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# Small area influences on the individual unhealthy lifestyle behaviors: a multilevel analysis of discriminatory accuracy

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## Abstract

We estimated the discriminatory power of area of residence (census tract) on the prevalence of main risk factors for chronic diseases. Results, based on a sample of 21,007 participants from the 2011-2012 National Health Survey of Spain, show a differential influence of the geosocial environment on the four health risk factors. Accounting for census tracts substantially increases the discriminatory power regarding at-risk alcohol consumption, unbalanced diet, and leisure-time sedentarism but not tobacco consumption.  However, the socioeconomic characteristics of the tracts played a minor role. Further research on the specific geosocial contextual variables explaining variability in these risk factors is necessary.



**Keywords:** Smoking: alcohol, diet; sedentarism; multilevel analysis; discriminatory accuracy


## Highlights:

-One geosocial environment may exert differential influence on distinct risk factors

-Quantifying the overall contextual effect for each specific risk factor is important

-Census tract increases discriminatory power regarding at-risk alcohol consumption

-Census tract discriminates in regards to diet and sedentarism but not smoking

# Introduction

Smoking, at-risk alcohol consumption, unbalanced diet, and low physical activity not only generate a substantial proportion of the disease load but comprise the main modifiable risk factors for chronic diseases. In Spain, estimates of attributable mortality for each of them are 15.4%, 7.6%, 12.5%, and 2.3%, respectively (Institute for Health Metrics and Evaluation, 2017). Thus, reducing the prevalence of these risk factors is one of the pillars of any chronic disease preventive strategy (World Health Organization, 2016).

Since the 90s there has been increasing interest regarding the influence the area of residence exerts on individuals´ health and its determinants; an acknowledgement that health status is a result of individual behaviors and the social context in which these individuals interact (Macintyre et al., 2002; Oakes et al., 2015; Roux, 2008). Thus, the determination of geographic and social boundaries defining variations in individuals´ health is a key ongoing effort in the public health arena. However, the results may differ widely according to the scale and the aggregation configuration of the areal units used. This phenomenon, called the modifiable areal unit problem (MAUP), poses a major concern for context research (Flowerdew, 2011). MAUP was first identified by Gehlke and Biehl (Gehlke and Biehl, 1934) and described by Openshaw almost 50 years later: "the areal units (zonal objects) used in many geographical studies are arbitrary, modifiable, and subject to the whims and fancies of whoever is doing, or did, the aggregating."(Openshaw, 1983) A similar issue has been discussed in the field of social epidemiology regarding the identification of the relevant context in multilevel analyses (Larsen and Merlo, 2005; Merlo, 2011; Merlo et al., 2009). Additionally, it is necessary to identify which specific characteristics of these social contexts are associated with the individual-level risk; thus explaining the geographic component of the total individual-level variation (Cummins et al., 2007; Merlo, 2003; Merlo et al., 2009, 2005).

Currently, several studies attempt to evaluate contextual effects using the spatial ecological analysis “small-area variations,” often using color atlases and disease maps. However, it is already well established that multilevel models are the most appropriate tool for the quantitative analysis of contextual effects on health (Duncan et al., 1999, 1998, 1993; Merlo et al., 2019, 2001).

Previous work underscore that in multilevel analysis specific contextual effects must be differentiated from the general contextual effect (Merlo et al., 2018) since they each provide different, though complementary, information. Specific contextual effects identify the association between the particular contextual characteristics and the individual variable under study. So far, this has been the most common type of analysis. In fact, many multilevel studies are designed to analyze the relationship between the particular contextual characteristics and the main risk factors for chronic disease, especially in physical activity (Kepper et al., 2019; Schüle and Bolte, 2015; Smith et al., 2017), diet, (Black et al., 2014; Caspi et al., 2012; Hilmers et al., 2012), obesity (Black and Macinko, 2008; Congdon, 2019), and, to a lesser extent, alcohol and tobacco consumption (Karriker-Jaffe, 2011). The contextual characteristics analyzed depend on the risk factor of interest but most focus on socioeconomic characteristics of the area of residence and on the built environment, i.e., all those infrastructures and facilities built to offer goods and services to the residents such as parks and playgrounds, walkability components, public transport, stores with fresh fruits and vegetables, package stores, bars and restaurants, fast food outlets (Black et al., 2014; Hilmers et al., 2012; Popova et al., 2009; Schüle and Bolte, 2015).

