Investigates the obesity transition by socioeconomic status (SES), gender, and age within the Colombian urban population at the country, regional and department levels.

To apply a SD model to investigate obesity transitions by SES, gender, and age, along with their relationship to Gross Domestic Product (GDP).

To identify in which regions and departments of Colombia the burden of obesity have shifted towards the lower SES

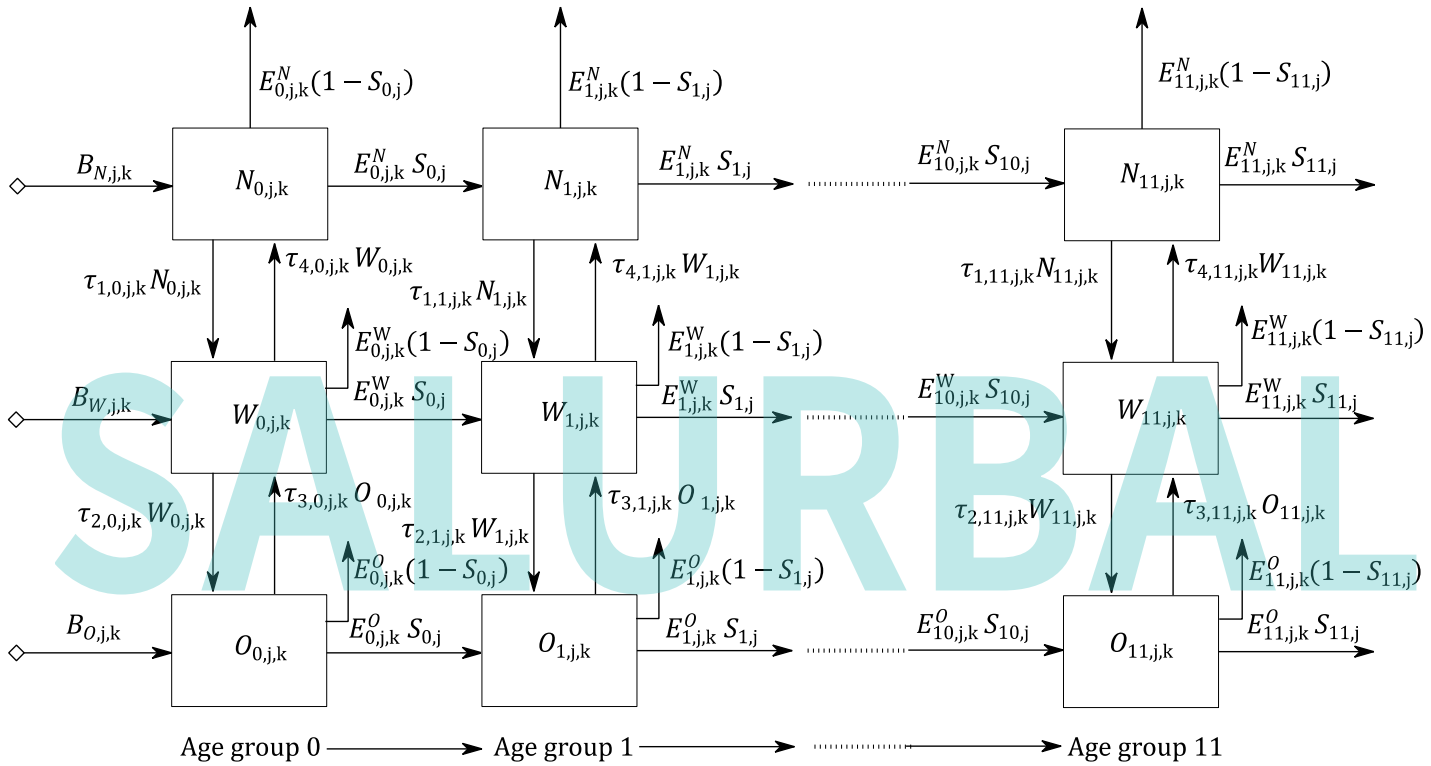

Mundo
Noname 1
SALURBAL
Porcentaje de hectáreas de yuca destinadas a producir etanol
Litros de etanol producidos por año con maíz
Noname 13
Hectáreas de yuca destinadas a alimentos
Otros usos del sorgo
Porcentaje de hectarias disponbles a Etanol
Litros de etanol producidos por año con sorgo
Porcentaje de etanol que se mezcla con gasolina
hectareas sembradas de caña de azúcar
Porcentaje de hectáreas de caña destinadas a producir etanol
Noname 4
Producción de mezcla etanol con gasolina
Siembra de caña
Hectáreas de caña destinadas a la producción de biocombustibles
Siembra de melaza
Hectáreas de melaza destinadas a la producción de biocombustibles
Porcentaje de siembra de caña
Porcentaje de siembra de melaza
Gasolina
Hectáreas de caña destinadas a alimentos
Otros usos de la melaza
Porcentaje de hectáreas de maíz destinadas a producir etanol
Porcentaje de hectáreas de melaza destinadas a producir etanol
Porcentaje de hectáreas de caña destinadas a producir etanol
Noname 8
Noname 3
Litros de etanol producidos
Porcentaje de hectarias disponbles a Etanol
Tasa de consumo mezcla etanol con gasolina
Noname 9
Porcentaje de consumo etanol
Crecimiento neto de la producción de gasolina en Colombia
Noname 10
Hectareas sembradas de sorgo
Porcentaje de hectarias disponbles a Etanol
Porcentaje de siembra de yuca
Hectareas sembradas de yuca
Siembra de yuca
Hectáreas de yuca destinadas a la producción de biocombustibles
Porcentaje de siembra de sorgo
Porcentaje de hectáreas de sorgo destinadas a producir etanol
Consumo de gas
Oferta de mezcla etanol gasolina
X
Z
Y
W
Hectáreas disponibles para sembrar en Colombia
Porcentaje de hectarias disponbles a Etanol
Interés del gobierno por tecnificar el campo
Interés del gobierno por encontrar salida a dependencia energétic
Hectareas sembradas de caña de azúcar
Porcentaje de hectáreas de caña destinadas a producir etanol
Siembra de caña
Hectáreas de caña destinadas a la producción de biocombustibles
Porcentaje de siembra de caña
Hectáreas de caña destinadas a alimentos
Porcentaje de hectáreas de caña destinadas a producir etanol
MUNDO
Modeling the system
SALURBAL
Urban Health in Latin America

