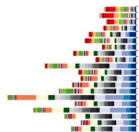


MODELADO EPIDEMIOLÓGICO APLICADO A LA PREVENCIÓN DE ENFERMEDADES CARDIOMETABÓLICAS

JOSÉ L. PEÑALVO

CENTRO NACIONAL DE EPIDEMIOLOGÍA
INSTITUTO DE SALUD CARLOS III
MADRID 18|01|2024





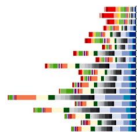
CARGA DE ENFERMEDADES CRÓNICAS +41M MUERTES POR ENT [~71%]



EU [~90%]
40% <60 AÑOS
500.000M EUROS

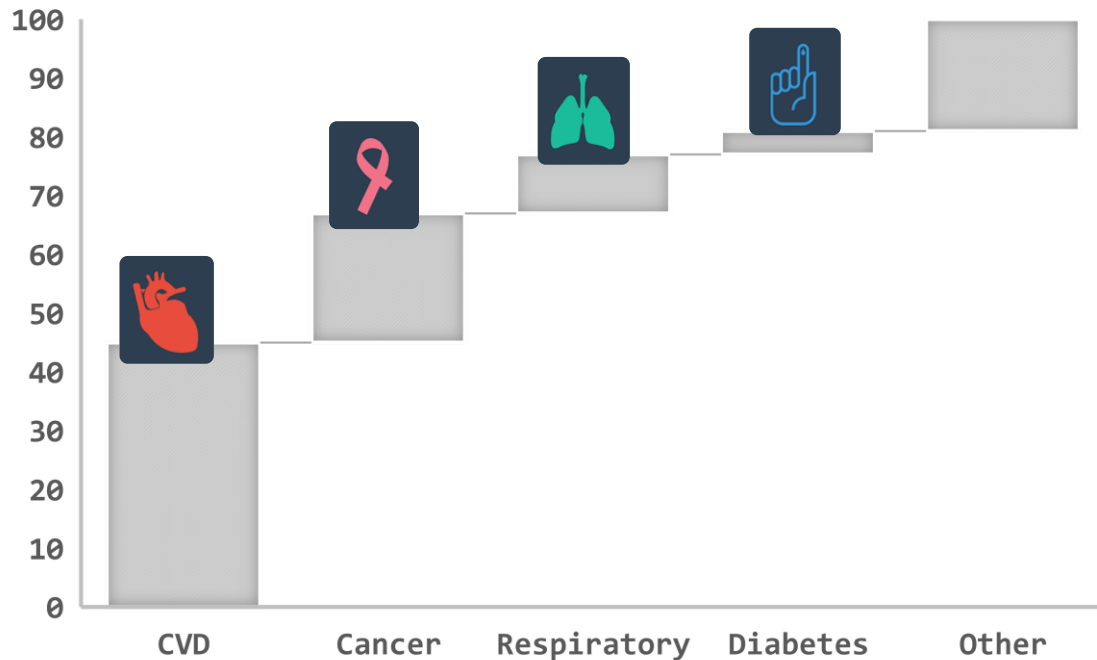


WHO, 2018
EU Science Hub, 2019



CARGA DE ENFERMEDADES CRÓNICAS

+41M MUERTES POR ENT [~71%]



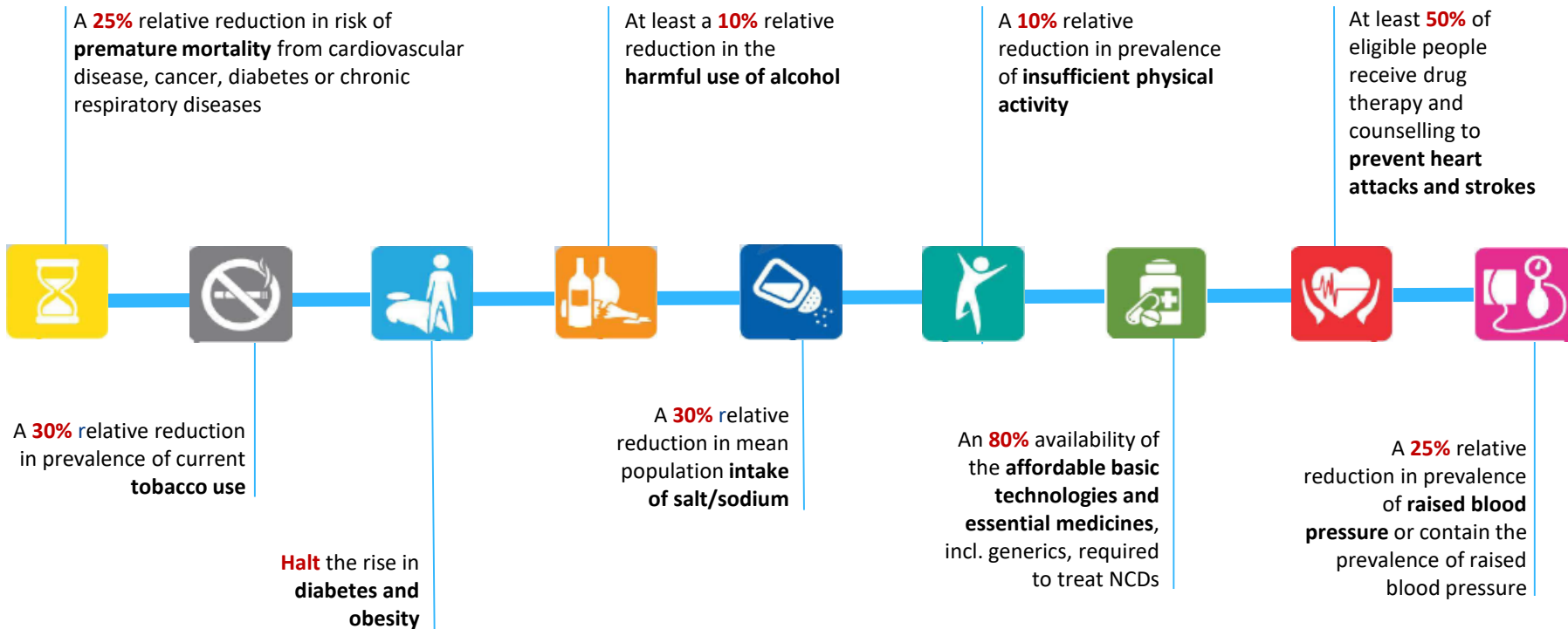
EU [~90%]
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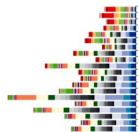


WHO, 2018
EU Science Hub, 2019

DISMINUIR LA CARGA DE CRÓNICAS

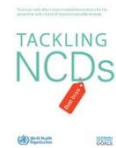
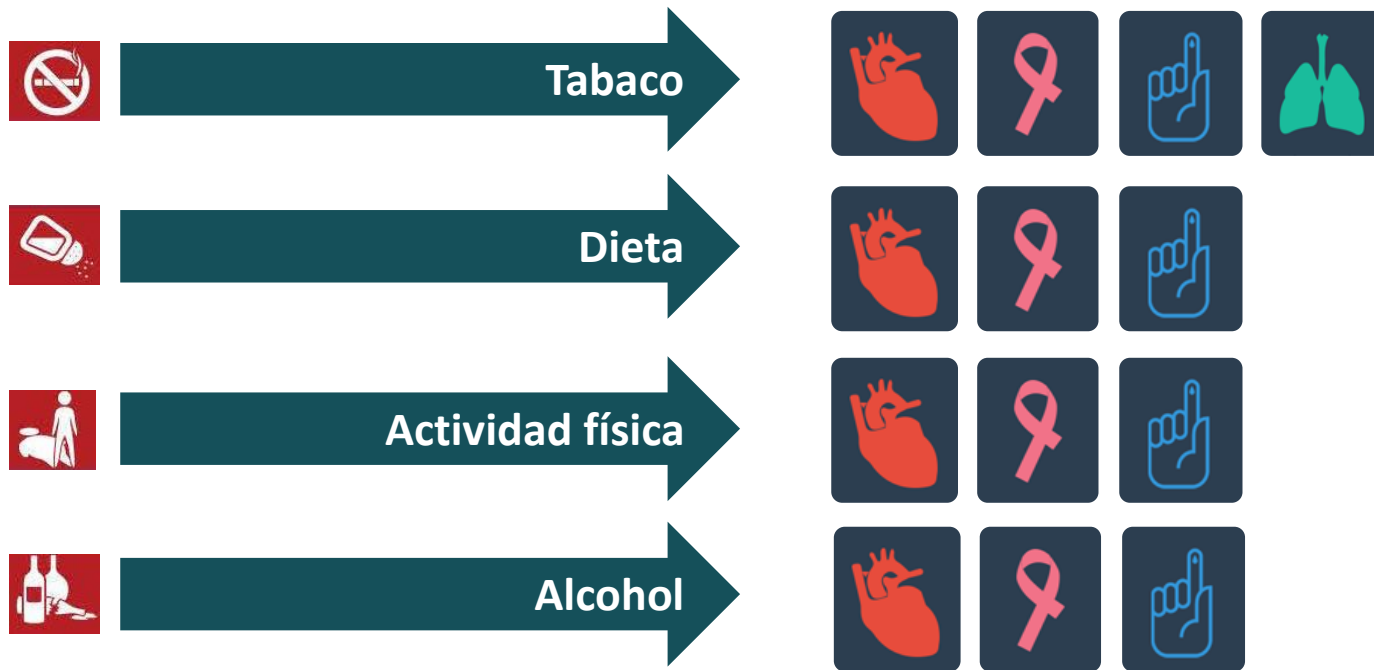
9 OBJETIVOS GLOBALES PARA 2025 [VS 2010]

