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RESEARCH

Understanding the role of inequality of opportunity in body mass index and waist circumference among Mexican adults

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Abstract
Mexico faces one of the most acute obesity crises worldwide. Despite policy efforts to decrease the prevalence of obesity among adults, an upward trend continues. The aetiology of obesity is complex and defined by multiple factors. While most of the literature has centered on studying behavioural attitudes that contribute to an energy balance that is positive (e.g., when energy intake is greater than expenditure), fewer studies have explored the role of inequality of opportunity (IOp), which focuses on studying the pathways from people's circumstances to health outcomes. In this study, IOp is measured, identified, and characterised in body mass index and waist circumference for Mexican adults. To address the challenges related to measuring IOp in these health outcomes, a modified version of the dissimilarity index and unconditional quantile regression models based on recentered influence functions are used. Results show that variation in both outcomes is related to inequality in circumstances. The two main drivers of these inequalities are parental health conditions and the geographic region where individuals live. These findings offer a broader perspective to the role of people's circumstances and their importance in tackling the obesity crisis in Mexico.

Keywords Overweight · Obesity · Inequality of opportunity in health · Distributive justice · Mexico

1 Introduction

Inequality of opportunity (IOp, from now on) aims to understand better and measure the fairness of (in)equality within a society. In economics, several studies have empirically measured the level of IOp in income (Brunori et al. 2013; Checchi et al. 2010; Ferreira et al. 2011; Lefranc et al. 2009; Plassot et al. 2022; Ramos et al. 2016), income acquisition (Hufe et al. 2017), consumption (Brunori et al. 2015), education (Gamboa et al. 2015; Jones et al. 2014; Palmisano et al. 2022) and well-being (Wendelspiess Chávez Juárez 2015a). Over the past decade, more attention has been paid to IOp in health (Bricard et al. 2013; Carrieri et al. 2018; Donni et al. 2014; Fleurbaey et al. 2009; Gallardo et al. 2017; Rosa Dias 2009; Trannoy et al. 2010). However, the measurement of IOp in health poses some challenges. As opposed to the measurement of IOp in income, for example, health variables can be ordinal,

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e.g., health status, which is most of the times captured via a self-assessed questionnaire using a five-point scale, with categories ranging from very poor to very good health. The presence of ordinal indicators of health precludes the application of mean-based inequality measures. Furthermore, for the specific case of BMI (body mass index) or WC (waist circumference), health is not monotonically increasing in them. For example, healthy and illness-related status occur across different parts of the BMI distribution: being underweight and overweight are both worse than being on a certain threshold for normal weight.

To overcome the latter challenges, two approaches are followed. First, BMI and WC are collapsed into binary measures according to clinical thresholds for excess weight and excess adiposity, and IOp is measured using the modified dissimilarity index proposed by Chávez-Juárez et al. (2015). Second, IOp is measured across the distributions of both outcomes using unconditional quantile regression models, although this permits the assessment of the contribution of circumstances at different points of the unconditional distribution of the health outcomes, under this method no overall measure of IOp can be obtained. Further description of IOp is done by decomposing measures of IOp to understand its main drivers better.

The study of IOp in over-nutritional outcomes in Mexico poses a relevant and intriguing case to follow. In the last decade, there has been a sharp rise in the proportion of Mexico's population classified as overweight or obese, coupled with an epidemiological and nutritional transition. The prevalence of overweight and obesity (OWOB) in the adult population was the highest among countries of the Organisation for Economic Cooperation and Development (OECD) in (2021) and has escalated from 69.7% in 2006 to 75.2% in 2018 (Barquera et al. 2013; National Institute of Public Health 2018). This is despite the implementation of several health policies and interventions[1]. Vast evidence exists about the social and economic burden, on a worldwide scale, that high rates of obesity and overweight have effects on lower quality and duration of life expectancy (Jarolimova et al. 2013), and the sustainability of public health systems as it imposes relevant opportunity costs to treat other diseases among the population. In the case of Mexico, it was estimated that 33.2% of the federal public health budget was spent on treating obesity-related comorbidities in 2008. Should the OWOB prevalence continue its rising trend, this cost could increase up to 110%, of the 2008 budget, by 2050 (Rtveladze et al. 2014).

For the sake of simplicity, in this paper OWOB is defined as the result of a prolonged positive energy balance, where energy intake is greater than energy expenditure. Obesity is a multiple etiological problem: genes, eating and life habits, people's living conditions and residency, attitudes and emotions, and income (Hojjat et al. 2017) are factors that contribute towards higher levels of OWOB. These factors can be classified according to their proximity as immediate, intermediate, or structural, and might affect individuals heterogeneously across their life course (Rivera-Dommarco et al. 2018). Immediate factors refer to people's lifestyles and behaviours. Intermediate are those linked with the production and distribution of food on a large scale, while structural are mainly related to the social, economic, and political situation in which people reside. Regarding immediate factors, several studies have documented the alarming increase in energy intake from sugar-sweetened beverages (SSBs) and nonessential high calorific energy-dense food in Mexico (Barquera et al. 2008; Barrientos-Gutierrez et al. 2017; PanAmerican Health Organization 2015), along with a decrease in physical activity (Medina et al. 2013), and changes in eating patterns, which differ substantially from recommendations for healthy living (Batis et al. 2018). The interplay between immediate and

[1] Such as the regulation of food and beverage marketing to children, the *National Agreement for a Healthy Nutrition* (Health 2010), the introduction of new clinical guidelines to diagnose overweight, and the sugar-sweetened beverages (SSBs) tax.

intermediate factors has also been analysed. For example, a study on the effects of the North American Free Trade Agreement (NAFTA) on Mexico's food environment found that the Mexican food system has been influenced and modified to the extent that changes in dietary patterns have taken place towards higher consumption of soft drinks, snacks, meat, and dairy products among the population (Clark et al. 2012).

The study of socioeconomic inequalities in over-nutritional health outcomes can be undertaken through different approaches, for example, under a pure distributional point of view that focuses on the economic gradient (Esposito et al. 2020; Fernald et al. 2007; Ullmann et al. 2011), or using rank dependent indices (Clément et al. 2021). However, the use of the IOp framework offers a better understanding of the sources of inequities since it explicitly establishes that an individual's health production function involves a combination of circumstances (social determinants of health), efforts (people's choices or free will) and luck (random shocks), and aims to isolate and disentangle the contribution of circumstances, which are illegitimate factors for differences across outcomes and, therefore, identifying unfair inequalities (inequities). These factors (circumstances, efforts, luck) are the common analytical categories used in other disciplines, such as epidemiology or public health, when analysing the aetiology of nutritional outcomes. However, the IOp framework brings and analyses them jointly. So, the IOp approach seems suitable to understand better whether and to what extent socioeconomic circumstances shape over-nutritional outcomes within Mexican society.