Data sources used in each model

Item	*Data Source*
Prevalence rates by BMI category, age, gender, WI at country, regional, and department level	
BMI for age and sex *z*-score for children and adolescents aged 0 to 17 years by WI	Colombia: Standard Demographic and Health Survey (DHS)-, 2005 Dataset [35]
BMI category prevalence by age and WI for adults	Colombia: Standard DHS, 2010 Dataset [36]
Population composition by BMI category, age, gender, WI at country, regional, and department level	
Population size	Colombian National Department of Statistics (DANE). Estimations and population projections for 1985–2020 [38]
Mortality rates by age group	DANE. Vital Statistics (2005) [37]
Fertility rate	World Data Bank. World Development Indicators (1960–2014) [39], and DANE. Projections for 2015–2030. Forecast series using the Holt-Winters no seasonal method in EViews 5 (Quantitative Micro Software, LLC)
Fraction of births by BMI category	Colombia: Standard DHS, 2005 Dataset [35]
Classification of individuals by BMI category, age, gender, WI at country, regional, and department level	
Height-for-age z-score and BMI for age and sex z-score cutoff points for children and adolescents aged 0 to 17 years: Not overweight: BMI for age and sex z-score ≤1 standard deviation. Overweight: BMI for age and sex z-score >1 standard deviation and ≤ 2 standard deviations. Obese: BMI for age and sex z-scores >2 standard deviations.	WHO child growth standards [40] WHO child growth references [41]
BMI category cut-points for adults aged 18 to 64 years: Not overweight: BMI <25 kg/m^2 Overweight: BMI ≥25 and <30 kg/m^2 Obese: BMI ≥30 kg/m^2	WHO cutoff points [42]

System Dynamics Model

Overview of the system dynamic model structure[34]



where

$N_{i,j,k}, W_{i,j,k}, O_{i,j,k}$ population of ***not overweight, overweight, and obese*** individuals in the age group *i*, (*i* ∈ (0,….,11)), gender j (*j* ∈ (1=men, 2=women)), and SES group *k* (*k* ∈ (1=lower, 2=middle, and 3=higher SES));

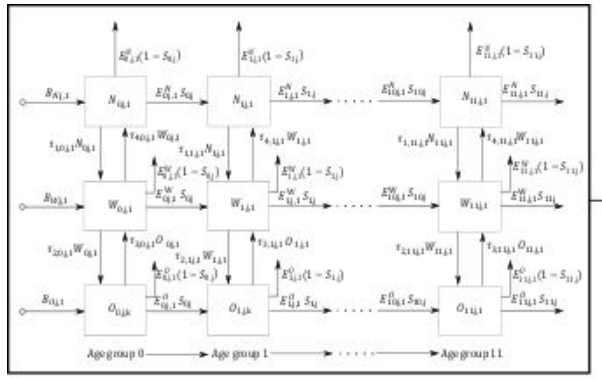
$B_{N,j,k}$, $B_{W,j,k}, B_{O,j,k}$ births per year of each BMI category, gender *j* and SES group *k*;

$E^N_{i,j,k}, E^W_{i,j,k}, E^O_{i,j,k}$ exit rates of individuals per year for each age group *i*, gender *j*, SES group *k*, and BMI category;

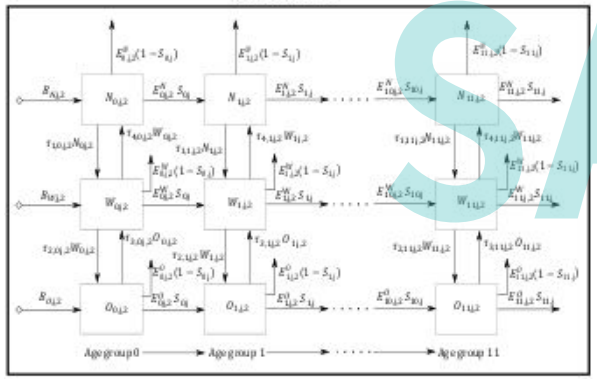
$S_{i,j,k}$ survival fraction of individuals per year for each age group *i*, gender *j*, SES group *k*, and BMI category;

$\tau_{1i,j,k}, \tau_{2i,j,k}, \tau_{3i,j,k}, \tau_{4i,j,k}$ transference rates (fractions of individuals that move) between BMI categories by age group *i*, gender *j*, SES group *k*