The general contextual effect is not measured with measures of association but with measures of variance. For this reason, the measurement of the general contextual effect must precede that of the specific effect; as the former yields essential information to understand to what extent the context under study influences individual health, even before specifying the particular characteristics of that context (Merlo et al., 2019, 2018). However, most results derived from multilevel analyses fail to describe the components of the variance. (Merlo et al., 2018, 2009; Riva et al., 2007)

For each health problem and each context, multilevel models estimate what proportion of the total individual variance corresponds to the area of residence. The larger this proportion, the more relevant the context is. If the proportion is very large, knowing where an individual resides would suffice to establish with certainty whether they suffer from the health problem in question. This information has great implications for designing and allocating public health interventions. When the proportion of total individual variance explained by area of residence is very small, to concentrate interventions in certain areas but not others is highly inefficient. In such a case, the intervention would need to be universal and include all geographical areas. In contrast, a high proportion of variance explained by area of residence would support focusing the resources of the intervention in specific areas. It is very likely that one environment or geographical context (e.g., census tract) may exert great influence on certain individual health issues, but not on others. Thus, the importance of quantifying the general contextual effect for each specific problem.

Once the general contextual effect is quantified, we then may analyze the specific contextual effect. That is, determine certain characteristics specific to that geographical context are associated to the individual health issue, and to what extent that association explains the contextual variance.

This analytical strategy fits well with the idea of the “Proportionate Universalism” developed by Marmot and Bell (Carey et al., 2015; Marmot and Bell, 2012), although our strategy focuses on the geographical differences (Merlo et al., 2019). The idea of the “Proportionate Universalism” argues that interventions should be universal, i.e., directed to the entire population (e.g., smoking bans in public spaces, built environments conducive to physical activity, or taxes on alcoholic drinks or processed foods) but proportionally more intensively to areas with greater need where specific interventions would be justified (e.g., development of information campaigns in certain neighborhoods of specific sub-populations)

As far as we are aware of, few studies to date have quantified, simultaneously, the influence of the area of residence on the main risk factors for chronic diseases at the individual level (Adams et al., 2009; Boing et al., 2019; Ecob and Macintyre, 2000). It is also still uncommon for studies to differentiate between general and specific contextual effects. We hypothesize that the social and economic environment characteristic of individuals´ census tract of residence influences their behavior related to the four main health risk factors. And, that such impacts vary by type of behaviors.

Therefore, and using a common methodology (Merlo et al., 2016), our study simultaneously analyzes the influence that census tracts and their socioeconomic privation index exert on smoking, alcohol abuse, unbalanced diet, and low leisure-time physical activity at the individual level.

# Methods

Population and Study Design

Cross-sectional study based on data from the 2011-2012 Spanish National Health Survey (ENSE for its Spanish acronym). The ENSE collects data on health status and the main social and environmental determinants and lifestyles of residents in Spain. The sample design is multistage, first selecting all provinces and then municipalities for each of them, and stratifying according to the sizes of the municipalities. For the chosen municipalities, a sample of census tracts are selected. Finally, households are sampled, selecting one adult ≥15 years of age for each household. Data were collected during face-to-face interviews between July 2011 and June 2012. Response rate was 71.1% of selected households. The sample included 21,007 individuals residing in 2,000 census tracts (Spanish Ministry of Health, Consumption, and Welfare and Spanish National Institute of Statistics, 2012).

Variables

Current / Former smokers versus never smokers: We identified current smokers (daily or not) and former smokers at the same risk category.

Unbalanced diet: Defined based on a synthetic index of diet quality derived from the Mediterranean Diet Adherence Screener (MEDAS), an instrument validated for rapid estimation of an individual´s adherence to the Mediterranean diet. MEDAS has been used in the Prevention with Mediterranean Diet (Prevención con Dieta Mediterránea in Spanish) (PREDIMED) study, a primary prevention nutrition-intervention trial developed and tested for the Spanish population (Schröder et al., 2011). The possible score ranges from 0 to 10 based on the following point system: 1-2 servings of fruit/day (1 point), ≥3 pieces/day (2 points); 1 serving of vegetables/day (1 point), >1/day (2 points); ≥3 servings of legumes/week (1 point); ≥3 servings of fish/week (1 point); <1 serving of meat/day (1 point); <1 serving of sugary drinks/day (1 point); <3 servings of sweets/pastries/week (1 point); <3 servings of fast food (including snacks)/week (1 point). A score <7 points defines an unbalanced diet.

Leisure-time sedentarism: It is based on the following question: Which of these options best describes how often are you physically active in your leisure time?: 1) I do not do physical activity. My leisure time is occupied almost completely by sedentary activities (e.g., reading, tv watching, going to the cinema); 2) I do some occasional physical or sports activity; 3) I do physical activity several times a month; and 4) I do sports or physical training several times a week. Individuals are classified as sedentary if they chose option 1 “I do not do physical activity. My leisure time is occupied almost completely by sedentary activities.”