The present study builds on and contributes to two interconnected bodies of literature. On the one side, although more attention has been paid to the measurement of unfair inequalities in Mexico regarding wealth (Plassot et al. 2022; Wendelspiess Chávez Juárez 2015a), income (Grajales et al. 2018), school enrolment (Figueroa et al. 2021), and education (Blanco 2019; Plassot et al. 2019), at the time of writing, no evidence exists about IOp in over-nutritional outcomes among adults in Mexico. On the other, this paper contributes to the overall IOp literature in health by underscoring that many health indicators are ordinal and, thus, careful consideration must be made when applying standard approaches to measure IOp. The remainder of this paper is as follows: the next section introduces the IOp framework and describes how inequality is measured and decomposed. The third section describes the data and key variables included in the analysis. Section four presents and interprets the main results, and the final section discusses them.

2 Definition and measurement of inequality of opportunity

Along with the work of Arneson (1989), Cohen (1990), and Sen (1995); Roemer (1998) defined two concepts to understand the fairness of (in)equality within a society: circumstances and efforts. Circumstances are unchosen situations over which people do not have control and, therefore, for which they cannot be held responsible, while efforts are acts that embrace individual responsibility[2]. IOp entails two ethical morals: the compensation, and the reward principles (Fleurbaey et al. 2012). The former claims that inequalities related to circumstances should be eliminated, and the latter argues to reward efforts among individuals who share the same circumstances. However, it is not possible to fully satisfy both principles unless circumstances and efforts do not interact with each other (Fleurbaey et al. 2013). Two approaches to identifying inequalities have been suggested: *ex-ante* and *ex-post*

[2] Although with different wording, the distinction between circumstances and efforts was also made by Fleurbaey (1995b), Fleurbaey (1995a), and Bossert (1995)

(Bruoni 2016; Ramos et al. 2016). The former is mainly interested in measuring whether *prior* to exerting any effort or observing any outcome, circumstances are equally distributed. The latter approach looks at what happens *after* efforts and outcomes are observed. This study adopts an *ex-ante* approach to measure inequalities related to circumstances. It identifies equality of opportunity if all individuals face an equal set of opportunities, irrespective of whether such opportunities are acted upon. Overall, the concept of IOp aims to study the pathways from people's circumstances to health outcomes (Jones 2019), and is applied when concerns about health inequality are tied to questions about access to rights that may guarantee an equal playing field. This normative approach is followed here to evaluate the extent of individual deviation from a benchmark of *basic* or *minimum* opportunities, to which by the Mexican constitutional law people are entitled. Since the outcomes under study are non-monotonic, in the sense that both the bottom and upper parts of the distribution capture illness, these outcomes are dichotomised and IOp is measured using a modified version of the dissimilarity index which is appropriate for binary variables. To complement this analysis, IOp is also measured across different percentiles of the distribution of the outcomes, and using a Shapley-Shorrocks decomposition approach the contribution of each circumstance towards IOp is estimated.

2.1 Measuring *ex-ante* inequality of opportunity

Under an *ex-ante* approach, inequality exists if before exerting any effort, circumstances are statistically correlated to outcomes. This has been tested in previous studies by relying on parametric approaches and evaluating the existence of outcome variation conditional on people's circumstances (Davillas et al. 2020a; Ferreira et al. 2011) while controlling for biological factors (Jusot et al. 2013)[3]. Following the reduced form proposed by Jones (2019) and Davillas et al. (2020a) based on the health production function defined in the spirit of Roemer's approach, IOp in overweight, obesity and excess adiposity is identified by estimating the following equation:

$$Prob\{y_i = 1\} = (e^{\beta_0+\beta_1 C_i+\beta_2 X_i+\epsilon_i}) \cdot (1 + e^{\beta_0+\beta_1 C_i+\beta_2 X_i+\epsilon_i})^{-1} \quad (1)$$

Where y_i represents the binary health outcomes of being overweight, obese or having excess adiposity according to clinical thresholds for individual i, ..., N; β_0 is the intercept; β_1 captures the *total*[4] contribution of circumstances, β_2 represents coefficients associated with biological controls, age and sex. Dummy variables indicating the interaction between sex and age have been included to control for differences between men and women across different stages of their adulthood. ϵ_i is the error term that captures random variation in outcomes. It is worth noting that efforts are not observed or needed.

[3] Previous studies about IOp in health have treated sex and age as circumstances. However, Jusot et al. (2013) highlight that although age and sex are circumstances in principle, health differences due to these *biological factors* are recognised as inevitable, in the sense that it would be costly to neutralise inequalities driven by them. To make their point, they explain that in cross-sectional analysis, the inclusion of age as a circumstance reflects the birth cohort to which each person belongs. Health inequalities between two individuals of different ages, say 31 and 56 years old, are said to reflect technological developments. Despite the urge to compensate the 56-year-old individual for not being exposed to the same technological advances as the 31-year-old, the counterargument is that these situations are unavoidable as this is something that everyone will unavoidably face across the life cycle. Thus, we adopt the estimation strategy used by Jusot et al. (2013), which treats age and sex as biological determinants of health status. This implies setting them apart from other circumstances.

[4] As it includes the direct effects of circumstances on the outcomes and the indirect effect of circumstances through efforts, see Davillas et al. (2020a)

Measuring *ex-ante* IOp is a two-step procedure (Ferreira et al. 2011). The first is to estimate the conditional probability of being overweight, obese or having excess adiposity, P_i. This probability can be estimated through Eq. 1 using logit models.

$$P_i = \hat{y}_i = P(y_i > \tau | C_i, X_i) \tag{2}$$

The second step is to plug P_i into an inequality measure. The inequality measure to use depends not only on the desired properties of the inequality measure but also on the type of the health outcome variable. For binary variables that observe both desired properties, scale and translation invariant, Chávez-Juárez et al. (2015) have proposed a modified version of the dissimilarity index, D^*, which normalises the original dissimilarity index proposed by Paes de Barros et al. (2008). This modified index has desired properties such as reflexivity, anonymity, transitivity, plus a normalised scale and translation invariance. This D^*-index is equal to twice the average absolute distance to the population mean (Chávez-Juárez et al. 2015). This is,

$$D^*(P_i) = \frac{2}{N} \sum_{i=1}^{N} \left| P_i - \bar{P}_i \right| \tag{3}$$

D^* is a translation invariant indicator and avoids inequality levels being driven by the level of access rather than inequalities in access. If equality exists, D^*=0.