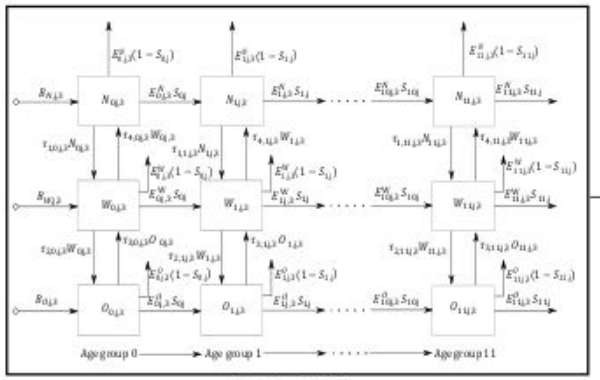
System Dynamics Model by SES



Lower SES



Middle SES



Higher SES

Obesity prevalence ratio (PR) for those aged 20-59

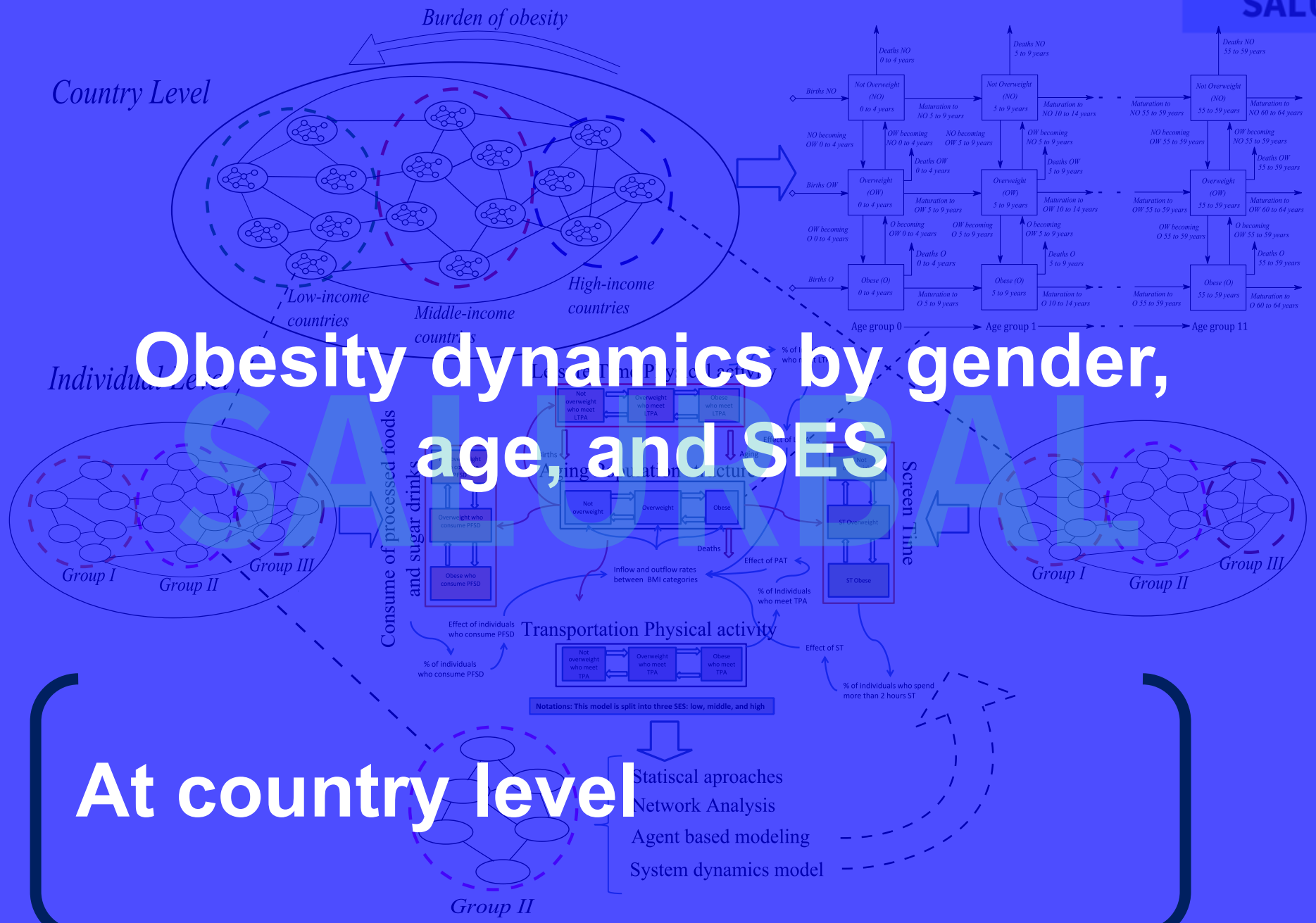
We calculate a obesity prevalence ratio (PR) by gender *j* at time *t* to examine the obesity transition of the Colombian urban individuals aged 20 to 59 years at different levels (national, regional and department level):

$$PR_j(t) = \frac{\sum_{i=4}^{11} O_{i,j,1}(t)}{\sum_{i=4}^{11}\left(N_{i,j,1}(t) + W_{i,j,1}(t) + O_{i,j,1}(t)\right)} \Bigg/ \frac{\sum_{i=4}^{11} O_{i,j,3}(t)}{\sum_{i=4}^{11}\left(N_{i,j,3}(t) + W_{i,j,3}(t) + O_{i,j,3}(t)\right)}$$

Where

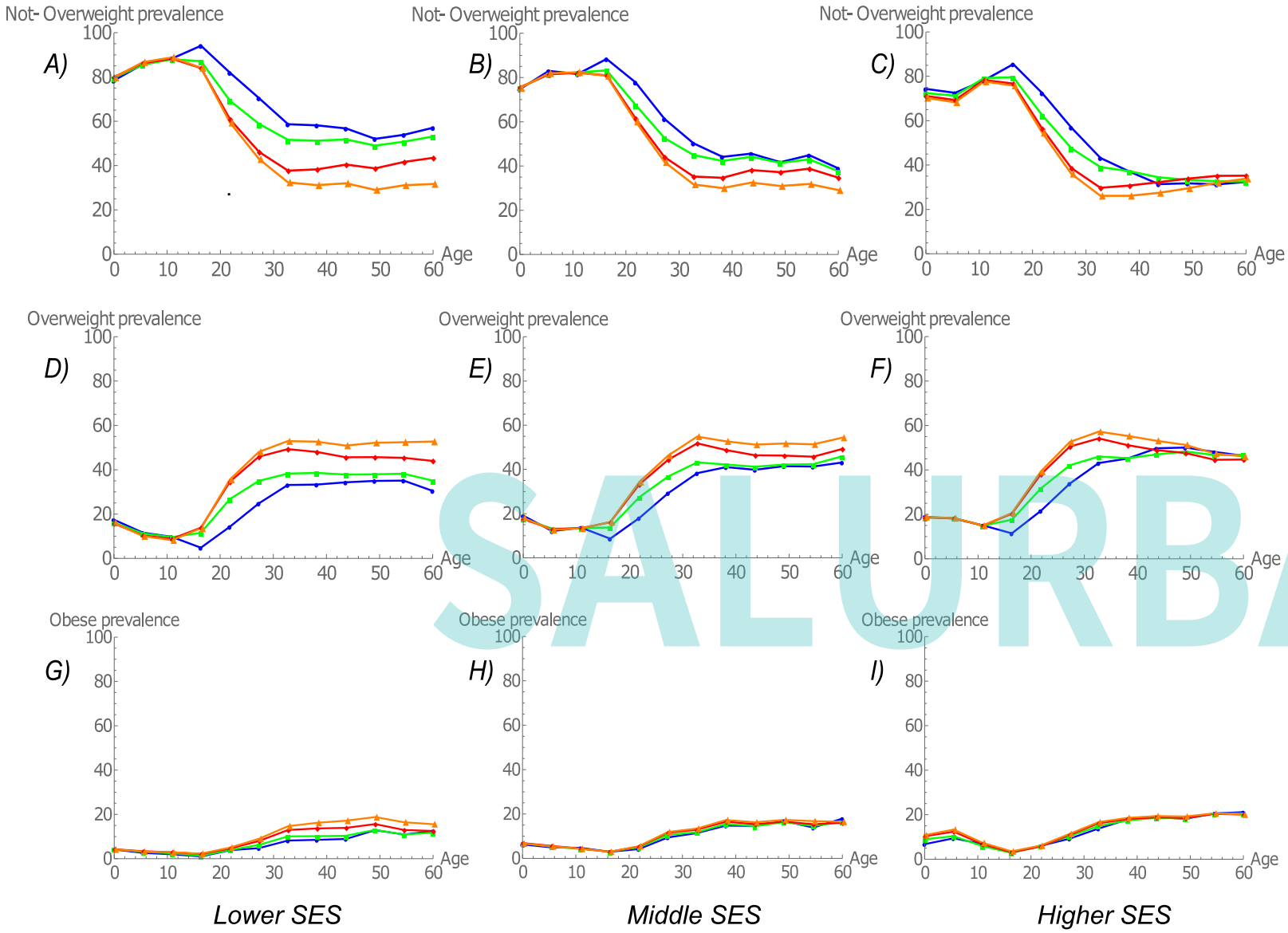
$N_{i,j,1}(t), W_{i,j,1}(t), O_{i,j,1}(t)$ Population of ***not-overweight, overweight, and obese*** individuals of the lower SES in the age group *i* and gender *j* respectively at time *t*.