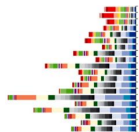




ESTILOS DE VIDA

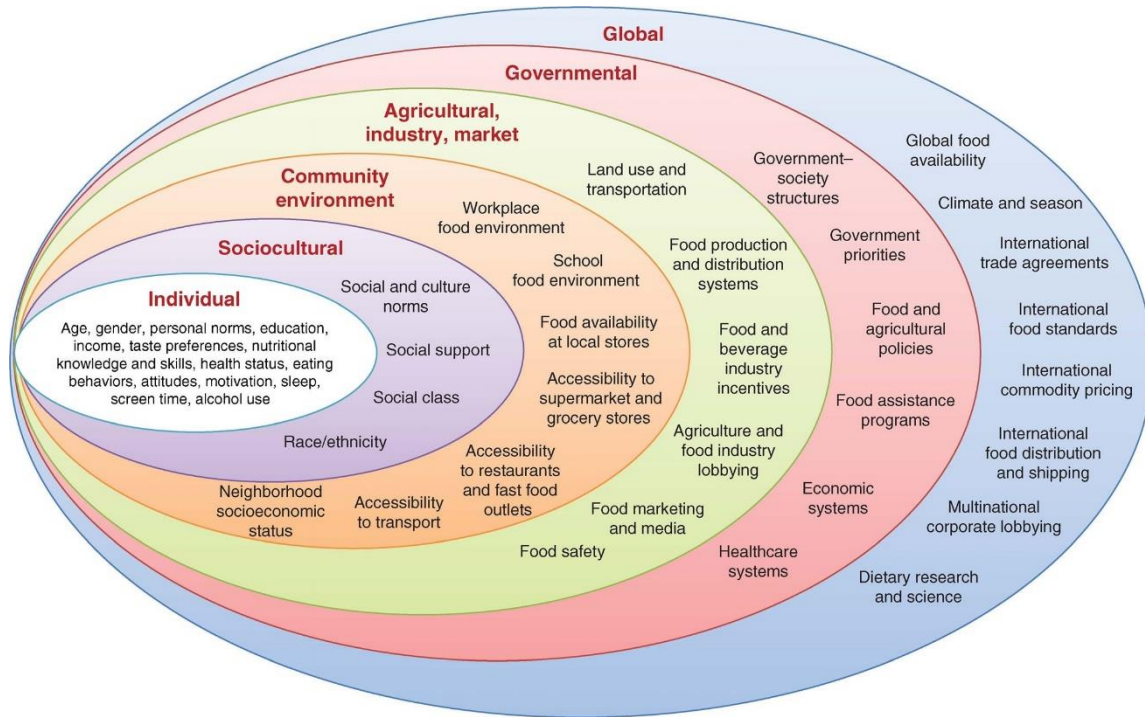
FACTORES DE RIESGO MODIFICABLES





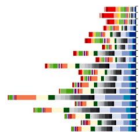
ESTILOS DE VIDA

FACTORES DE RIESGO MODIFICABLES



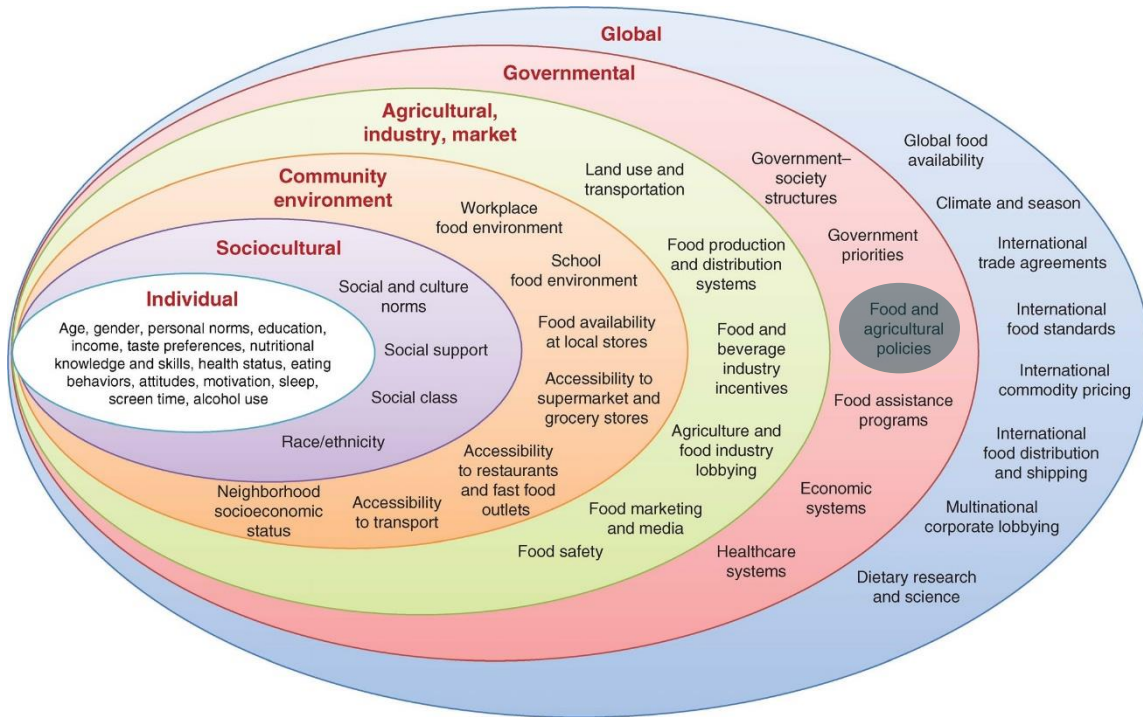
SISTEMAS COMPLEJOS

Afshin, Peñalvo, [...] & Mozaffarian. 2015. Curr Cardiol Rep



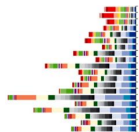
ESTILOS DE VIDA

FACTORES DE RIESGO MODIFICABLES



SISTEMAS COMPLEJOS

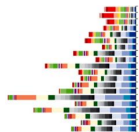
Afshin, Peñalvo, [...] & Mozaffarian. 2015. Curr Cardiol Rep



PREVENCIÓN CARDIOVASCULAR

MODELADO EPIDEMIOLÓGICO

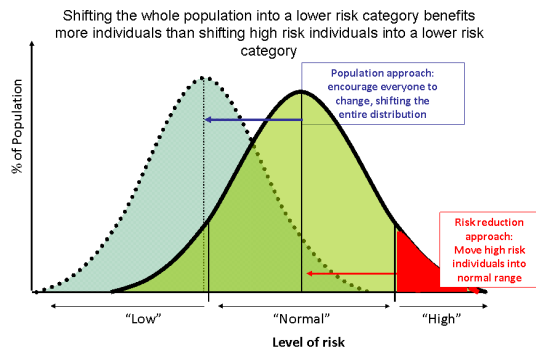
- MODELADO COMO HERRAMIENTA PRIORITARIA PARA ELUCIDAR ASOCIACIONES MULTIFACÉTICAS E INTERACCIONES COMPLEJAS ENTRE FACTORES DE RIESGO Y DETERMINANTES SOCIOECONOMICOS DE LA SALUD
- EVALUACION DE EFECTIVIDAD DE POLÍTICAS Y ESTRATEGIAS DE SALUD PÚBLICA
- CON BBDD CADA VEZ MAS DISPONIBLES Y DE MAYOR CALIDAD, EL MODELADO EPIDEMIOLÓGICO ES UNA PIEZA CLAVE PARA INFORMAR POLÍTICAS DE PREVENCIÓN Y CONTROL DE ENFERMEDADES CRÓNICAS