2.2 Drivers of *ex-ante* inequality of opportunity

Identifying the main drivers behind IOp is paramount to designing policies that address inequalities. For this, estimates of IOp in BMI and WC are decomposed into their sources and the relative importance of each circumstance to the overall predicted probability. This is done using the Shapley-Shorrocks decomposition method. Thus, we calculate the marginal contribution of each circumstance included in C to the variance of the outcomes used. This is calculated as the difference in the variance explained when the c^{th} circumstance is included and the variance when that circumstance is excluded. Differences are calculated using all possible permutations of circumstances. Then, the sum of the differences is averaged across the number of all possible permutations. It is worth noting that the contribution of each circumstance is not equivalent to the causal effect of each circumstance on IOp since unobservable determinants of nutrition-related outcomes are likely to be correlated with the observable circumstances as discussed by Ferreira et al. (2011). Thus, this decomposition only indicates the relative importance of each circumstance to the overall outcome probability (Chávez Juárez et al. 2014).

2.3 Analysing IOp at different percentiles of the distributions of the outcomes

Equation 1 measures inequality by assigning homogeneous weights to the contribution of circumstances within those individuals who share the same circumstances. Nevertheless, this might not be the case and could be too restrictive to uncover inequalities in OWOB. BMI and WC outcomes are non-monotonic health outcomes, lower and higher values of these measures reflect illness in the form of undernourishment or overnutrition. Thus, the analysis is complemented by now allocating different weights to the contribution of circumstances across the outcome distribution and using unconditional quantile regression (UQR) models as in Davillas et al. (2020a).

For this, a recentered influence function (RIF) (Borgen 2016; Firpo et al. 2009) of the over-nutrition outcome is estimated directly from the data. First, a sample quantile q is computed, and the density of the distribution of the outcomes at that quantile is estimated using kernel density methods. For a given observed quantile, q_τ, a RIF that can take one out of two values depending upon whether the observation's value of the outcome variable is less than or equal to the observed quantile that is generated, such as:

$$RIF(y; q_\tau) = q_\tau + \frac{\tau - 1\{Y \leq q_\tau\}}{f_y(q_\tau)} \tag{4}$$

where q_τ is the observed sample quantile, $1[Y \leq q_\tau]$ is an indicator variable equal to 1 if the observation's value of the outcome is less than or equal to the observed quantiles, and 0 otherwise. $f_Y(q_\tau)$ is the estimated kernel density of the outcome at the τ_{th} quantile.

Second, the RIF defined in the above equation is used as a dependent variable in an OLS regression on the vector of circumstances *(C)*, while controlling for sex and age X. This is equivalent to estimating a re-scaled LPM (Linear Probability Model) (Jones et al. 2015). The unconditional quantile of the outcome, q_τ, can be estimated as:

$$q_\tau = \mathbb{E}_c\left[\mathbb{E}[\widehat{RIF}(Y; q_\tau)|C, X]\right] \tag{5}$$

$\widehat{RIF}(Y; q_\tau)|C, X$ represents the estimate of RIF as defined in the first equation conditional on circumstances. Given this linear approximation, the law of iterated expectations can be applied to the approximated quantile, and used to estimate the total contribution of circumstances at each quantile:

$$RIF(y; q_\tau) = C_i\beta_1^\tau + X_i\beta_2^\tau + \epsilon_i^\tau \tag{6}$$

Where τ=15th, 25th, 50th, 75th and 95th percentiles and ϵ_i^τ represents the model error. The presence of IOp is assessed by comparing the deviation of the actual outcome with the predicted distribution of outcomes, given by:

$$\sim \widehat{y_i}^\tau = C_i\widehat{\beta_1^\tau} + X_i\widehat{\beta_2^\tau} \tag{7}$$

The MLD to measure absolute IOp and identify the main sources of inequalities. Results from this distributional analysis are found in the Appendix.

The percentiles have been chosen equally across both outcomes and complement the measurements of IOP at different parts of the distribution. These are located across different health statuses (e.g., healthy weight, overweight, obese type I and II). Indeed, the use of top-end percentiles allow us to understand better where higher levels of IOP are found. This, however, comes at the expense of not being able to obtain an overall measure of IOp, as the RIF approach does not aggregate over the percentiles. It is then worth noting that this approach only gives a sense of differences across types at different parts of the distribution.

Throughout the analysis, ENSANUT sample weights are used, which make the results representative of the Mexican population for the two years studied.

3 Data

Data from the cross-sectional National Surveys of Health and Nutrition (ENSANUT, using its Spanish acronym) for 2012 and 2018 are analysed. The datasets are nationally representative surveys whose target population is the inhabitants of private households in Mexico. These national cross-sections are multi-stage and stratified surveys (by urbanity and geographical areas). The sample design of the waves permits inferences about the health of the Mexican population. A full and detailed description of the sampling methodology is found elsewhere (Romero-Martínez et al. 2013, 2019).

The datasets consist of a collection of demographics, social and economic conditions, as well as nutrition-related health outcomes of the population, via anthropometric measurements, such as weight, waist circumference and height. Even though ENSANUT has a 2016 wave, this was not used since it is a mid-way survey with a smaller sample size and some of the questions included in other surveys were not asked[5].

3.1 Key variables

The units of analysis throughout are adults, defined by the survey as those aged 20 to 69 years old at the time of data collection.