$N_{i,j,3}(t), W_{i,j,3}(t), O_{i,j,3}(t)$ Population of ***not-overweight, overweight, and obese*** individuals of the higher SES in the age group *i* and gender *j* respectively at time *t.*



Obesity dynamics by gender, age, and SES

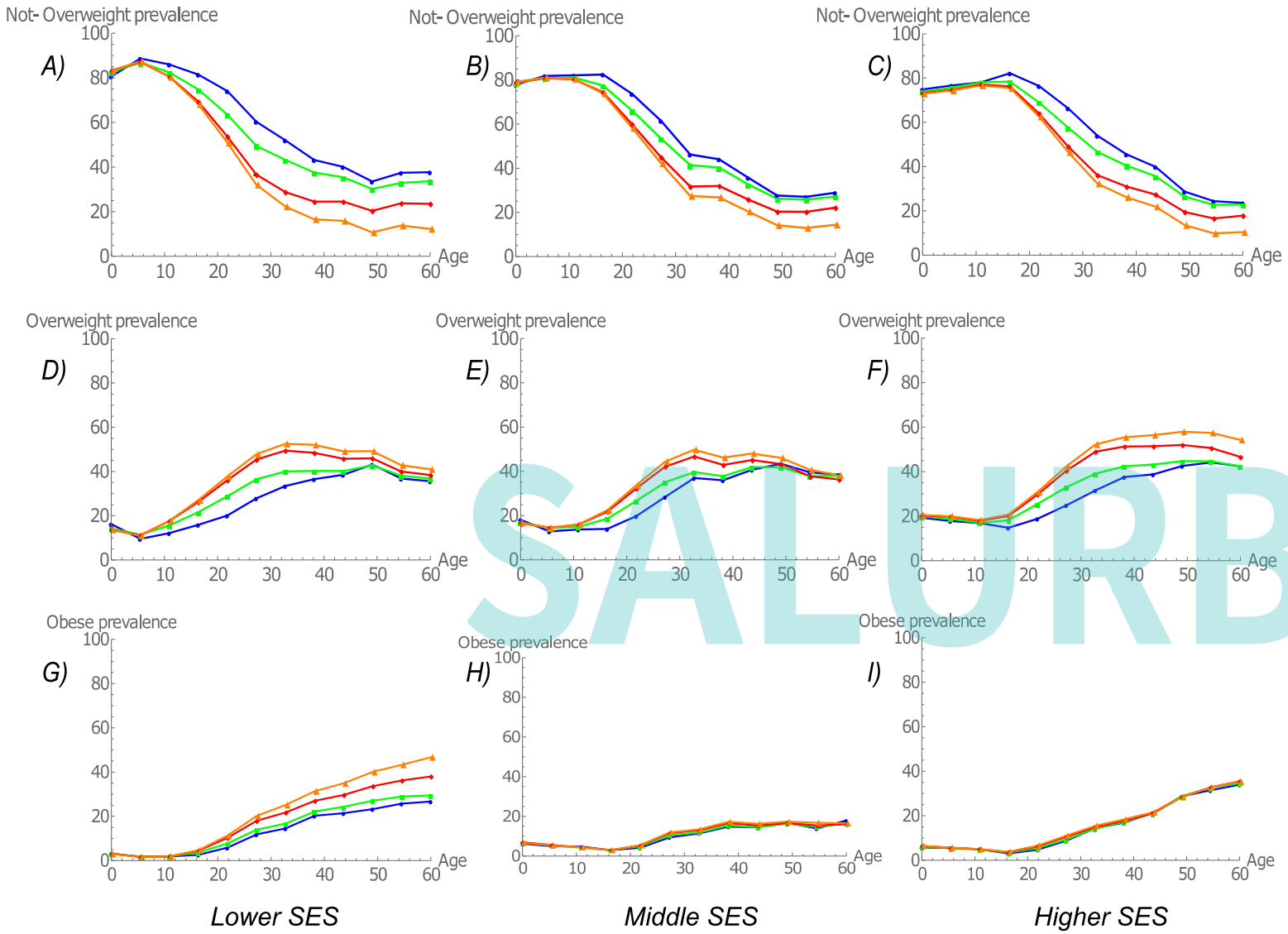
At country level



The obese prevalence increase more rapidly among individuals with a lower SES than among individuals with a middle or higher SES

This analysis show that men may be experiencing an obesity transition in which the higher prevalence of obesity is changing from higher SES to the lower.