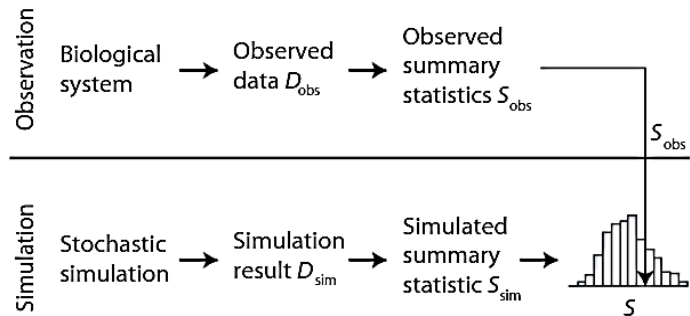
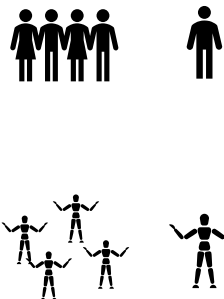
PREVENCIÓN CARDIOVASCULAR

MODELADO EPIDEMIOLÓGICO

The Bell-Curve Shift in Populations



Source: Rose G. Sick Individuals and sick populations. *Int J Epidemiol.* 1985; 12:32-38.



Hartig et al. (2011). *Ecology Letters*

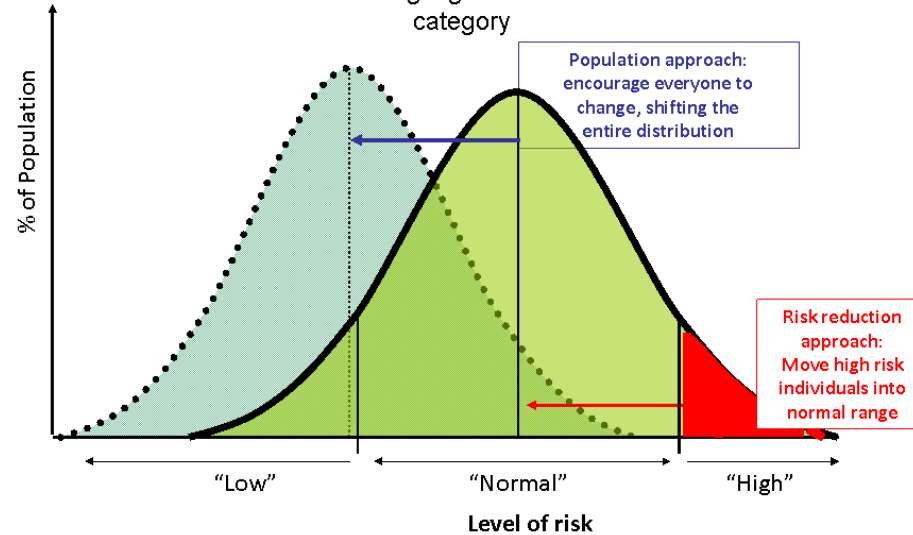


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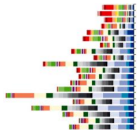
MODELOS DE EVALUACION COMPARATIVA DE RIESGOS [CRA]

The Bell-Curve Shift in Populations

Shifting the whole population into a lower risk category benefits more individuals than shifting high risk individuals into a lower risk category

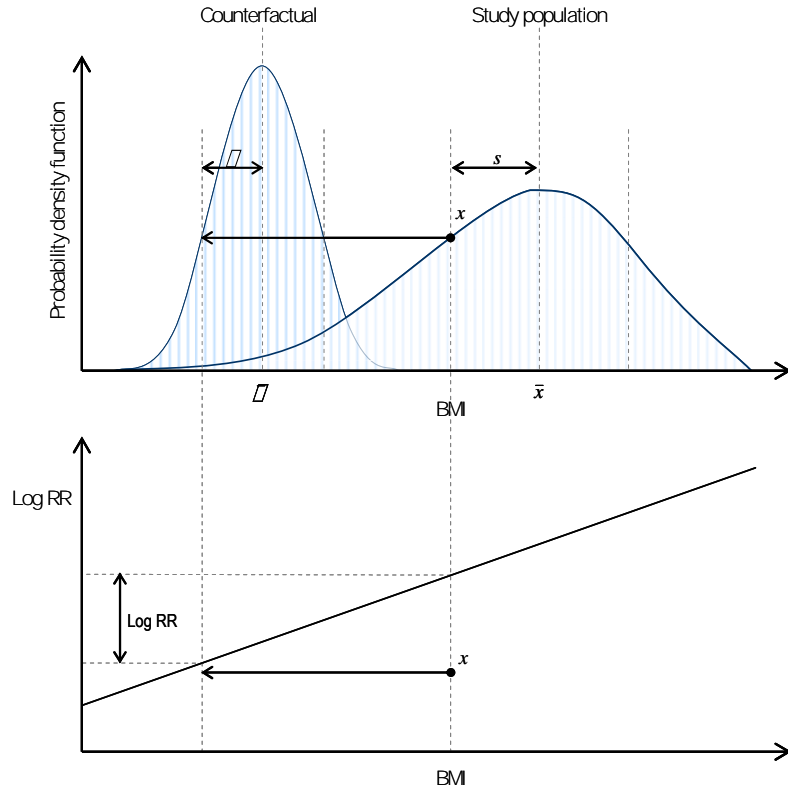


Source: Rose G. Sick Individuals and sick populations. *Int J Epidemiol.* 1985; 12:32-38.



EFFECTIVIDAD COMPARATIVA

MODELOS DE EVALUACIÓN COMPARATIVA DE RIESGOS (CRA)



$$PIF = \frac{\int_{x=0}^m RR(x)P(x)dx - \int_{x=0}^m RR(x)P'(x)dx}{\int_{x=0}^m RR(x)P(x)dx}$$

$$PAF = \frac{p(RR - 1)}{p(RR - 1) + 1},$$

$RR(x)$ is the relative risk at exposure (in this case, food intake) level x
 $P(x)$ is the population distribution of exposure
 $P'(x)$ is the counter-factual population distribution of exposure (had a different food policy been in effect)
 m is the maximum exposure level

MODELO CRA

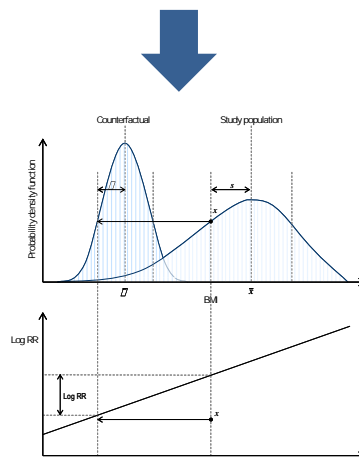
EXPOSICIÓN RIESGO ENCUESTAS

EFEECTO DE LA POLÍTICA
META-ANÁLISIS

COUNTERFACTUAL



ASOCIACIONES RR
META-ANÁLISIS



MORTALIDAD
IHD
ACV
DM2

REGISTROS

inputs estratificados
EDAD
SEXO
INDICADORES SES

Outputs
DISEASE-SPECIFIC DEATHS

TOTAL DEATHS

DEMOGRAFÍA

REGISTROS

EFFECTOS ETIOLÓGICOS DE FACTORES DIETÉTICOS POSITIVOS

Dietary Risk Factors	Studies	Outcomes	Unit	RRs (95% CI)
Fruits	9 cohorts	CHD	100g/day	0.91 (0.87, 0.96)
	9 cohorts	Ischemic stroke	100g/day	0.88 (0.83, 0.93)
	5 cohorts	Hemorrhagic stroke	100g/day	0.73 (0.62, 0.87)
Vegetables	9 cohorts	CHD	100g/day	0.93 (0.90, 0.96)
	8 cohorts	Ischemic stroke	100g/day	0.89 (0.82, 0.97)
	5 cohorts	Hemorrhagic stroke	100g/day	0.83 (0.72, 0.96)
Whole grains	6 cohorts	CHD	50g/day	0.89 (0.85, 0.92)
	6 cohorts	Diabetes	50g/day	0.89 (0.85, 0.93)
Nuts and seeds	1 RCT, 5 cohorts	CHD	28g/day	0.84 (0.76, 0.93)
	1 RCT, 5 cohorts	Diabetes	28g/day	0.95 (0.92, 0.99)
Omega-3 FA	5 RCTs, 7 cohorts	CHD	100mg/day	0.89 (0.86, 0.92)
PUFA	8 RCTs, 10 cohorts	CHD	5% energy	0.89 (0.84, 0.95)