3.1.1 Outcomes

BMI and WC are used as proxies of overnutrition health outcomes, although these indicators differ in what they specifically measure. BMI is the ratio of weight to height in squared meters and is the most common measure of overweight and obesity due to its availability and simplicity of measurement. Nevertheless, BMI does not consider the body fat distribution and the mass of abdominal fat (visceral fat). This can over-and under-estimate body fat (Dalton et al. 2003). For example, people with considerable muscle mass will have a higher BMI, whereas people with lower mass, for example, elderly people, will have a lower BMI. To overcome these concerns, an individual's WC, which accounts for intra-abdominal fat mass is also used. Both indicators are accurate predictors of diabetes (Vazquez et al. 2007), but WC provides a better approximation to coronary heart disease risk (Flint et al. 2010). Anthropometric measurements were taken by trained and specialised staff from the National Institute of Public Health (INSP) in Mexico. Weight, height, and waist circumference were measured twice, thus, we took the average of both measures. Pregnant women, individuals who reported having problems relating to measurement procedures, and individuals with biologically implausible values for BMI (BMI$<$10 and BMI$>$59 González et al. 2013) and WC ($<$51cm and $>$190cm Jacobs et al. 2010) were excluded from the analysis. This amounts to 493 observations for 2012, and 312 for 2018.

Outcomes were dichotomised according to the following clinical thresholds: 1 for overweight if an individual's BMI$>=$25 & BMI$<$29.9; obesity if BMI$>=$30 (WHO 1995), excess adiposity if WC$>$90cm in men and WC$>$80 cm in women (Alberti et al. 2009), and 0 for clinically normal weight (18.5-24.9) or waist circumference (WC$<$90cm in men, and WC$<$80 cm in women).

[5] ENSANUT surveys are intended to be undertaken every six years. Nevertheless, given the accelerated increase in the prevalence of overweight and obesity, it was decided to conduct a *mid-term* survey between 2012 and 2018 to monitor the health and nutritional status of the population (National Institute of Public Health 2016). As a result, the 2016 survey was designed differently from the 2012 and 2018 surveys which do not allow us to make comparisons in IOp measures across three points in time. For example, the 2016 survey did not collect data from two States: Colima and Oaxaca. Instead, additional observations from Chiapas, Tabasco and Veracruz were added to substitute data from Oaxaca (Romero-Martínez et al. 2017). It is not clear how data from Colima were replaced. This affects comparisons when using geographical regions, as well as information at the State level. Additionally, this re-assignment has important implications if information about the Indigenous population is used

3.1.2 Circumstances

In practice, the *ex-ante* approach focuses only on the total contribution of circumstances while efforts are unobservable factors. The set of circumstances chosen for this study incorporates the normative framework embedded in the Mexican Constitution, where the fundamental principles are established, and the *possibilist criterion* (Ramos et al. 2016), which claims that contextual factors matter and should be considered, for example, access to basic public services, such as running water, electricity, sanitation, etc. The first article of the Mexican Constitution stipulates that *"any discrimination based on ethnic or origin, gender, age, disability, social or health condition, religion, opinions, sexual preferences, marital status or any other that threatens dignity is prohibited"* (Mexican Constitution 2017). The definition of circumstances is a matter of debate (Jusot et al. 2019). In this piece of research, the circumstances to be included are based on the normative and legal grounds stated in the Mexican Constitution, the document that sets out the fundamental principles and social rights all Mexicans are entailed, rather than in a purely statistical sense. Thus, it is more in line with the definition of *formal* equality of opportunity (Williams et al. 2000) that no legal barriers should exist to access equal basic rights. This follows Roemer's strategy of drawing on the socio-legal context for the analysis to help define where the responsibility cut should be drawn. Thus, circumstances encompass proxies of the right not to be discriminated against based on ethnicity, to have running water in the household and to have social protection in health. As well as the parent's health condition, and the characteristics of where individuals live, such as their urbanity, level of deprivation and geography.

Ethnicity is a characteristic that people cannot choose. Indigenous people in Mexico are often treated unequally in social and economic terms, although they are entitled to the same rights as non-indigenous people. In this study, ethnicity is claimed to be an illegitimate cause for observing health inequities. The ethnic condition was defined according to the National Commission for the Development of Indigenous People of Mexico (Comisión Nacional para el Desarrollo de los Pueblos Indígenas, CDI, using its Spanish acronym), which asserts that indigenous people are those who speak at least one indigenous language. **Health insurance** is said to be an illegitimate cause of inequalities since it is a constitutional right that was first established in the Mexican Constitution in an amendment to Article 4th in 1983 and stated "every person has the right to health protection. The law will define the ways and means for access to health services and will establish the concurrence of the Federation and the Federated entities in matters of public health" (Mexican Constitution 2017). Nevertheless, it was not until the 2003 reform of the country's General Law of Health that health protection was effectively exercised. This reform explicitly adopted social inclusion, equality of opportunity, individual autonomy, financial justice, and social responsibility as its ethical values (Frenk et al. 2015). We included a categorical variable that indicates whether the individual is affiliated with a public or private health institution or if the person has no health insurance whatsoever[6]. **Parental diabetes and hypertension** are also defined as a circumstance that

[6] This has been framed as a circumstance because given that the Mexican health system is fragmented into several health institutions, the quality of care is very heterogeneous and this affects people's health. The Mexican health system is primarily divided into public/private spheres, within the public system, six institutions provide health and social care. These institutions are the Mexican Social Security Institute (IMSS); the Civil Service Social Security and Services Institute (ISSSTE); Health Ministry programmes, such as *Seguro Popular* or INSABI (the *Seguro Popular* programme was targeted at people with no health insurance and started in 2003. A reform took place in 2019 and the *Seguro Popular* programme disappeared); the state-owned petroleum company: Mexican Petroleum (PEMEX); the Secretariat of National Defence (SEDENA), and the Secretariat of Navy (SEMAR). Membership in these institutions depends on people's jobs. For example, on average, private company workers have private health insurance or that of the IMSS. Workers of PEMEX, SEDENA or SEMAR receive health and social care services in their institutions.

proxies health conditions inherited from parents and acquired behaviours through exposure. It also reflects *genetic luck* (Dworkin 1981; Lefranc et al. 2009). These circumstances are used to reflect the role of familial predisposition to obesity (Nielsen et al. 2015) and, therefore, account for the inherited environment and behaviours present within the household. These are binary variables that indicate whether either the mother or father reported to have been medically diagnosed with diabetes or hypertension.

Despite the fourth article of the Mexican Constitution declaring that *"everyone has the right to access and dispose of clean water for personal and domestic consumption in a sufficient, healthy, acceptable and affordable way"* (Mexican Constitution 2017), by 2015, 5.6% of the Mexican population declared not to have running water in their households. Furthermore, empirical evidence highlights that the OWOB situation in Mexico is driven, in part, by the high intake of SSBs. We argue that this behaviour could be partially driven by the lack of **availability of running water inside the house** due to this constitutional right not being guaranteed by the government[7]. As such, this household characteristic was included, by itself, as a circumstance. Another circumstance that captures the *geography of opportunity*, a concept that describes how the area and geographical space where people live condition access to opportunities (Rosenbaum 1995) is included and proxied by the level of **social deprivation at the State level**. This variable is a weighted index that considers access to education, health, basic services, and housing spaces at the State level (Consejo Nacional de Evaluación de la Política Social 2007). The index is estimated by the National Council for the Evaluation of Social Development Policy (CONEVAL, for its acronym in Spanish) every five years. Thus, we used the 2010 and 2015 indices.