Fig 1. Estimated prevalence rates of BMI categories by age and SES groups for men. (A) *Not overweight*, lower SES; (B) *not overweight*, middle SES; (C) *not overweight*, higher SES; (D) *overweight*, lower SES; (E) *overweight*, middle SES; (F) *overweight,* higher SES; (G) *obese,* lower SES; (H) *obese*, middle SES; and (I) *obese*, higher SES. Blue = 2005; Green = 2010; Red = 2020; Orange = 2030.



It is more evident that the obese prevalence increase more rapidly among women with a lower SES than among women with a middle or higher SES.

This analysis show that women may be experiencing also an obesity transition.

Fig 2. Estimated prevalence rates of BMI categories by age and SES groups for women. (A) *Not overweight*, lower SES; (B) *not overweight*, middle SES; (C) *not overweight*, higher SES; (D) *overweight*, lower SES; (E) *overweight*, middle SES; (F) *overweight,* higher SES; (G) *obese,* lower SES; (H) *obese*, middle SES; and (I) *obese*, higher SES. Blue = 2005; Green = 2010; Red = 2020; Orange = 2030.

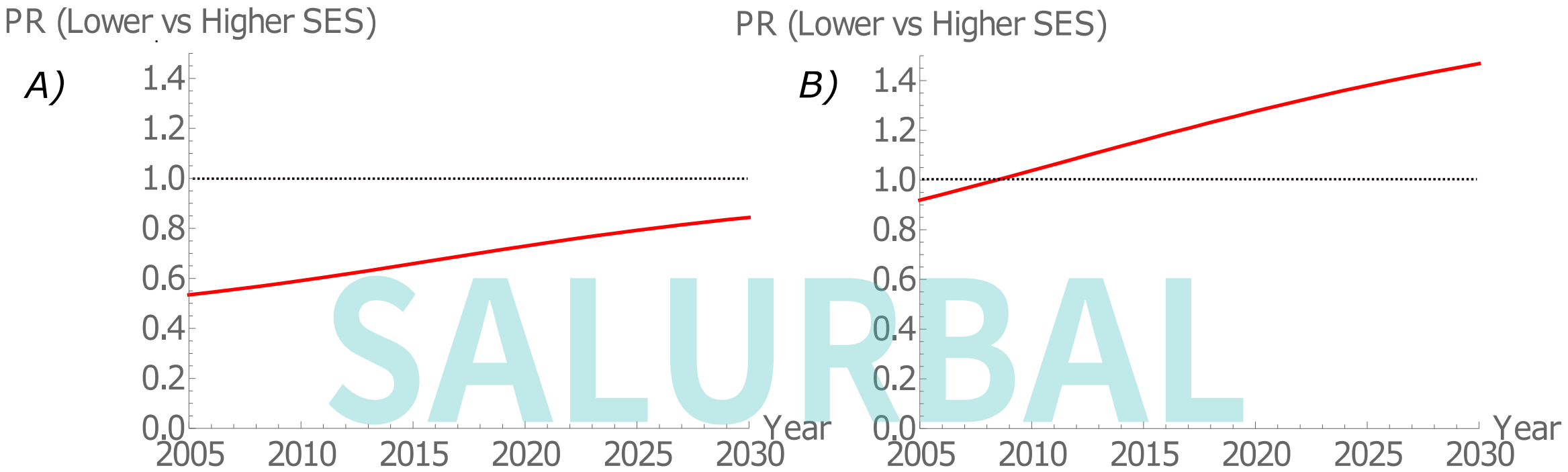
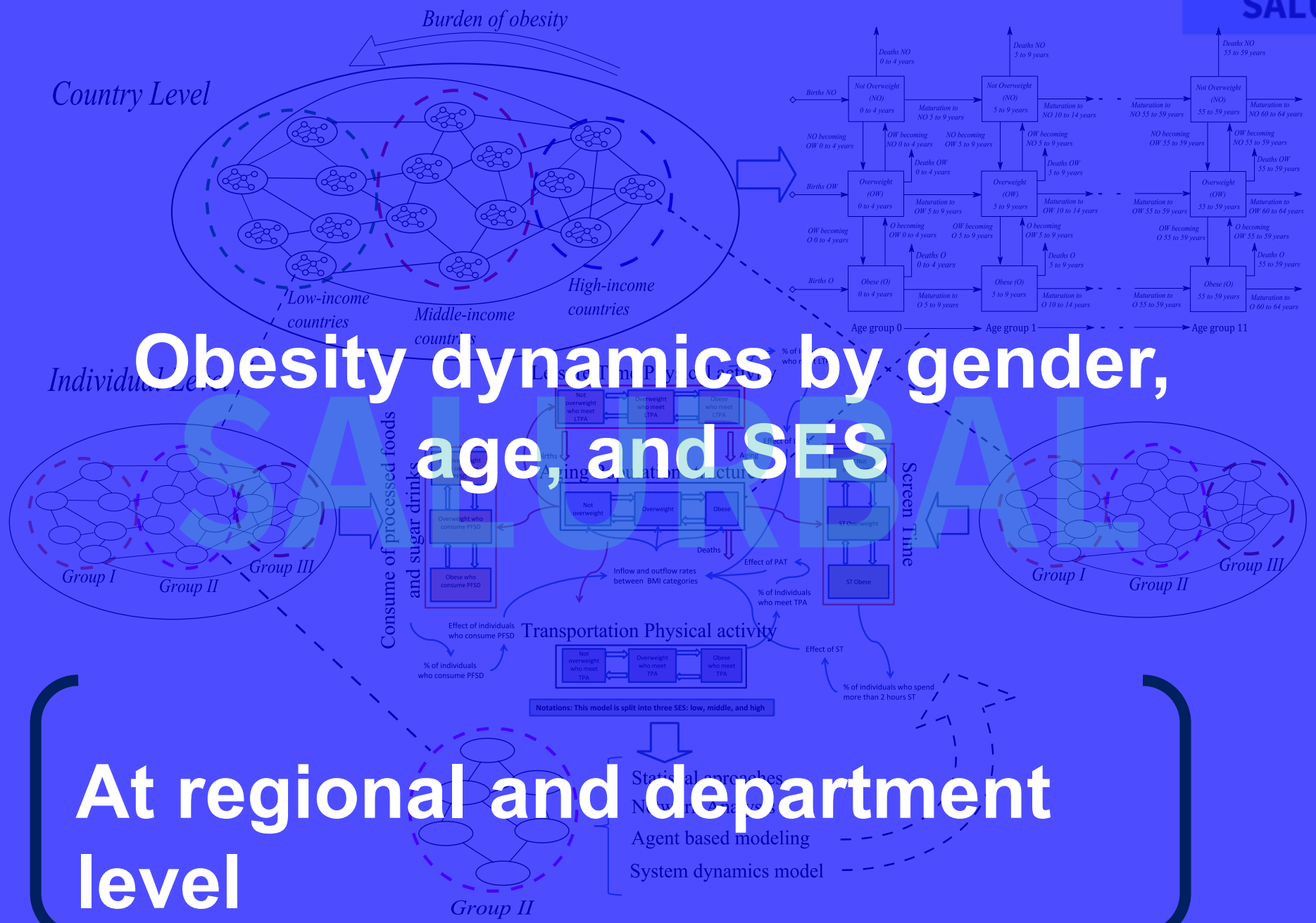