Micha, Peñalvo, et al. (2017) JAMA

CARGA
ATRIBUIBLE
FUNCIONES
DE RIESGO



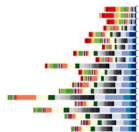
EFFECTOS ETIOLÓGICOS DE FACTORES DIETÉTICOS **NEGATIVOS**

Dietary Risk Factors	Studies	Outcomes	Unit	RRs (95% CI)
Red meat	9 cohorts	Diabetes	100g/day	1.19 (1.04, 1.37)
Processed meat	5 cohorts	CHD	50g/day	1.42 (1.07, 1.89)
	8 cohorts	Diabetes	50g/day	1.51 (1.25, 1.83)
SSBs	3 cohorts	BMI (<25)	226g/day	0.09 kg/m ² (0.05, 0.14)
	3 cohorts	BMI (≥25)	226g/day	0.23 kg/m ² (0.14, 0.32)
	8 cohorts	Diabetes	226g/day	1.26 (1.12, 1.41)
Trans FA	2 cohorts	CHD	2% energy	1.27 (1.18, 1.35)
Sodium	107 RCTs	SBP	100mmol/day	-3.71 mmHg (-5.14, -2.29)

CARGA
ATRIBUIBLE
**FUNCIONES
DE RIESGO**



Micha, Peñalvo, et al. (2017) JAMA



EFFECTIVIDAD COMPARATIVA

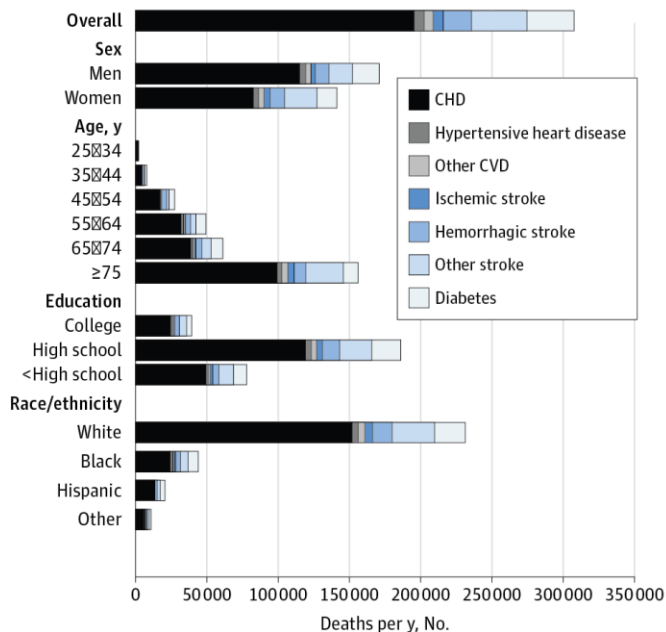
MODELOS DE EVALUACIÓN COMPARATIVA DE RIESGOS (CRA)



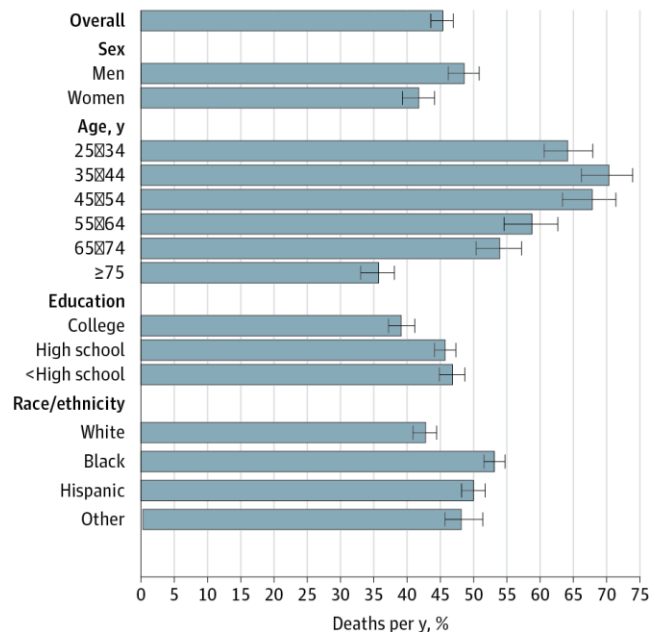
**45% MUERTES
ATRIBUIBLES A
DIETA
SUBÓPTIMA**



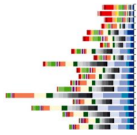
Absolute cardiometabolic mortality attributable to overall suboptimal diet in the United States in 2012



Proportional cardiometabolic mortality attributable to overall suboptimal diet in the United States in 2012

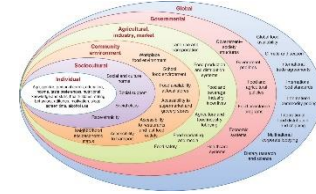
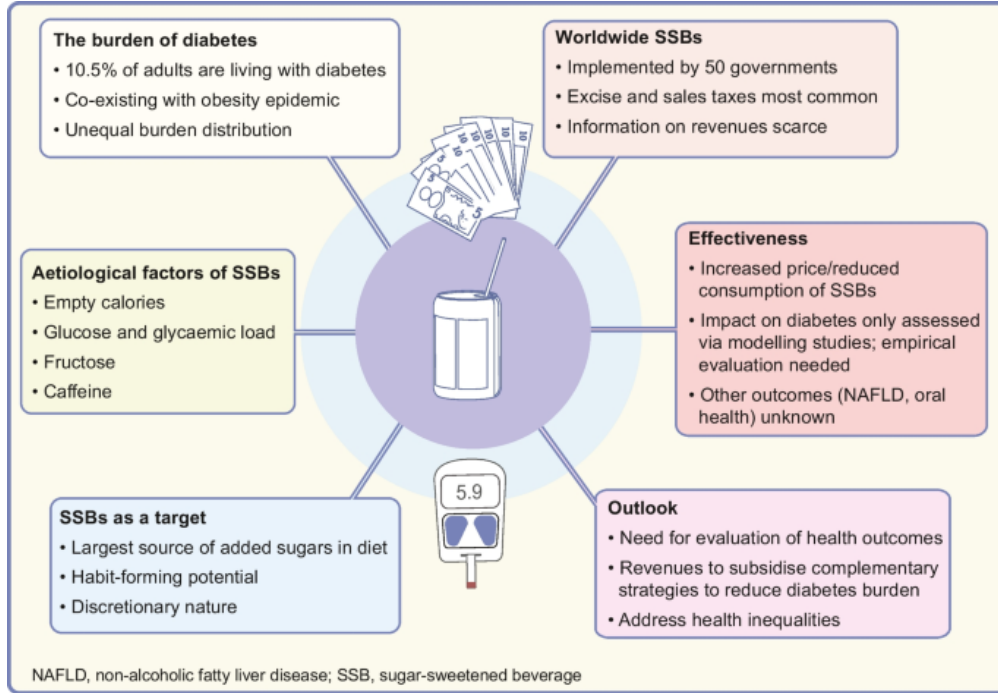


Micha, Peñalvo, et al (2017) JAMA

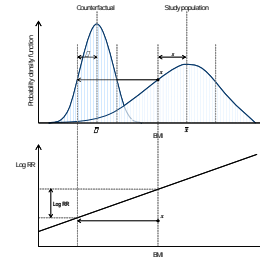


ESTILOS DE VIDA

FACTORES DE RIESGO MODIFICABLES



SISTEMAS COMPLEJOS



Peñalvo. 2024. Diabetología

REDUCCIÓN DE CONSUMO POR MODIFICACIÓN (10%) DE PRECIOS

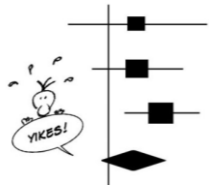
ESTRATEGIAS PREVENTIVAS MEDIDAS FISCALES