Additionally, we included as a circumstance the **geographical region** where people live. This is so because Mexico is a country with a noticeable North-South divide, with the North being more economically advantaged. Recent studies about inequalities in access to public goods and health found that place of residence matters (Altamirano et al. 2018; Monroy-Gómez-Franco et al. 2020, 2021; Plassot et al. 2022). Thus, we included region together with **urbanity** as potential sources of illegitimate inequality. The 32 Federal States of Mexico were grouped into six regions, see Fig. A.1 in the Appendix, as well as Table A.1 which provides further details about the circumstances variables.

All these variables have been specifically chosen and titled *circumstances* because they represent illegitimate sources of disparities. This connotes the idea that personal choices, the labour market or the political party governing should not influence the lack of running water or health insurance. The definition of a circumstance used in this paper entails a combination of those given characteristics that people cannot change, but also those factors that should guarantee an equal playing field for everyone before exerting any effort. Therefore, the normative and legal framework mentioned when defining each circumstance is of high relevance.

[7] A clear case is found in San Cristóbal de las Casas, a town in the South-eastern state of Chiapas in Mexico where families were reported to consume more Coca-Cola than bottled water for hydration (López et al. 2018). This appears to be due to a combination of a lack of water, the liquid being heavily chlorinated, and a higher availability of Coca-Cola compared to bottled water, which results in the former being cheaper to purchase than the latter (Pliego 2019).

4 Results

4.1 Circumstances and Outcomes

Table 1 describes the samples in terms of the key variables used in the analysis. For demographics, around 48-42% of the individuals in each sample were men. Also, 66-74% of the people were between 20 to 49 years old, and around 27-34% were older than 50, but younger than 69 years old. Most people in the samples were not from an indigenous ethnicity (93-94%). In terms of social care in health protection, by 2018 at least 16% of the adult population were not affiliated with any public or private health institution. Of those affiliated with a public institution, most of them were subscribed to the IMSS or the former Seguro Popular programme. Only 2% of the adults received private health services in 2018. Regarding familial factors, across the two years, the proportions of individuals with a father or mother not diabetic or without hypertension decreased. For diabetes, this decline was from 82% to 78% in fathers and 75% to 71% in mothers. For hypertension, the proportions decreased from 82% to 74% for fathers and 67% to 57% for mothers. In terms of household conditions, the proportion of individuals that have piped water inside of their household increased from 69 to 75%, conversely individuals with piped water outside of their household or no piped water decreased (24% to 20%, and 7% to 5%, respectively). With regards to State deprivation, around half of the sample lived in States considered to be of low and very low deprivation. Finally, most of the adults lived in urban, metropolitan areas or in the Central Region.

Figure 1 displays the distribution of the outcomes for both survey years. The median BMI and WC have increased over time. It is worth noticing that these median values were above the cut-off points for normal weight. Indeed, only 27% and 21% of the individuals in 2012 and 2018, respectively, had a normal BMI (Table 2). While obesity was at about 33% in 2012, 41% of individuals were obese in 2018.

4.2 Inequality of opportunity in BMI and WC among Mexican adults

Table 3 shows the levels of *ex-ante* inequality of opportunity in BMI and WC for Mexican adults in 2012 and 2018. The second column depicts the estimates for IOp in the probability of being overweight, having obesity and excess adiposity. Results show that the highest magnitudes were found for obesity and, that a decrease in IOp across time in all outcomes was observed.

4.3 Drivers of Inequality of Opportunity

Figure 2 shows the results of using the Shapley-Shorrocks decomposition method to identify circumstances that contribute the most to *ex-ante* IOp. Across survey years and outcomes, parent's health was the circumstance that accounted for most of *ex-ante* inequality, at around 57-64%. The second most relevant circumstance was the geographical region where people lived (9-13%). For both outcomes, the relevance of state deprivation, urbanity, social protection in health, and ethnicity decreased across the years. Overall, the relevance of water availability remained unchanged over time, but it is of higher importance for WC than BMI. Specific relative contributions can be found in Table A.2 in the Appendix.

Table 1 Descriptive statistics of the circumstances by health outcome and year

	BMI 2012	BMI 2018	WC 2012	WC 2018
Men	0.48	0.42	0.48	0.43
Age groups				
20 to 29	0.28	0.21	0.27	0.21
30 to 39	0.25	0.21	0.25	0.21
40 to 49	0.21	0.24	0.22	0.24
50 to 59	0.16	0.19	0.17	0.20
60 to 69	0.10	0.14	0.10	0.14
Ethnicity				
Non-indigenous	0.93	0.94	0.94	0.94
Health Affiliation				
None	0.25	0.16	0.25	0.17
IMSS	0.32	0.34	0.33	0.34
ISSSTE	0.06	0.07	0.06	0.07
Seguro Popular	0.35	0.40	0.35	0.39
PEMEX, Defensa or Marina Secretariat	0.01	0.01	0.01	0.01
Private	0.01	0.02	0.01	0.02
Parents' health				
Father non-diabetic	0.82	0.78	0.82	0.78
Father without hypertension	0.82	0.74	0.82	0.74
Mother non-diabetic	0.75	0.71	0.75	0.71
Mother without hypertension	0.67	0.57	0.67	0.57
Water availability				
Piped inside household	0.69	0.75	0.69	0.75
Piped outside household	0.24	0.20	0.24	0.20
No piped water	0.07	0.05	0.07	0.05
State Deprivation				
Very high State deprivation	0.10	0.10	0.10	0.10
High State deprivation	0.25	0.22	0.25	0.22
Medium State deprivation	0.16	0.17	0.16	0.17
Low State deprivation	0.31	0.33	0.31	0.34
Very low State deprivation	0.19	0.17	0.19	0.17
Geographical Region				
Urban-Metropolitan	0.79	0.79	0.79	0.79
Northwest	0.08	0.09	0.08	0.09
Northeast	0.18	0.17	0.18	0.18
West	0.19	0.19	0.19	0.19
Centre	0.33	0.32	0.33	0.32
South	0.17	0.17	0.16	0.16
Southeast	0.06	0.06	0.06	0.06
Observations	34,265	14,517	33,353	14,246