Fig 3. Obesity prevalence ratio amongst urban adults aged 20 to 59 years. A) Men . B) Women

The simulated obesity PRs among urban men and women aged 20–59 years confirm that the burden of obesity among adults, especially women, tends to shift towards those with lower SES



Obesity dynamics by gender, age, and SES

At regional and department level

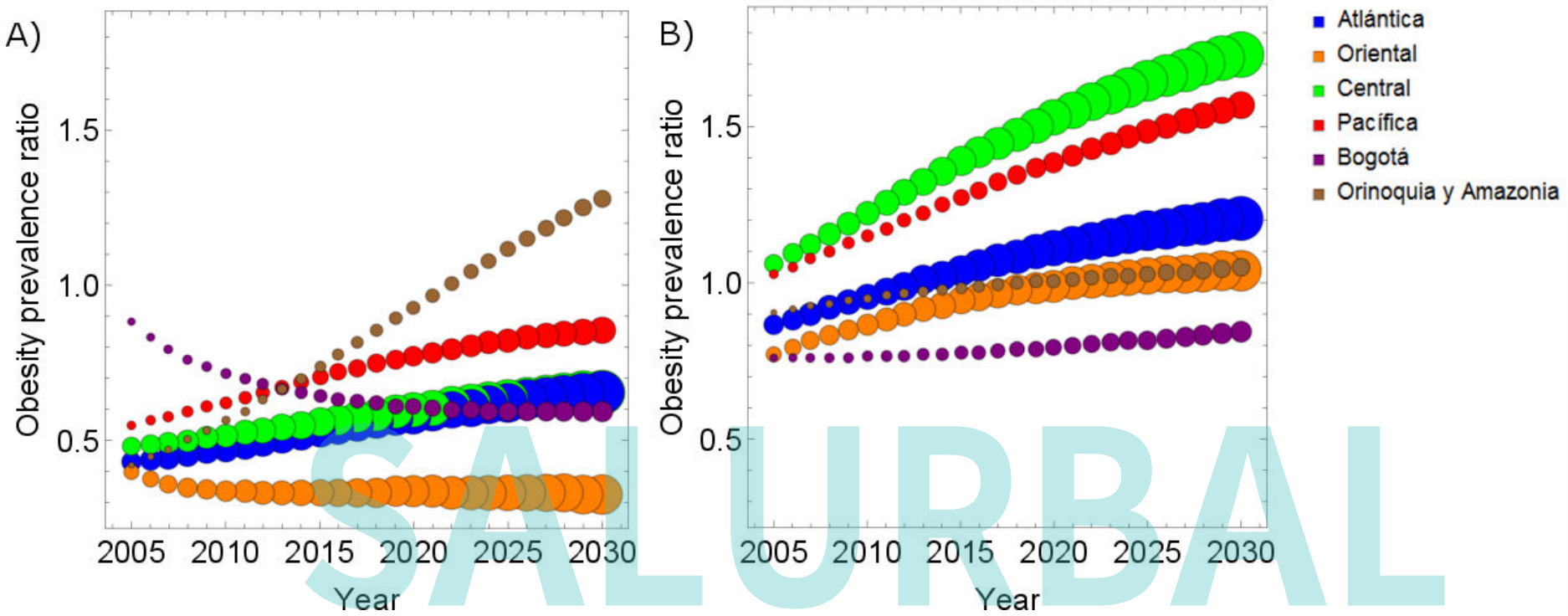
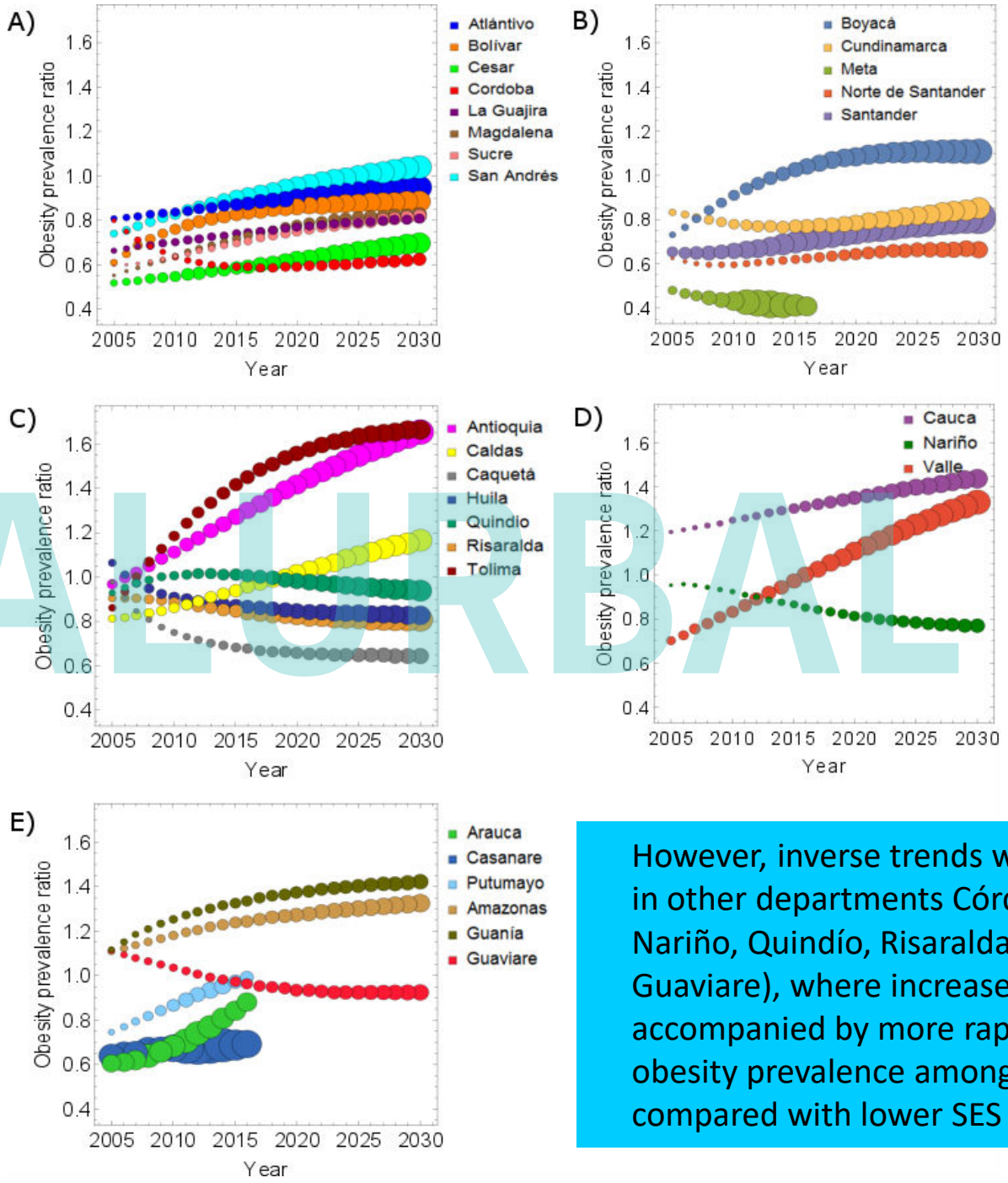