At-risk alcohol consumption: based on the data available, we defined two variables: Heavy regular consumption and Binge drinking. The former was determined by the frequency of regular consumption of 6 types of alcoholic drinks (beer, wine or cava (Spanish Champagne); aperitifs; liquor, anise, pacharan; whisky, cognac, mixed drinks; and local drinks (cider, *carajillo*, the Spanish word for coffee with a splash of liquor). Respondents were asked about their daily consumption on a regular week. We then calculated their regular alcohol consumption in grams of pure alcohol. We defined heavy regular consumption as the intake of ≥40 g/day for men and ≥24 g/day for women. Binge drinking was defined as the consumption of ≥6 alcoholic drinks for men or ≥5 for women in a 4-6 hr interval at least once in the previous month. Reports of heavy regular consumption and/or binge drinking were classified as at-risk alcohol consumption.

Individual covariates collected in the ENSE included: sex; age (7 subgroups); educational level (primary or less, secondary-first level, secondary-second level, university); household income weighted by household size (tertiles); urban/rural municipality (rural <10,000 vs. urban ≥10,000 residents); country of birth (Spain- or foreign-born).

Socioeconomic privation index: Contextual variable based on the 2011 census. This is a synthetic index developed for Spain at the census tract level by the Spanish Epidemiology Society. It takes into account the percentages of 6 indicators: manual labor, temporary workers, unemployment, individuals 16 and over and between 16 and 29 years of age with low educational levels, and primary households without internet access (Duque et al., 2020).

Analyses

From the 21,007 individuals interviewed as part of the ENSE, our analyses included the 20,468 participants who had complete data on all variables of interest. Based on a previous publication, we elaborated simple logistic regression models followed by multilevel logistic regression models (Merlo et al., 2016) as described below.

Model 1 estimates a simple logistic regression with the individual variables as fixed effects. This model provides information on the predictive power of individual variables before taking into account the contextual information of the census tract.

Model 2 estimates a multilevel logistic regression with the census tract as a random effects variable and the individual variables as fixed effects. By comparing it to model

1, it facilitates the identification of the added value of accounting for the census tract in our understanding of the individual risk regarding the exposure variable.

Finally, in model 3 we included the specific contextual variable (the index of socioeconomic privation). Now, we can determine if the contextual variable is associated to the individual risk factor and to what extend does it explain the variance of the census tract obtained in model 2.

Models 1-3 are adjusted for all individual covariates by entering them simultaneously into the model.

We repeated this modeling process separately for each of the risk factors.

We also differentiated between specific and general contextual effects:

Specific contextual effects

Specific contextual effects provide information regarding the existence of an association between the particular characteristics of the section (the socioeconomic privation index) and the individual risk factor. We estimated these effects using regression coefficients expressed as odds ratios (OR) with 95% confidence intervals (CI). A similar process was followed to estimate the associations at the individual level.

General contextual effects

General contextual effects provide information regarding the degree to which census tracts under study affect individual risk differences of practicing an unhealthy lifestyle. That is, no contextual characteristic is specified but only the limits defining the census tract. We used two different measures to calculate the general contextual effect: (i) variance partition coefficient (VPC); (ii) change (Δ) in the Area Under the Curve (AUC) Receiver Operating Characteristic (ROC) or Δ-AUC; and (iii) proportional change of the variance (PCV).

(i) We calculated the VPC at the census tract level using the latent variable method (Goldstein et al., 2002) as follows:

VPC = Census Variance / (Census Variance + π^2 / 3)

where π^2 / 3 or 3.29 is the value of the variance of the variable at the underlying individual level according to the logistic distribution.  Given the hierarchical nature of our data, in this study the VPC corresponds to the intraclass correlation coefficient because it represents the correlation of the likelihood of having a risk factor between two individuals chosen at random in the same census tract.

The VPC should be interpreted as the proportion of total individual variance one may ascribe to the census tract where individuals reside. If the census tract exerts a strong contextual effect on the individual likelihood of practicing one of the risk factors, the VPC will be high. In contrast, if this effect is weak or non-existent, the VPC will be close to zero.

The general contextual effect provides information on the size of the geographic differences. In other words, instead of ranking these geographic differences by comparing census tracts´ average values or the variations of census tracts by themselves the VPC compares that census variance with the total individual variance. To assess the VPC´s magnitude we took the classification proposed by Merlo and colleagues as the point of reference (Merlo et al., 2019).