Table 2 Descriptive statistics of the health outcomes split by sex and year

	2012					2018				
	Under	Norm.	Over	Ob.	EA	Under	Norm.	Over	Ob.	EA
Women										
Observations	242	4,605	7,090	7,842	19,906	97	1,580	2,985	3,932	8,644
Prop.	0.01	0.25	0.35	0.38	0.83	0.01	0.19	0.35	0.45	0.89
Men										
Observations	123	4,043	5,972	4,131	14,359	44	1,483	2,636	2,262	6,475
Prop.	0.01	0.29	0.42	0.28	0.64	0.01	0.23	0.41	0.35	0.74
Total										
Observations	365	8,648	13,062	11,973	34,265	141	3,063	5,621	6,194	15,119
Prop.	0.01	0.27	0.39	0.33	0.74	0.01	0.21	0.37	0.41	0.83

Note: Prop. means proportion, and Norm. Normal weight. Under means underweight, and Over overweight. Ob. and EA mean, respectively, obesity and excess adiposity. Underweight defined as BMI < 18.5, normal weight as BMI >=18.5 & BMI<25, overweight as BMI>=25 & BMI<29.9, obesity as BMI>=30, and excess adiposity as WC>90cm in men and WC>80 cm among women

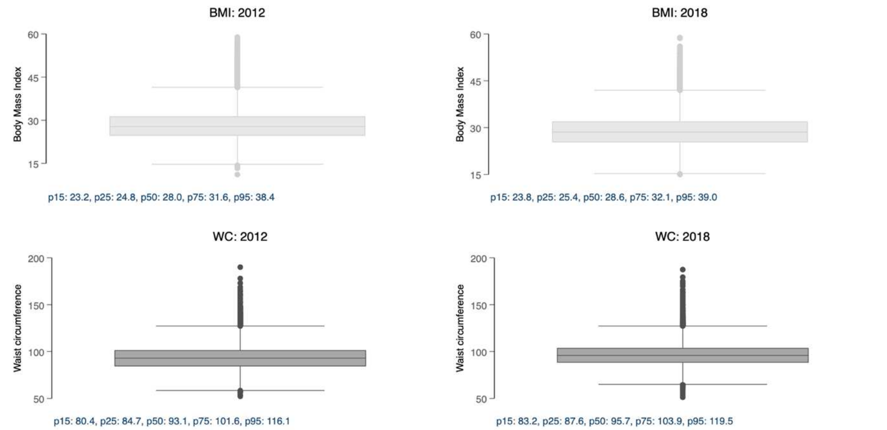

Fig. 1 Distribution of BMI and WC split by sex and year

4.4 Inequality of Opportunity at different percentiles of the distributions

When estimating Eq. 7 to the different percentiles, outcomes and surveys, it was found that, shown in Table 4, absolute inequality is higher at the upper parts of both outcomes' distributions (shown in Table 4). This implies that circumstances mattered more for individuals at the top than at the bottom of the distribution. The highest absolute inequality associated with circumstances occurred at the 95^{th} percentile for BMI for both years. It is important to note that these estimates are not aggregated measures of inequality, but rather estimates at specific points of the outcomes distribution.

When identifying the relative contribution of each circumstance towards *ex-ante* IOp in these percentiles, consistent results were found. Figure 3 shows that, for most outcomes percentiles, parents' health condition was the main driver of illegitimate disparities. However, in 2018, its contribution decreased to the upper percentiles (75^{th} and 95^{th}). The second driver was the geographical region where people lived, again with differences across outcomes: the

Table 3 Inequality of Opportunity in Overweight, Obesity and Excess adiposity in 2012 and 2018

Outcome-Year	D^*	*BSE*
Overweight (BMI)-2012	0.2411***	0.0021
Overweight (BMI)-2018	0.2275***	0.0053
Obesity (BMI)-2012	0.3274***	0.0043
Obesity (BMI)-2018	0.2852***	0.0097
Excess adiposity (WC)-2012	0.2634***	0.0035
Excess adiposity (WC)-2018	0.2217***	0.0033

Notes: D^* means modified dissimilarity index. BSE=bootstrapped standard errors (500 replications). BMI and WC dichotomised and assigned the value of 1 for overweight (BMI>=25 & BMI<29.9), obesity (BMI>=30) and excess adiposity (WC>90cm in men and WC>80 cm in women), and 0 for clinically normal weight or waist circumference. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001

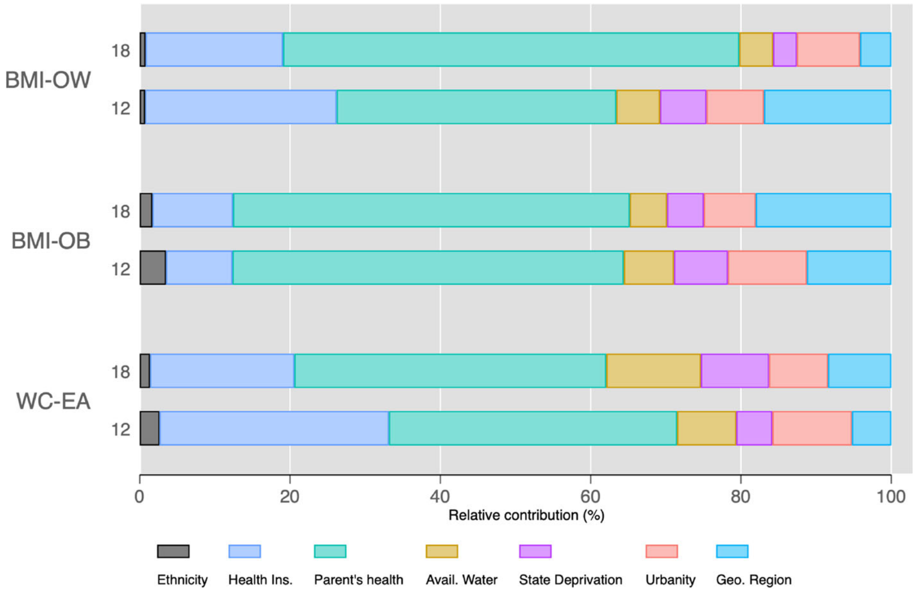

Fig. 2 Relative contribution of each circumstance to IOp split by outcome and year