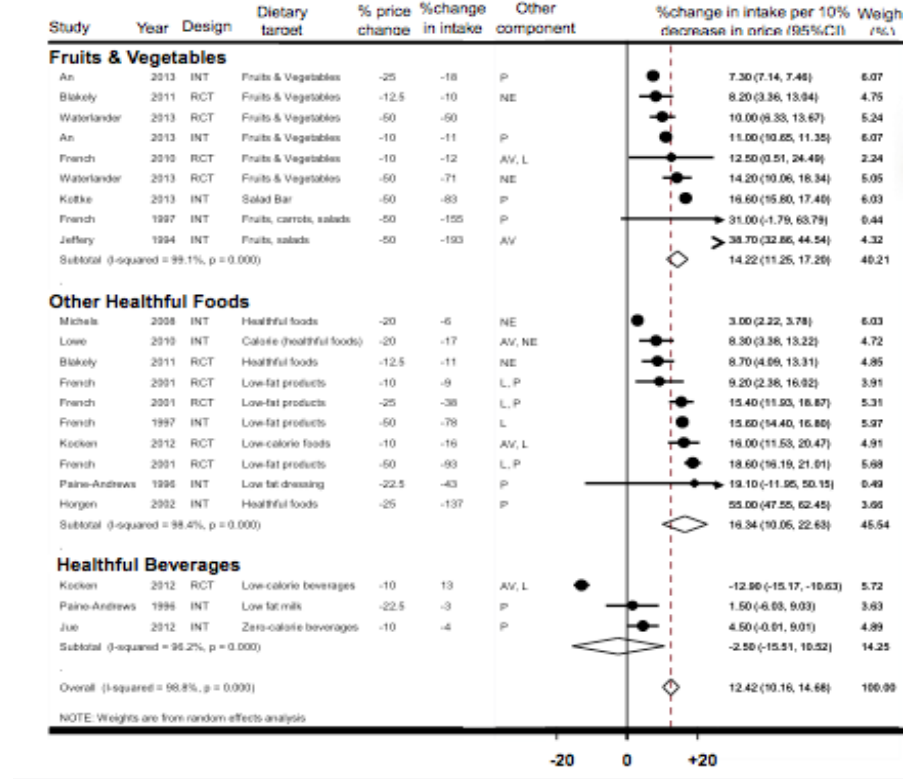
+16%



-2%



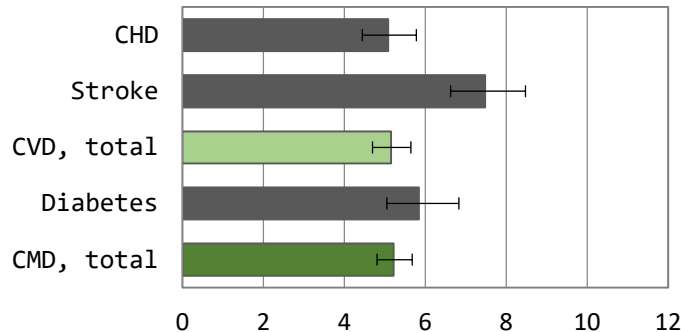
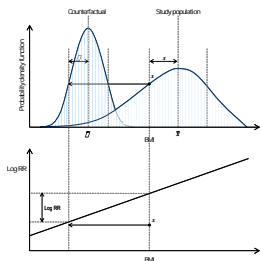
Brita



Afshin, Peñalvo, Et al (2016), PLoS One

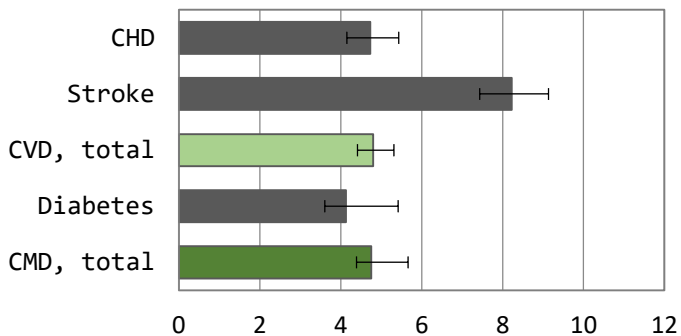
ESTIMACIÓN DE REDUCCIÓN DE MUERTES POR CMD POR MODIFICACION (10%) DE PRECIOS

~5% MUERTES POR
CMD PREVENIDAS AL AÑO
MEDIDAS FISCALES



↓ SES

% (95%UI)
MUERTES
PREVENIDAS
ANUALMENTE

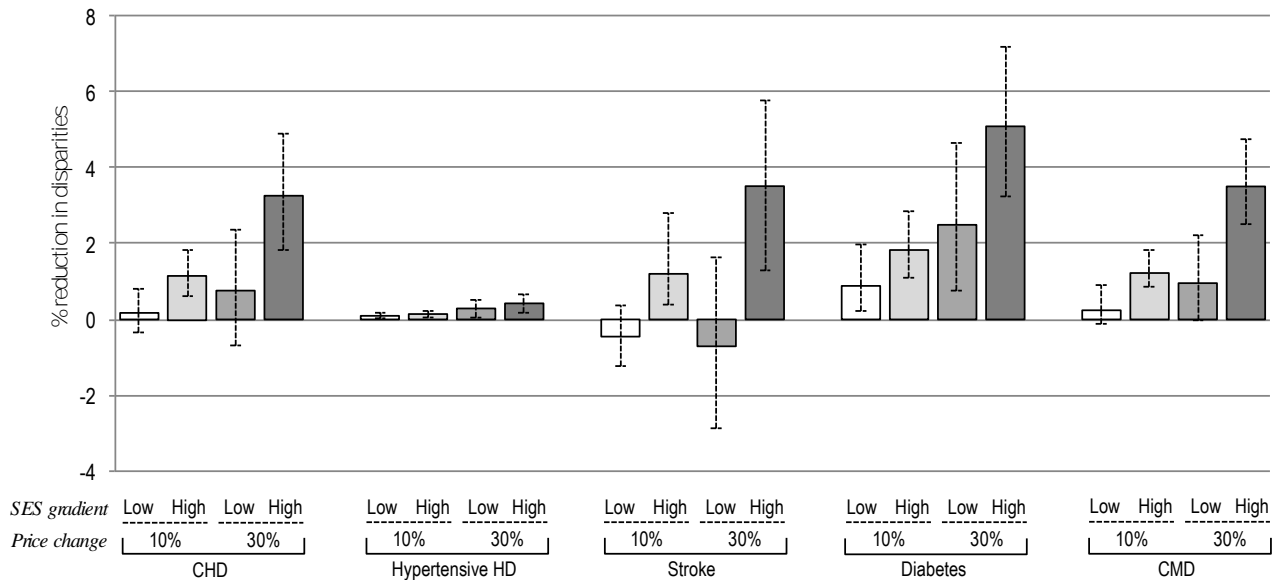


↑ SES

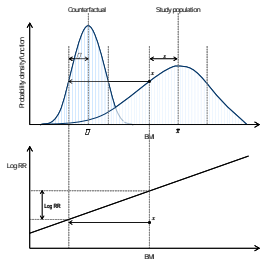
Peñalvo et al. (2017). BMC Medicine

ESTIMACIÓN DE REDUCCIÓN EN BRECHAS POR MODIFICACION (10% OR 30%) DE PRECIOS

ESTRATEGIAS PREVENTIVAS MEDIDAS FISCALES



Bars represent the potential relative (% 95%CI) change of the ratio of annual deaths per million adults of low (<high school) versus high (\geq college) education according to 10% or 30% price change in all 7 dietary targets. Low/high refers to a low SES gradient (18.2%) or high SES gradient (65%) of price responsiveness between low (<high school) and high (\geq college) education strata. CHD, coronary heart disease; HHD, heart disease; CMD, cardiometabolic diseases.