(ii) The Δ-AUC between models 1 and 2

Initially, in model 1 we calculated the AUC to quantify the discriminatory power of the individual variables to accurately classify individuals with or without the risk factor (Merlo et al., 2016; Pepe et al., 2004). Next, we calculated the AUC of model 2 and we compared it to that of model 1. This Δ-AUC indicates the increase in discriminatory power due to the general contextual effect. The AUC takes a value between 0.5 and 1, where 1 denotes perfect discrimination and 0.5 means that the variables examined have no discriminatory power.

(iii) The proportional change of variance (PCV)

To complement the evaluation of contextual effects, we calculated Model 2´s proportion of census variance explained after adding the contextual variable of socioeconomic privation in model 3. This measure is known as the proportional change of variance (PCV). The PCV tells us to what extent the specific contextual variable (census socioeconomic privation) acts as a mediator of the general contextual effect.

All analyses were performed using Stata v.15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

# Results

Table 1 shows the sample characteristics and its distribution according to the four risk factors of interest. Almost half of the sample (45.2%) was current smoker or ex-smoker, 72.3% reported an unbalanced diet, 44.7% were sedentary in their leisure time, and 5.1% reported at-risk alcohol consumption.

**Current and Ex-smokers**

Table 2 shows that individual characteristics across the three models are homogeneous with a greater prevalence among men, among those 25 to 64 years of age, with mid-educational level, and born in Spain. We found no differences regarding income level or rural/urban residence.

Regarding to the socioeconomic privation index, the specific contextual factor of interest, individuals residing in census tracts falling in the quartile with greater privation had a lower likelihood of smoking with an estimated OR=0.89 (95%CI: 0.81-0.99)

In model 2, we can observe the general contextual effect by adding the census tract as a random effect to the model already adjusting for the individual variables. The estimated VPC is 3.7% (95%CI: 2.7-5.0) indicating a weak general contextual effect. The AUC of model 1 was 71.9% which, after including the census tract (model 2), increased to 74.9% (Table 2 and Figure 1a). The inclusion of the specific contextual variable, the privation index (model 3), hardly modifies the variance estimated in model 2, which translates into an AUC for model 3 similar to that for model 2.

**Unbalanced diet**

Table 3 shows the individual variables associated to an unbalanced diet. Men reported worse diet. Other factors related to poor diet were younger age, lower educational achievement, low income, urban residence, and being foreign-born.

The privation index shows that residing in census tract with greater privation increases the likelihood of having an unbalanced diet (OR=1.35, 95%CI: 1.14-1.60). Regarding the general contextual factor, the VPC of model 2 was 21.6% (95%CI: 19.6-23.8) which denotes a strong effect. Model 1 AUC was 68.3% which, upon adding the census tract (model 2), increased to 82.3% (Table 3 and Figure 1b). The addition of the privation index (model 3) did not change the estimated variance in model 2, and thus, no change in AUC between model 3 and model 2 is observed.

**Leisure-time sedentarism**

Table 4 shows the association between individual variables and leisure-time sedentarism. Women, individuals of middle- and advanced age, those with low educational achievement, and foreign-born were more likely to be sedentary.

In comparison with those in the quartile denoting the least privation, those classified in the second quartile were close to be more likely to be sedentary (OR=1.12, 95%CI: 0.99-1.27). Those in the third and fourth quartile (highest privation) were significantly more likely to be sedentary (OR=1.27, 95%CI: 1.11-1.44 and OR=1.31, 95%CI: 1.14-1.50, respectively).

General contextual effects showed a VPC=14.5% (95%CI: 13.0-16.2) in model 2. The AUC for model 1 was 64.1% which, after adding the census tract (model 2), increased to 77.2% (Table 4 and Figure 1c). The addition of the privation index (model 3) reduced minimally the variance estimated in model 2, and no changes in AUC were observed in model 3 vs. model 2.

**At-risk alcohol consumption**

Table 5 shows the individual characteristics associated to at-risk alcohol consumption. Men, younger individuals, those with mid- to high-incomes, and residents of rural municipalities, showed a direct association with at-risk alcohol consumption.

No relation with the privation index was observed.

Finally, regarding the general contextual effect, model 2 shows an estimated VPC=30% (95%CI: 25.8-34.6%). The AUC for model 1 was 76.8% which, after adding the census tract (model 2), increased to 91.3% (Table 5 and Figure 1d). Accounting for the privation index (model 3) did no reduced the estimated variance in model 2 and no changes in AUC between model 3 vs model 2 were observed.