Table 4 Absolute and Total Inequality of Opportunity across Outcome's distribution

Outcome-Year	*Absolute*	*BSE*	*Total*	*BSE*	*Observations*
BMI q15 2012	0.0007***	0.0000	0.0750***	0.0009	27,612
BMI q25 2012	0.0006***	0.0000	0.0408***	0.0004	27,612
BMI q50 2012	0.0007***	0.0000	0.0249***	0.0000	27,612
BMI q75 2012	0.0008***	0.0000	0.0266***	0.0001	27,612
BMI q95 2012	0.0011***	0.0000	0.0475***	0.0013	27,612
WC q15 2012	0.0002***	0.0000	0.0343***	0.0005	26,808
WC q25 2012	0.0003***	0.0000	0.0262***	0.0002	26,808
WC q50 2012	0.0004***	0.0000	0.0152***	0.0000	26,808
WC q75 2012	0.0004***	0.0000	0.0146***	0.0001	26,808
WC q95 2012	0.0005***	0.0000	0.0263***	0.0007	26,808
BMI q15 2018	0.0008***	0.0000	0.0798***	0.0012	12,644
BMI q25 2018	0.0007***	0.0000	0.0400***	0.0004	12,644
BMI q50 2018	0.0007***	0.0000	0.0229***	0.0000	12,644
BMI q75 2018	0.0009***	0.0000	0.0277***	0.0003	12,644
BMI q95 2018	0.0016***	0.0000	0.0473***	0.0016	12,644
WC q15 2018	0.0004***	0.0000	0.0417***	0.0008	12,392
WC q25 2018	0.0004***	0.0000	0.0226***	0.0003	12,392
WC q50 2018	0.0003***	0.0000	0.0122***	0.0000	12,392
WC q75 2018	0.0004***	0.0000	0.0150***	0.0002	12,392
WC q95 2018	0.0007***	0.0000	0.0300***	0.0012	12,392

Notes: BSE=bootstrapped standard errors (500 replications). Percentiles levels for BMI-2012: p15=23.2, p25=24.9, p50=28, p75=31.7, and p95=38.4 kg/mts^2. BMI-2018= p15=23.8, p25=25.4, p50=28.5, p75=32, and p75=39 kg/mts^2. Percentiles levels for WC-2012: p15=80.4, p25=85, p50=93.1, p75=101.7, and p95=116 cm. WC-2018: p15=83.2, p25=87.5, p50=95.5, p75=103.8, and p95=119.6 cm. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001

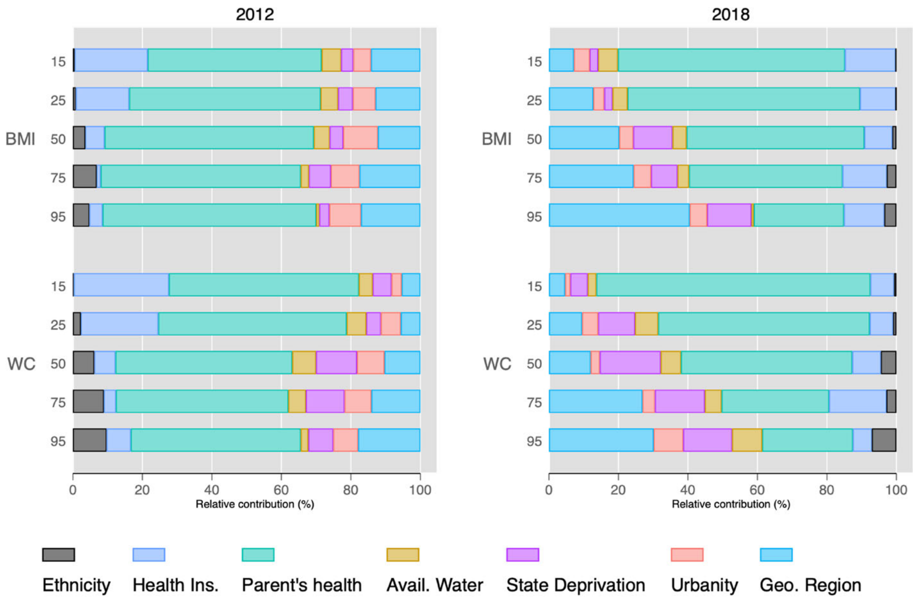

Fig. 3 Relative contribution of each circumstance to IOp at different percentiles in 2012

relevance of geography was higher at the upper parts of the distribution (e.g., the 75^{th} and 95^{th} percentiles), around 17% for BMI in 2012 and 24-40% in 2018, and 14-17% in WC for 2012 and 26-30% in 2018. Specific relative contributions at different parts of both distributions can be found in Table A.3 in the Appendix.

5 Discussion

Following the work of Roemer and others, subsequent research has acknowledged that not all inequalities in health are unfair. A first step in identifying illegitimate IOp is to disentangle the extent to which inequalities in outcomes are due to circumstances. In this regard, if circumstances play a role in achieving a certain outcome, individuals face unequal *playing fields*. This analysis has measured the level of inequality related to circumstances in two nutrition-related health outcomes among the adult Mexican population while tackling the methodological issues at hand when measuring these health outcomes.

The main findings indicate that inequality attributed to circumstances in the probability of having obesity in 2018 is higher than the probability of being overweight (0.2852 *versus* 0.2275). Estimates for IOp in the probability of observing excess adiposity in this year was 0.2217. These estimates only considered a normative-based opportunity set representing lower-bound levels of IOp (Ferreira et al. 2011) acknowledging the potential omission of other relevant circumstances. One circumstance that could be of high relevance, but that was not included in this analysis due to the lack of data, is information about epigenetics: how parents' behaviours and living conditions affected the adiposity-related genes inherited by their children. Also of relevance might be adverse childhood conditions, such as the presence of food insecurity within the household, or richer information on the role of economic shocks and their effect on maintaining good nutrition. This is important since the adults analysed in this study were exposed to the 1988 economic crisis and the market-oriented policies that followed suit. There is evidence that this affected severely the quantity and quality of the food consumed by families and individuals. These are potential circumstances that were not included but might be relevant for the estimation of IOp in nutrition-related outcomes. Furthermore, it must be noted that this is a cross-sectional analysis that focused only on adult individuals (20 to 69 years old) and it is very likely that IOp in these outcomes varies across different stages of the lifespan. This aspect is missing in this analysis. Furthermore, while other studies have conceptualised sex and age as circumstances (Davillas et al. 2020a), this study uses them as control variables to capture biological factors of health status.