Peñalvo et al. (2017). BMC Medicine

1

MODELOS DE EVALUACION COMPARATIVA DE RIESGOS [CRA]



SIMPLICIDAD CONCEPTUAL

MENOR DEMANDA DE DATOS

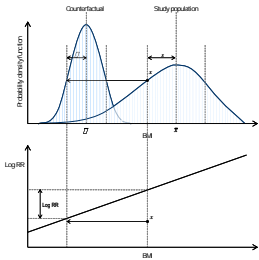
ESTABILIDAD EN RESULTADOS

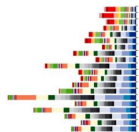


NO CONSIDERAN LA VARIABILIDAD

SENSIBILIDAD A CONDICIONES INICIALES

INCAPACIDAD PARA MODELAR EVENTOS ALEATORIOS

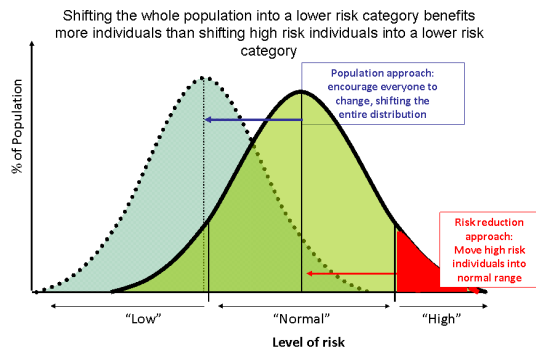




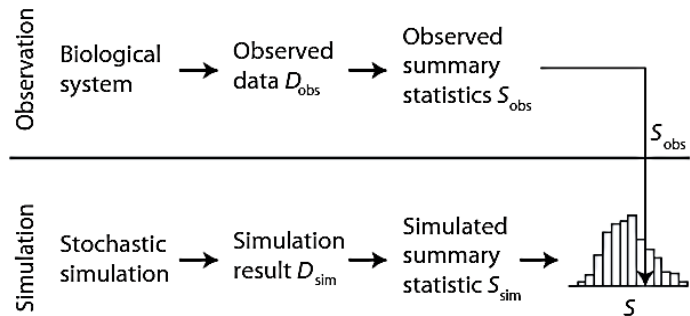
PREVENCIÓN CARDIOVASCULAR

MODELADO EPIDEMIOLÓGICO

The Bell-Curve Shift in Populations

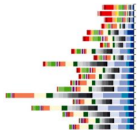


Source: Rose G. Sick Individuals and sick populations. *Int J Epidemiol.* 1985; 12:32-38.



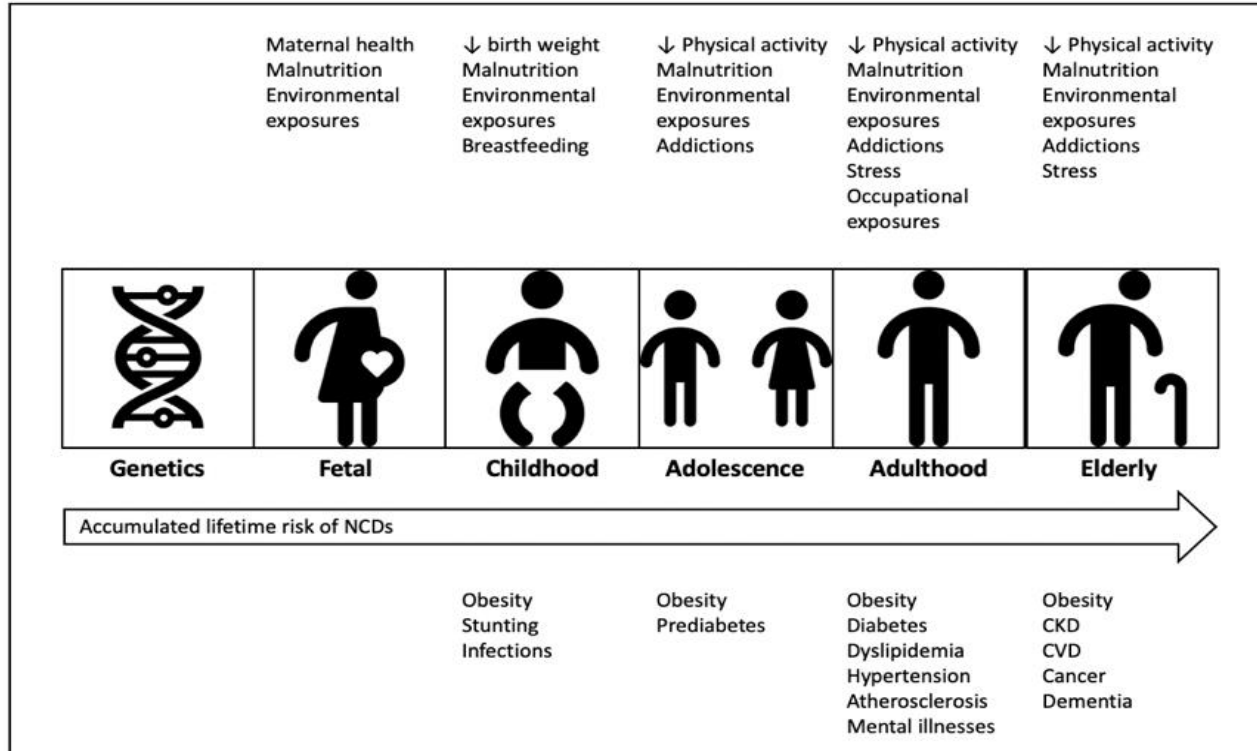
Hartig et al. (2011). *Ecology Letters*





ESTILOS DE VIDA

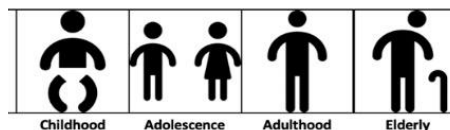
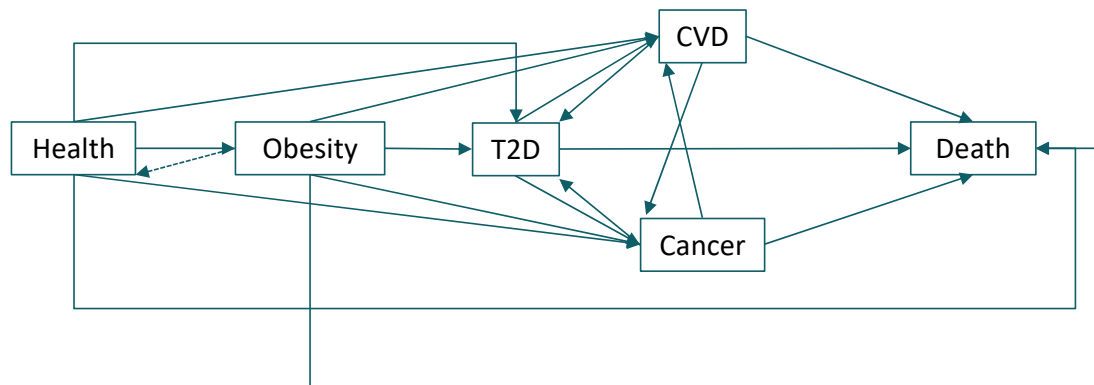
FACTORES DE RIESGO MODIFICABLES



2

MODELOS
ESTOCÁSTICOS
MICROSIMULACIÓN
[MSM]

Objetivo general: desarrollar y validar un método de modelización del curso de la vida capaz de captar la contribución del de los factores de riesgo a la carga de las ENT a lo largo de la vida



Burden

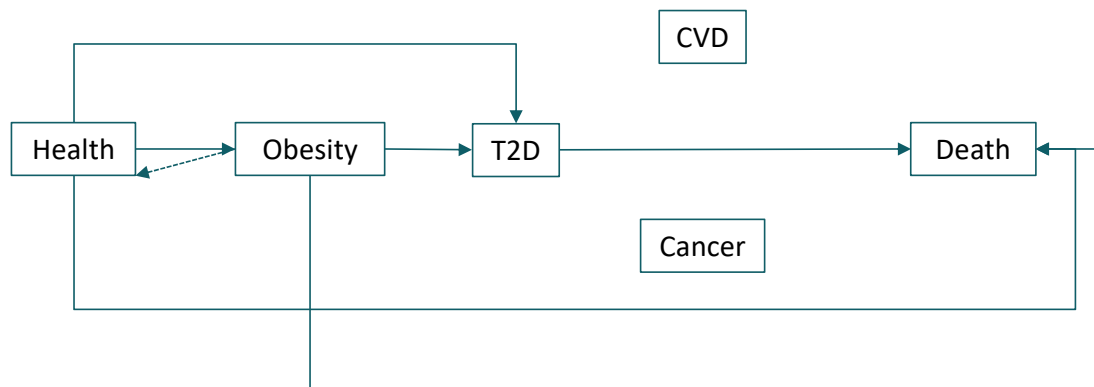
- Incidence, Prevalence, Mortality
- YLL, YLD, DALYs