# Discussion

Our results show the differential influence of the environment associated to the census tract (area of residence) on the four main health risk factors related to behavior. Neighborhood context plays a highly relevant role in our understanding of the geosocial determinants of at-risk alcohol consumption, unbalanced diet, and leisure-time sedentarism. In contrast, the contextual influence on individual tobacco consumption is far less. These results confirm our two hypotheses. First, the residential environment has an impact on the behavior related to the four main health risk factors and, secondly, the associations do vary by type of behaviors.

On average, the association between the socioeconomic status of the census tract and each risk factor varies. Whereas smoking risk is lower in those census tracts with higher levels of privation, the opposite is true for unbalanced diet and sedentarism. We found no association with at-risk alcohol consumption. In any case, the socioeconomic privation index fails to emerge as a key component of the overall contextual effect of the census tract as it does not explain census tract variance for any of the health risk factor examined here.

Our results suggest that interventions to prevent at-risk alcohol consumption, unbalanced diet, and sedentarism, albeit always universal (i.e., at the national level), should, nevertheless, focus on census tracts with high prevalence of these risk factors. In contrast, campaigns against tobacco should be deployed at the national level and target individuals with socioeconomic and demographic factors associated with the most risk.

As far as we are aware of, few studies have approached this issue in a similar two-pronged approach. First, analyses of several risk factors simultaneously using multilevel models while controlling for a homogeneous group of variables. And second, an evaluation of the variance to determine the contribution of the geosocial environment to the risk factors independently from that of the individual characteristics.

Adams and colleagues studied the effect of the contextual socioeconomic status on risk factors of an Australian population (based on Collector Districts, about 200 dwellings). They observed that the variance explained by the area of residence for physical activity, current smoking, and at-risk alcohol consumption was 5.9%, 7.2%, and 5.1%, respectively (Adams et al., 2009). Ecob and colleagues analyzed the variability of behavior-related risk factors in Scotland. They observed the differential influence exerted by the environment (defined by postcode sectors) which manifested only on "poor" diet but not on physical activity, smoking, or alcohol intake (Ecob and Macintyre, 2000). Finally, Boing et al., analyzed the same four risk factors on a Brazilian sample and, similar to our study, they failed to observe an environmental influence (based on census tracts) on tobacco consumption. However, they reported an intra-class correlation coefficient (ICC), which interpretation mirrors that of the VPC, of

0.8% for unbalanced diet, 5.2% for physical activity, and 3.8% for problem drinking (Boing et al., 2019).

Studies using multilevel models to evaluate the influence of the area of residence on tobacco consumption, despite incorporating the estimate of the variance of the random effect, do not quantify the general environment effect regarding individual variables (Caraballo et al., 2019; Chaix et al., 2004; van Lenthe, 2006).

Regarding influences on diet, there seems to be great heterogeneity in the variance explained by the environment. Alves and colleagues in Portugal, reported ICCs of 3.6% (men) and 6.6% (women) for fruit and vegetable consumption when individual variables and the random effect (census block) were included. These are much lower than the VPC observed ones in our study (Alves et al., 2013). However, results from the NHANES report variability across census tracts in the consumption of fruits and vegetables about 17% (Dubowitz et al., 2008) supporting our findings. Nevertheless, Giskes and colleagues, based on the Dutch study GLOBE, failed to detect any significant variability among areas of residence (defined as municipal administrative units) and various measures of an unbalanced diet (Giskes et al., 2006).

As regards to physical activity studies, Alves et al., in Portugal, reported ICCs of 4.9% and 10.1% in leisure-time physical activity for men and women, respectively, which suggests a greater variability in exercise than in fruit and vegetable consumption from the same study (Alves et al., 2013). Robinson and colleagues in the U.S. estimated that the area of residence explained 4% of the variance in the daily physical activity, but it could not be calculated for leisure-time activity specifically (Robinson et al., 2016).

Finally, concerning alcohol intake, few studies have analyzed the variance explained by the area of residence. Scribner and colleagues in the U.S. estimated that 11.5% of the variance of weekly alcohol consumption was explained by census tract (Scribner et al., 2000). Further, Fone et al. in Wales, reported a similar result with 13% (Fone et al., 2013). Both estimates are much lower than the 30% observed in our study.