Results also showed that illegitimate inequality is mainly driven by people's parental conditions and determined by the geographical place where they live. Particularly, having parents who have been diagnosed with diabetes greatly contributes to higher IOp. This could potentially be associated with mechanisms in which parents with obesity-related diabetes pass to their children certain physical characteristics that lead to inter-generational obesity (Brisbois et al. 2012; Wrotniak et al. 2004) and familial predisposition to obesity (Nielsen et al. 2015; Teran-Garcia et al. 2013). In Mexico, the prevalence of type 2 diabetes in adults is around 13-22% (Meza et al. 2015; Saeedi et al. 2019). It has been estimated that 90% of the cases are linked to OWOB (Dávila-Torres et al. 2015; Health 2010), which suggests that familial context matters. A recent study that compared growth trajectories and children's caloric intake according to post-partum mothers' BMI found that social environmental factors, such as the food landscape might play a decisive role in shaping children's obesity (Téllez-Rojo et al. 2019). This underscores the inter-generational transmission of obesity-prone behaviours. Given the implicit egalitarian principle behind the *ex-ante* approach, compensatory policies should, therefore, exist to dampen the effect of unequal early-life circumstances. These could take the form of differentiated healthcare policies or interventions that focus on obesogenic environments in households during pregnancy and early life stages (Haire-Joshu et al. 2016).

The geographical region where individuals live is the second main driver of disparities. Where people develop their life matters and it is more relevant for people in the upper parts, 75^{th} and 95^{th} percentiles, of both BMI and WC distributions. This sheds light on geographical differences in risk exposures to worse health that might potentially be attenuated by localised and differentiated health and social policies. This complements and coincides with the recent findings about the contribution of geography *per se* on excess adiposity in England. Davillas et al. (2020b) explored the relative contribution of geographic areas on excess adiposity and found that the role of geography is more pronounced and relevant for individuals at the top of the BMI and WC distribution. This highlights that factors beyond individual control can be modifiable via health, social and economic local programmes, and interventions.

Although previous evidence explored the connection between no running water availability and excessive drinking of sweetened beverages (López et al. 2018; Pliego 2019), this study did not find that a limited extent of water access was a major source of OWOB inequities. However, decomposition results showed that unfair inequalities in BMI and WC are boosted by the lack of social protection in health, despite the entitlement of the right to protection of health. Health insurance explains around 8-30% of *ex-ante* inequalities. Its relevance was higher for overweight and excess adiposity. This could potentially be linked with evidence that points out that the lack of primary healthcare, which is aimed at enhancing health promotion and timely detect obesity and overweight, is related to higher rates of diabetes and hypertension in Mexico (Alcalde-Rabanal et al. 2018).

This analysis is not without limitations. The most important one is that our health outcomes and social welfare are not concave along all their distribution. Social welfare will certainly increase if the BMI of an underweight adult rises. The clinical literature acknowledges that if the BMI of an underweight adult (BMI<18.5kg/m^2) increases, those individuals will reach a normal and thus healthy weight. However, once BMI passes the cut-off of 25kg/m^2, individuals are not healthy, as they are overweight, and become unhealthier, where BMI goes beyond 30-35kg/m^2 (e.g., obese or extremely obese). This is also the case for WC, which also shows a nonlinear relationship concerning social welfare. Social utility increases as WC increases but up to a threshold. Thus, the Pigou-Dalton (PD) principle does not hold given the nature of our outcomes. This issue has been tackled in two ways, first, by dichotomising the outcomes according to the clinical cut-off points for overweight, obesity, and excess adiposity according to an individual's BMI and WC. IOp was then measured following a modified version of the dissimilarity index (Chávez-Juárez et al. 2015). This measure is scale and translation invariant which is favourably for making comparisons over time. Second, by adopting a distributional perspective and measuring IOp at several points of the BMI and WC distribution. The distributional analysis allowed us to examine the different weights that circumstances have across the BMI and WC distribution, assessing IOp for those individuals at the bottom of the distribution, presumably with normal weight or with lack of adiposity, and at the top of the distribution, where individuals suffer overweight, different levels of obesity, and excess adiposity. However, a relevant drawback of this approach is that RIF regressions only capture inequalities at the specific points of the outcome distribution, which provides an incomplete vision of inequalities. Future research might focus on developing measures of inequality of opportunity using polarisation indices[8] (Apouey 2007) or entropy measures (Contoyannis et al. 2007).

Another important drawback is the data. ENSANUT neither collected retrospective data about the familial background nor collected data in a panel format. More robust influence could be obtained with panel data or retrospective information about parents' health backgrounds. In addition, parental diabetes and hypertension condition is self-reported, which might potentially induce bias through measurement error. Nevertheless, the proportion of parents with diabetes (18-26%) and hypertension (24-43%) in this study are relatively similar to the expected national prevalence rates of 13-22% for diabetes (Meza et al. 2015; Saeedi et al. 2019), and 13% to 44% for hypertension (Sudharsanan et al. 2019).

In democratic societies, such as in Mexico, equality of opportunities in health is not only desirable, but also paramount for social well-being and development. Unequal health outcomes across individuals are not necessarily unfair. Based on ethical grounds, there is a problem if health outcomes depend on people's ethnicity, parental background or unequal access to fundamental rights and services. Within this context, this study has explored another aspect of the acute OWOB situation in Mexico. This analysis has further implications for the economic approach to obesity. For example, obesity has been seen as a side-effect of technology changes or increased female participation in the labour market (Rashad et al. 2004). Although this might be the case, the economics of obesity should also incorporate the social, political, and institutional structures in which people develop their lives, accounting for the role that governments have in implementing policies to outweigh these side effects and guaranteeing fundamental rights to all citizens. This study claims that unequal opportunities condition further choices and lifestyle decisions. In this regard, further interventions should acknowledge that equalising the playing field is a premise for effective public policies to tackle this OWOB crisis.

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[8] Polarisation measures are ideal to describe situations where the extremes of a distribution grow, and the middle shrinks. While inequality measures look at variations across distributions.

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Availability of data and materials All our data are in the public domain.

Declarations

Ethical Approval This does not apply.

Competing interests The authors declare that they have no conflict of interest.

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