2

MODELOS ESTOCÁSTICOS MICROSIMULACIÓN [MSM]

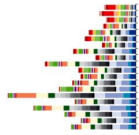


Objetivo general: desarrollar y validar un método de modelización del curso de la vida capaz de captar la contribución del de los factores de riesgo a la carga de las ENT a lo largo de la vida



Burden

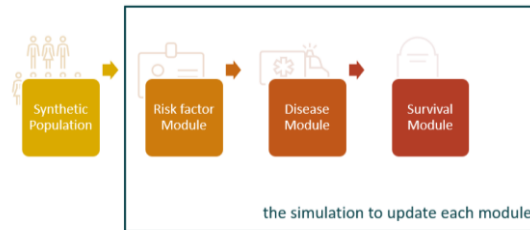
- Incidence, Prevalence, Mortality
- YLL, YLD, DALYs



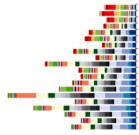
ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM]

- Modelo de simulación de eventos discretos y procesos continuos basados en transiciones probabilísticas entre estados de salud
- En base a población teórica semejante a la población de interés
- Simulación en ciclos anuales a través de procesos estocásticos:
 - Actualización anual de factores de riesgo por medio de probabilidades de transición
 - Actualización de la predicción anual del riesgo de evento por medio de ecuaciones de riesgo
 - Actualización de supervivencia por medio de probabilidad de muerte por franjas poblacionaes



Mertens [...] & Peñalvo et al. (2023). Res Square



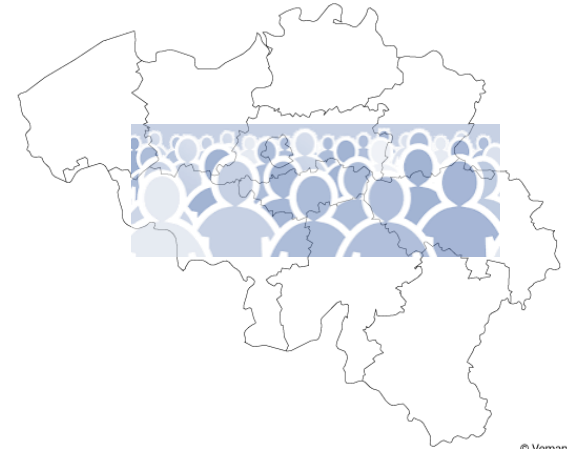
ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM] > COHORTE SINTÉTICA

- BELGIAN HEALTH INTERVIEW SURVEY 2018
 - 2,172 (0-17) + 9,439 (18+)
 - EDAD, SEXO, PROVINCIA
 - IMC (0-80), BP MED, T2D STATUS
- BELGIAN HEALTH EXAMINATION SURVEY 2018
 - 1,184 (18+)
 - EDAD, SEXO, PROVINCIA
 - CC, GLICEMIA
- BELGIAN CENSUS 2018
 - 11,430,000
 - EDAD, SEXO, PROVINCIA

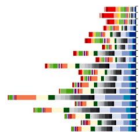


cran/**simPop**



© Vemaps.com

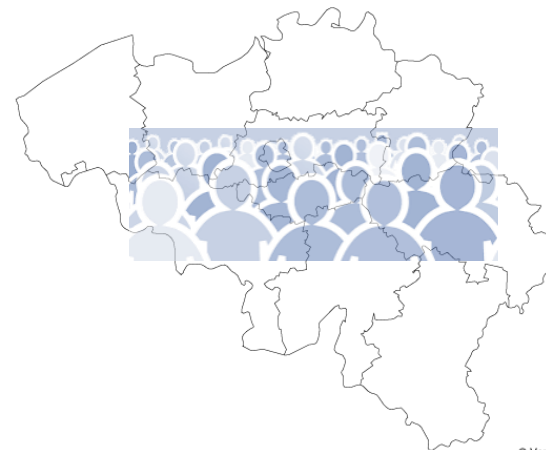
Mertens [...] & Peñalvo et al. (2023). Res Square



ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM] > COHORTE SINTÉTICA

		< 18 yrs (n=2,301,495)	18-34 yrs (n=2,374,218)	35-64 yrs (n=4,561,902)	>65 yrs (n=2,138,454)
Sex	Men	51.17	50.27	50.09	44.04
	Women	48.83	49.73	49.91	55.96
Region	Brussels	11.94	12.93	10.07	7.37
	Flanders	55.25	54.95	58.19	61.83
	Wallonia	32.8	32.12	31.74	30.8
Nationality	Belgians	90.11	86.1	87.32	95.17
	Non-Belgians, Europeans	5.94	6.51	7.65	4.06
	Non-Europeans	3.95	7.4	5.03	0.77
Education level	Low	12.21	12.16	14.08	38.44
	Intermediate	27.97	33.88	33.7	29.9
	High	59.82	53.96	52.22	31.66
BMI status¹	< 25 kg/m ²	74.75	67.76	45.62	41.29
	25-30	14.97	22.98	35.78	38.86
	> 30	10.28	9.26	18.61	19.85
Waist circumference²	M: <94cm; F:<80cm	NA	62.02	34.83	18.49
	M: 94-102cm; F: 80-88cm	NA	20.94	26.8	24.18
	M: ≥102cm; F: ≥88cm	NA	17.04	38.37	57.33
High blood pressure	Yes/No	NA	2.56	17.46	38.27
Hyperglycemia	Yes/No	NA	1.34	3.7	11.95
Diabetes	Yes/No	NA	1.37	5.07	13.83

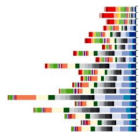


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2018. 2019. 2020. 2021. 2022. 2023. 2024. 2025. 2026. 2027. 2028. 2029. 2030

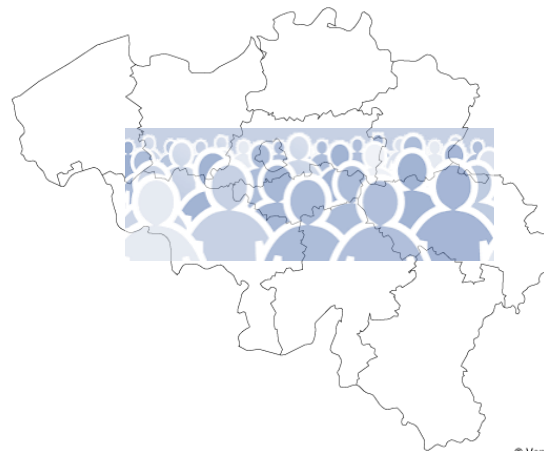
Mertens [...] & Peñalvo et al. (2023). Res Square



ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM] > COHORTE SINTÉTICA

- COHORTE ABIERTA, TODAS LAS EDADES 2018-2030, EN CADA CICLO
 - ENTRAN NACIDOS VIVOS (CENSO)
 - SALEN DECESOS
 - MIGRACIÓN INVARIABLE
- INCREMENTO DE EDAD EN CADA CICLO ANNUAL
 - SEXO, RESIDENCIA, EDUCACION, NIVEL ECONÓMICO INVARIABLE



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VLAAMS
SUPERCOMPUTER
CENTRUM