On one hand, it is not that surprising for general contextual effects to vary substantially across studies since the definition of geographical context is arbitrary (Merlo et al., 2009). On the other hand, it is peculiar that only a small portion of the studies using multilevel models describe in detail the general contextual effect, given that the study of the different components of the variance may provide information of consequence for public health. Whereas estimating the VPC is the main reason for multilevel regression modelling, in reality, these models are used solely to calculate the specific contextual effects (Merlo et al., 2018). In our study, the estimation of the discriminant power of each of our models, directly related to VPC values (Merlo et al., 2019), revealed the very important role the geosocial context may play as a potential arena for new strategies for health prevention and control interventions.

The increase in discriminatory power of our models when the census tract is taking into account strongly suggests that interventions at the contextual level should be prioritized for all risk factors studied here except tobacco consumption for which the increment in AUC was very small.

The mechanisms through which the socioeconomic status of the area of residence might influence behavioral risk factors include both the social environment as well as the built environment. These two dimensions are related because, frequently, low-income neighborhoods also lack facilities and their infrastructures are in worse shape (Schüle and Bolte, 2015). However, a recent review examining physical activity environment according to area-level socio-economic position failed to find a clear pattern (Jacobs et al., 2019). In fact, many studies have found associations between neighborhood-level socioeconomic status and individual health independent from built environmental characteristics, and many others have shown associations between built environment and health independently of neighborhood socioeconomic position (Schüle and Bolte, 2015).

The specific contextual factor we examined here, the privation index, was inversely associated with tobacco consumption and directly related to unbalanced diet and leisure-time sedentarism. No association with at-risk alcohol intake was found.

The review of literature shows inconsistent results regarding these factors and measures of socioeconomic status. Most research using multilevel regression analysis observed an inverse association with smoking, i.e., the lower the status, the higher the risk of tobacco consumption (Adams et al., 2009; Caraballo et al., 2019; Diez Roux, 2003; Ecob and Macintyre, 2000; van Lenthe, 2006). However, a French study showed the opposite effect, higher probability of smoking in better off areas (Chaix et al., 2004), and another study reported no association (Boing et al., 2019).

In terms of diet, there is evidence of inequalities in access to healthy foods at the contextual level in the U.S., but those are not easily found in other industrialized countries (Black et al., 2014). Likewise, a recent review by Mackenbach and colleagues concluded that there is no clear evidence of socioeconomic differences in the association between the dietary environment and diet quality (Mackenbach et al., 2019). This inconsistency is also found in the study by Ball and colleagues covering 7 countries in which they observed that only in four of them there was an association between low neighborhood-level socioeconomic status and low fruit and vegetable consumption (Ball et al., 2015).

Concerning physical activity, a comprehensive review suggests that infrastructural improvements in the built environment increases physical activity, but that the greater benefits are reaped by higher-income groups than lower socioeconomic ones (Smith et al., 2017). In contrast, another review concludes that there might not be an association between environment socioeconomic status and physical activity levels (Schüle and Bolte, 2015). Out of the multilevel studies including contextual socioeconomic status, four of them describe a positive association, greater activity in areas of greater status (Boing et al., 2019; Boone-Heinonen et al., 2011; Robinson et al., 2016; Turrell et al., 2010) whereas two report no association (Adams et al., 2009; Alves et al., 2013).

Evidence is inconclusive when it comes to alcohol consumption. Some studies report an increase in intake in lower socioeconomic status, whereas others report the opposite (Karriker-Jaffe, 2011).

If the contextual effects of the area of residence were mediated by the index of privation, we would expect a significant reduction in the variance in models 3 vs. that of models 2. However, change in variance for all risk factors examined is very small. Thus, it is highly likely that other contextual factors not included in the model explain the general contextual effects observed in this study. These factors may include, among others, all infrastructures, assets and facilities built to offer goods and services such as accessibility of food sources, availability of different types of food outlets, density of bars and restaurants, parks, walkability components, public transportation (Black et al., 2014; Hilmers et al., 2012; Popova et al., 2009; Schüle and Bolte, 2015). Since specific and general contextual effects may differ across urban and rural areas we ran a complementary analysis (data not shown). Those results showed that the specific contextual effects were similar between urban or rural areas. In regards to the general contextual effects the ICCs were slightly higher in the rural areas except for alcohol.