Fig 4. Prevalence ratio of obesity (Lower SES vs Higher SES) amongst urban adults aged 20 to 59 years vs gross domestic product (GDP) per capita at regional level. Bubble size based on the total GDP per capita for each region. We calculated the forecast of the GDP per capita from 2017 to 2030. A) Men. B) Women

The regions of Colombia are in different stages of the obesity transition. For men, the only region that was projected to experience an obesity transition was Orinoquia y Amazonia. In the case of women, in five out of the six regions (i.e., Atlántica, Oriental, Central, Pacífico and Orinoquia y Amazonía) the burden of obesity was projected to shift towards populations with lower SES, as the GDP per capita increases.

Fig 5. Prevalence ratio of obesity (Lower SES vs Higher SES) amongst urban adults aged 20 to 59 years vs gross domestic product per capita. A) Atlántica region. B) Oriental region. C) Central region. D) Pacífica region. E) Orinoquia y Amazonia region. Bubble size based on the gross domestic product per capita. We calculated the forecast of the GNP per capita from 2017 to 2030



In nine departments, we observed that the burden of obesity was projected to shift towards populations with lower SES, as the GDP per capita increases : Amazonas, Guanía, Cauca, Valle del Cauca, Boyacá, Antioquia, Tolima, Caldas, and San Andres.

However, inverse trends were observed in other departments Córdoba, Huila, Nariño, Quindío, Risaralda, Caquetá and Guaviare), where increases in GDP were accompanied by more rapid increases in obesity prevalence among higher compared with lower SES groups.

Discussion and future work

Using the population SD model:

- At country level,
  - Transitions from overweight to obesity were projected to increase sharply among lower SES adults, particularly among women, suggesting that these groups will undergo an obesity transition by 2030.
- At regional and department level,
  - Regions and departments of Colombia are in different steps in the obesity transition process.
  - The obesity transition were also observed across most regions of Colombia where increases in GDP were predicted to shift the burden of obesity from higher to lower SES groups, also being most evident for women.
  - At the department level, trends in the burden of obesity were mixed. Some departments expected to undergo an obesity transition. However, inverse trends were observed in other departments, where increases in GDP were accompanied by more rapid increases in obesity prevalence among higher compared with lower SES groups.

Discussion and future work

- The model offers policymakers a useful tool to better monitor obesity transitions among diverse segments of the population.
  - The model could be employed to estimate the TRs between BMI categories by age, gender, and SES, and to help identify which subgroups of the population should be targeted.
  - The model could also be used to monitor the impact of health interventions implemented to prevent the development of overweight and obesity related to age, gender, and SES.
- Future research might consider this model:
  - To assess the obesity transition in other LMICs, especially on understanding the dynamics of obesity by SES in other urban Latin American settings.
  - To understand the effects of some factors, such as Physical activity level, sedentary behaviours and consumption of processed food and sugary drinks on transference rates between BMI categories.

¡Thanks!

Questions

José David Meisel
Associate Professor
School of Engineering
Universidad de Ibagué
Jose.meisel@unibague.edu.co

The Salud Urbana en América Latina (SALURBAL)/ Urban Health in Latin America project is funded by Wellcome Trust [205177/Z/16/Z].