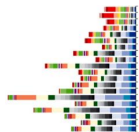


Vlaanderen
is supercomputing



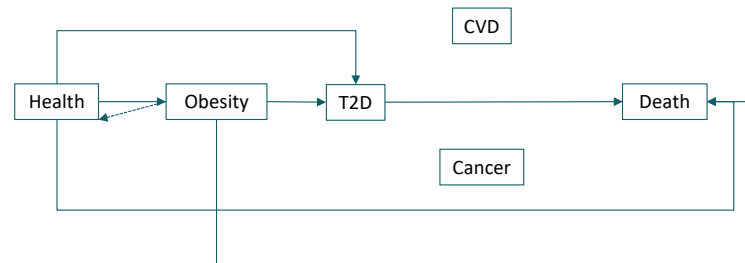
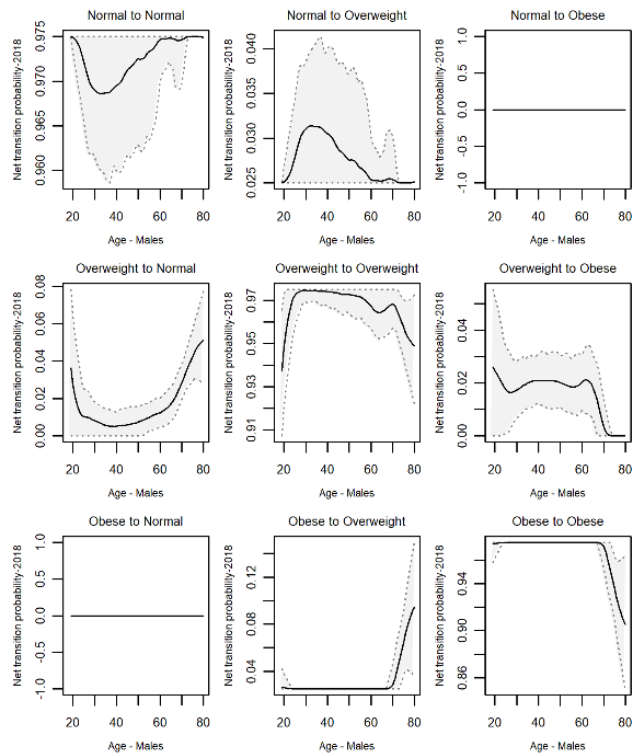
2018. 2019. 2020. 2021. 2022. 2023. 2024. 2025. 2026. 2027. 2028. 2029. 2030

Mertens [...] & Peñalvo et al. (2023). Res Square



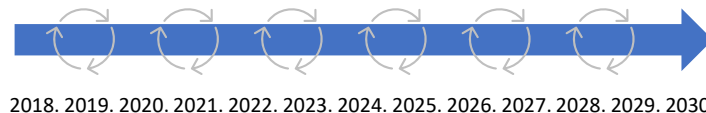
ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM] > FACTORES DE RIESGO



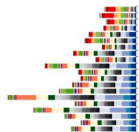
Burden

- Incidence, Prevalence, Mortality
- YLL, YLD, DALYs



2018. 2019. 2020. 2021. 2022. 2023. 2024. 2025. 2026. 2027. 2028. 2029. 2030

Mertens [...] & Peñalvo et al. (2023). Res Square



ACUMULACIÓN DE RIESGO

MODELOS DE MICROSIMULACIÓN [MSM] > INCIDENCIA ANUAL

EPIDEMIOLOGY/HEALTH SERVICES/PSYCHOSOCIAL RESEARCH | MARCH 01 2003

The Diabetes Risk Score:

A practical tool to predict type 2 diabetes risk **FREE**

Jaana Lindström, MSc; Jaakko Tuomilehto, MD, PHD

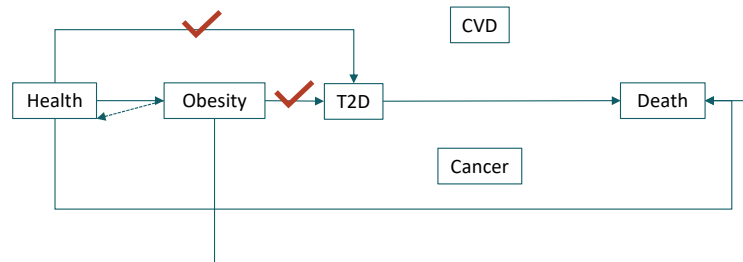


Diabetes Care 2003;26(3):725-731

<https://doi.org/10.2337/diacare.26.3.725>



| Regression coefficients | Categories | Log odds | OR (95% CI) |
|-------------------------------|---------------------------|----------|--------------------|
| Intercept | | -5.514 | |
| Age (years) | <45 | 0 (Ref) | 1 (Ref) |
| | 45-54 | 0.628 | 1.87 (1.12, 3.13) |
| | 55-64 | 0.892 | 2.44 (1.48, 4.01) |
| BMI (kg/m ²) | ≤25 | 0 (Ref) | 1 (Ref) |
| | >25-<30 | 0.165 | 1.18 (0.57, 2.45) |
| | ≥30 | 1.096 | 2.99 (1.31, 6.81) |
| Waist circumference (cm) | men: <94; women: <80 | 0 (Ref) | 1 (Ref) |
| | men: 94-102; women: 80-88 | 0.857 | 2.36 (1.25, 4.45) |
| | men: ≥102; women: ≥88 | 1.350 | 3.86 (1.92, 7.71) |
| Use of BP medication | No | 0 (Ref) | 1 (Ref) |
| | Yes | 0.711 | 2.04 (1.46, 2.83) |
| History of high blood glucose | No | 0 (Ref) | 1 (Ref) |
| | Yes | 2.139 | 8.49 (5.66, 12.73) |



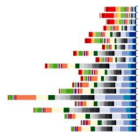
Burden

- Incidence, Prevalence, Mortality
- YLL, YLD, DALYs

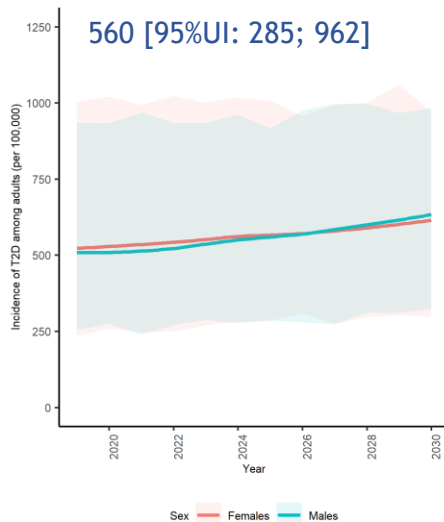


2018. 2019. 2020. 2021. 2022. 2023. 2024. 2025. 2026. 2027. 2028. 2029. 2030

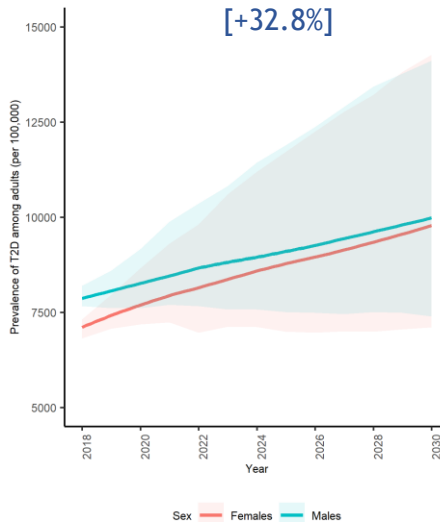
Mertens [...] & Peñalvo et al. (2023). Res Square



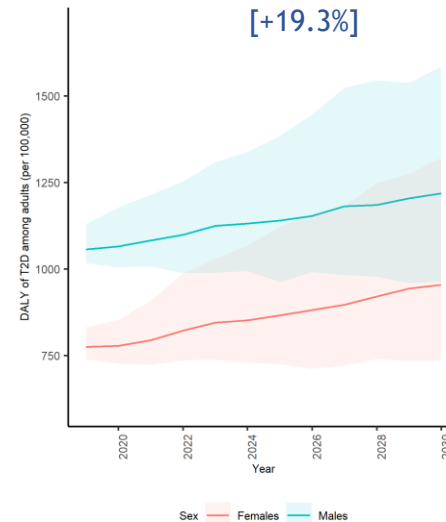
PREVISIÓN DE EVOLUCIÓN DE DIABETES TIPO 2



1A Incidence of T2D (2019 to 2030)



1B Prevalence of T2D (2018 to 2030)



1C DALYs of T2D (2019 to 2030)

Forecast of Incidence, prevalence, and DALYS rates [100,000] of T2D in the adult population aged 35-80 years, by sex

Mertens [...] & Peñalvo et al. (2023). Res Square

2

MODELOS
ESTOCÁSTICOS
MICROSIMULACIÓN
[MSM]



CAPTURA DE LA VARIABILIDAD

ADAPTABILIDAD

INCERTIDUMBRE



COMPLEJIDAD

DEMANDA DE DATOS Y COMPUTACIÓN

INTERPRETABILIDAD



Gracias