Our results should be interpreted taking certain limitations into consideration. First, the cross-sectional design precludes us from establishing causal associations. Data on risk factors is self-reported and, although underreporting of behaviors as tobacco or alcohol consumption is possible, this bias is unlikely to be differential rendering our estimates conservative. Finally, the selection of census tract as the unit of contextual observation to define the area of residence was one of convenience given the sample design of the Spanish National Health Survey. In geographical research, it is well known that results may differ widely according to the configuration of the areal units used. This phenomenon, called the modifiable areal unit problem (MAUP), poses a major concern for context research (Flowerdew, 2011). The MAUP problem was initialize identified by Gehlke and Biehl in 1934 (Gehlke and Biehl, 1934) and described by Openshaw in 1983 (Openshaw, 1983). An analogous issue has been discussed in the field of social epidemiology when it comes to identify the relevant context in multilevel analyses (Larsen and Merlo, 2005; Merlo, 2011; Merlo et al., 2009). However, the census tracts are the most commonly used units of observation to learn about the effects of the physical and social environment on health (Arcaya et al., 2016), and they show a good correlation with the socioeconomic status of the area of residence when compared to other units of observation (Krieger et al., 2003; Merlo et al., 2012). When examining diet, physical activity and alcohol consumption, census tracts are probably the most appropriate units as many services (bars, restaurants, food stores, supermarkets) are geographically distributed and accessible on a census tract basis. However, in the case of tobacco, its consumption might be closer related to larger geographic units associated with policies and regulatory bodies (autonomous regions, states, country) (Diez Roux, 2001). That might very well be the reason why we failed to find an influence on smoking at the census tract level. Our investigation was limited given the only available relevant information were official data aggregated in a predetermined manner by census tracts. Thus, we encourage future research to explore how different geographic scales and zone regrouping may affect our results and conclusions. Thereby providing a more thorough understanding of how environments interact with individual characteristics to influence individual behavior. We also need to mention the complex bias of self-selection into a neighborhood. Data on changes of residence were not available but others have suggested that this type of bias may underestimate the true association with the socioeconomic status of the area of residence (James et al., 2015).

The study also has certain strengths. First, data come from a large representative sample of the population residing in Spain. Second, the multilevel analyses facilitated an integrated examination of general and specific contextual effects and the four main behavioral risk factors, which allowed for the determination of the discriminative power of the area of residence for each of the risk factors.

In sum, results from this study show that the environment exerts a differential influence on the four main risk factors related to lifestyles. The inclusion of the census tract of residence in the analyses increases substantially the discriminative power for at-risk alcohol consumption, unbalanced diet, and leisure-time sedentarism, but not for tobacco consumption. Census tracts of lower socioeconomic status present lower smoking prevalence, but higher prevalence of unbalanced diets and sedentarism, with no differences in at-risk alcohol consumption.

Further research should focus on the identification of contextual variables explaining the variability in lifestyles observed within areas of residence. Our and future results may greatly inform preventative strategies regarding these major health risk factors.

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**Table 1. Prevalence of risk factors according to sample characteristics. Population 15 years of age or older, Spain 2011-2012.**

| | N | Current or past smokers % | Unbalanced diet % | Leisure-time sedentarism % | At-risk alcohol consumption % |
|---|---|---|---|---|---|
| **Total** | 20468 | 45.2 | 72.3 | 44.7 | 5.1 |
| **Sex** | | | | | |
| Men | 9366 | 59.4 | 77.4 | 39.2 | 8.6 |
| Women | 11102 | 33.1 | 68.1 | 49.4 | 2.2 |
| **Age** | | | | | |
| 15-24 | 1607 | 32.3 | 90.0 | 35.2 | 9.8 |
| 25-34 | 2686 | 50.6 | 85.4 | 41.2 | 8.7 |
| 35-44 | 3855 | 51.9 | 79.3 | 42.7 | 5.4 |
| 45-54 | 3469 | 62.0 | 72.1 | 43.8 | 5.1 |
| 55-64 | 3100 | 50.7 | 63.5 | 41.9 | 5.1 |
| 65-74 | 2668 | 36.0 | 59.2 | 42.3 | 2.9 |
| ≥75 | 3083 | 22.1 | 63.4 | 61.3 | 1.3 |
| **Educational level** | | | | | |
| Primary or less | 5594 | 32.4 | 69.2 | 55.5 | 3.2 |
| Secondary 1st level | 6543 | 50.0 | 73.6 | 46.4 | 5.1 |
| Secondary 2nd level | 5301 | 51.6 | 75.3 | 38.7 | 6.6 |
| University | 3030 | 46.9 | 70.2 | 31.9 | 6.3 |
| **Household income** | | | | | |
| Low | 5381 | 41.1 | 75.0 | 50.6 | 3.8 |
| Medium | 5314 | 45.9 | 69.0 | 45.0 | 5.2 |
| High | 4675 | 53.1 | 70.2 | 35.2 | 7.0 |
| Not available | 5098 | 41.3 | 75.0 | 47.1 | 4.7 |
| **Municipality of residence** | | | | | |
| Urban | 15627 | 45.4 | 73.3 | 44.1 | 5.0 |
| Rural | 4841 | 44.5 | 69.3 | 46.7 | 5.7 |
| **Country of birth** | | | | | |
| Spain | 18699 | 45.6 | 71.6 | 44.4 | 5.1 |
| Other | 1769 | 40.2 | 80.6 | 48.1 | 5.1 |
| **Privation Index** | | | | | |
| Q1 least privation* | 5109 | 46.7 | 70.7 | 37.9 | 5.6 |
| Q2 | 5142 | 46.0 | 70.6 | 43.2 | 5.2 |
| Q3 | 5134 | 45.4 | 72.5 | 47.6 | 5.3 |
| Q4 greatest privation | 5083 | 42.5 | 75.5 | 50.3 | 4.5 |