Universidad de Ibagué
Comprometidos con el desarrollo regional

SALURBAL
Urban Health in Latin America

LEARN MORE AND CONTACT US

SALURBAL

LACURBANHEALTH.ORG

SALURBAL@DREXEL.EDU

FOLLOW US

@LACURBANHEALTH

Referencias

1. GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet, 2016; 388(10053):1659-17247
2. Murray CJL, Aravkin AY, Zheng P, Abbafati C, Abbas KM, Abbasi-Kangevari M, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. 17 de octubre de 2020;396(10258):1223-49.
3. World Health Organization. GLOBAL STATUS REPORT on noncommunicable diseases 2014
4. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? *Health Aff (Millwood)*. 2003;Suppl Web Exclusives:W3-219-26.
5. Thorpe KE, Florence CS, Howard DH, Joski P. The impact of obesity on rising medical spending. *Health Aff (Millwood)*. 2004;Suppl Web Exclusives:W4-480-6.
6. Yang Z, Hall AG. The Financial Burden of Overweight and Obesity among Elderly Americans: The Dynamics of Weight, Longevity, and Health Care Cost. *Health Serv Res*. 2008;43(3):849-868.
7. Zarate A, Crestto M, Maiz A, et al. [Influence of obesity on health care costs and absenteeism among employees of a mining company]. *Rev Med Chil*. 2009;137(3):337-344.
8. Jaacks LM, Vandevijvere S, Pan A, et al. The obesity transition: stages of the global epidemic. Lancet Diabetes Endocrinol 2019;7:231–40.
9. Monteiro CA, Conde WL, Lu B, Popkin BM. Obesity and inequities in health in the developing world. *Int. J. Obes. Relat. Metab. Disord.* 2004a;28(9):1181-1186.
10. Monteiro CA, Moura EC, Conde WL, Popkin BM. Socioeconomic status and obesity in adult populations of developing countries: a review. *Bull. World Health Organ.* 2004b;82(12):940-946.
11. Dangerfield, B. C. & Zainal Abidin, N. Towards a model-based tool for evaluating population-level interventions against childhood obesity. in *Procs of the International System Dynamics Conference, Korea, 2010.* (2010). at <http://www.systemdynamics.org/conferences/2010/proceed/index.html>
12. Abdel-Hamid, T. K. Modeling the dynamics of human energy regulation and its implications for obesity treatment. *System Dynamics Review* **18,** 431–471 (2002).
13. Abdel-Hamid, T. K. Exercise and diet in obesity treatment: an integrative system dynamics perspective. *Med Sci Sports Exerc* **35,** 400–413 (2003).
14. Flatt, J.-P. Carbohydrate-fat interactions and obesity examined by a two-compartment computer model. *Obes. Res.* **12,** 2013–2022 (2004).
15. Nohoglu, M. Simulation and Web Game Development of Body Weight Dynamics. (Bogazici University, 2009).
16. Abdel-Hamid, T. K. *Thinking in Circles About Obesity: Applying Systems Thinking to Weight Management*. (Springer, 2009).
17. Karanfil, Ö. A System Dynamics Model of Body Weight Regulation and Obesity. in (2009).
18. Sabounchi, N. S., Hovmand, P. S., Osgood, N. D., Dyck, R. F. & Jungheim, E. S. A novel system dynamics model of female obesity and fertility. *Am J Public Health* **104,** 1240–1246 (2014).
19. Rahmandad, H. & Sabounchi, N. S. Building and estimating a dynamic model of weight gain and loss for individuals and populations. in (2011).
20. Rahmandad, H. & Sabounchi, N. S. Modeling and estimating individual and population obesity dynamics. in 306–313 (Springer-Verlag, 2012). doi:10.1007/978-3-642-29047-3_37

Referencias

21. Rahmandad, B. Modeling the dynamics of human body growth and maintenance. in (2012).
22. Dangerfield, B. & Norhaslinda, Z. A. The Role of Behaviour Change in Eating and Physical Activity in the Battle against Childhood Obesity. in (2011).
23. Homer, J., Jones, A. P., Seville, D. A., Essien, J. D. K. & Milstein, B. The CDC's diabetes system modelling project: developing a new tool for chronic disease prevention and control. in (2004).
24. Homer, J., Milstein, B., Dietz, W, Buchner, D & Majestic, E. Obesity population dynamics: exploring historical growth and plausible futures in the US. in (2006).
25. Homer, J. *et al.* Modeling the local dynamics of cardiovascular health: risk factors, context, and capacity. *Prev Chronic Dis* **5,** A63 (2008).
26. Homer, J. *et al.* Simulating and evaluating local interventions to improve cardiovascular health. *Prev Chronic Dis* **7,** A18 (2010).
27. Fallah-Fini, S., Rahmandad, H., Huang, T. T.-K., Bures, R. M. & Glass, T. A. Modeling US adult obesity trends: a system dynamics model for estimating energy imbalance gap. *Am J Public Health* **104,** 1230–1239 (2014).
28. De la Haye, K., Robins, G., Mohr, P. & Wilson, C. Obesity-related behaviors in adolescent friendship networks. *Social Networks* **32,** 161–167 (2010).
29. Sawka, K. J., McCormack, G. R., Nettel-Aguirre, A., Hawe, P. & Doyle-Baker, P. K. Friendship networks and physical activity and sedentary behavior among youth: a systematized review. *Int J Behav Nutr Phys Act* **10,** 130 (2013).
30. Valente, T. W., Fujimoto, K., Chou, C.-P. & Spruijt-Metz, D. Adolescent affiliations and adiposity: a social network analysis of friendships and obesity. *J Adolesc Health* **45,** 202–204 (2009).
31. Christakis, N. A. & Fowler, J. H. The spread of obesity in a large social network over 32 years. *N. Engl. J. Med.* **357,** 370–379 (2007).
32. Auchincloss, A. H., Riolo, R. L., Brown, D. G., Cook, J. & Diez Roux, A. V. An agent-based model of income inequalities in diet in the context of residential segregation. *Am J Prev Med* **40,** 303–311 (2011).
33. Phillips, C. V. Complex systems model of dietary choice with implications for improving diets and promoting vegetarianism. *Am. J. Clin. Nutr.* **70,** 608S–614S (1999).
34. Butland, B. *et al. Tackling Obesities: Future Choices –Project Report. 2nd Edition*. (UK Government's Foresight Programme. Government Office for Science, 2007). at https://www.gov.uk/government/publications/reducing-obesity-future-choices
35. Meisel JD, Sarmiento OL, Olaya C, Lemoine PD, Valdivia JA, Zarama R (2018) Towards a novel model for studying the nutritional stage dynamics of the Colombian population by age and socioeconomic status. PLoS ONE 13(2): e0191929. https://doi.org/10.1371/journal.pone.0191929