*Q: Quartiles

**Table 2. Individual and Contextual factors associated with current and past tobacco consumption. Population 15 years of age and older, Spain 2011-2012.**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| ***Specific Individual Average Effects*** | | | | | | |
| **Sex** | | | | | | |
| Men | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Women | 0.36 | 0.34-0.39 | 0.35 | 0.33-0.37 | 0.35 | 0.33-0.37 |
| **Age** | | | | | | |
| 15-24 | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| 25-34 | 2.40 | 2.09-2.75 | 2.46 | 2.14-2.84 | 2.47 | 2.15-2.85 |
| 35-44 | 2.52 | 2.22-2.87 | 2.60 | 2.28-2.98 | 2.61 | 2.28-2.98 |
| 45-54 | 4.08 | 3.57-4.66 | 4.25 | 3.70-4.87 | 4.25 | 3.71-4.87 |
| 55-64 | 2.67 | 2.33-3.06 | 2.75 | 2.40-3.16 | 2.75 | 2.39-3.16 |
| 65-74 | 1.58 | 1.37-1.82 | 1.59 | 1.37-1.84 | 1.58 | 1.36-1.83 |
| ≥75 | 0.86 | 0.74-1.00 | 0.84 | 0.72-0.98 | 0.83 | 0.71-0.97 |
| **Educational level** | | | | | | |
| Primary or less | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Secondary 1st level | 1.46 | 1.34-1.59 | 1.47 | 1.34-1.61 | 1.45 | 1.33-1.59 |
| Secondary 2nd level | 1.42 | 1.29-1.57 | 1.43 | 1.29-1.58 | 1.40 | 1.26-1.55 |
| University | 1.14 | 1.01-1.27 | 1.13 | 1.00-1.27 | 1.11 | 0.98-1.25 |
| **Household income** | | | | | | |
| Low | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Medium | 1.03 | 0.94-1.12 | 1.03 | 0.94-1.12 | 1.02 | 0.93-1.11 |
| High | 1.09 | 0.99-1.19 | 1.08 | 0.98-1.18 | 1.06 | 0.96-1.17 |
| Not available | 0.84 | 0.77-0.91 | 0.84 | 0.76-0.91 | 0.83 | 0.75-0.90 |
| **Municipality of residence** | | | | | | |
| Urban | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Rural | 1.00 | 0.93-1.08 | 1.00 | 0.92-1.09 | 1.02 | 0.94-1.11 |
| **Country of birth** | | | | | | |
| Spain | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Other | 0.64 | 0.57-0.71 | 0.62 | 0.56-0.70 | 0.62 | 0.56-0.70 |
| ***Specific Contextual Average Effects*** | | | | | | |
| **Privation Index** | | | | | | |
| Q1 least privation | | | | | 1 (ref) | |
| Q2 | | | | | 0.98 | 0.89-1.08 |
| Q3 | | | | | 1.00 | 0.90-1.10 |
| Q4 greatest privation | | | | | 0.89 | 0.81-0.99 |
| ***General Contextual Effects*** | | | | | | |
| Census tract variance | | | 0.13 | 0.09-0.17 | 0.12 | 0.09-0.17 |
| PCV (%) | | | | | -7,7 | |
| VPC (%) | | | 3.7 | 2.7-5.0 | 3.7 | 2.7-5.0 |
| AUC (%) | 71.9 | 71.2-72.6 | 74.9 | 74.3-75.6 | 74.9 | 74.3-75.6 |
| AUC Change | | | 3 | | 0 | |

AUC, Area under the curve; AUC Change (model 3 vs model 1; model 4 vs model 3); PCV, proportional change of the variance (model 4 vs model 3; Q, Quartiles; VPC, Variance Partition Coefficient

**Table 3. Individual and Contextual factors associated with unbalanced diet. Population 15 years of age and older, Spain 2011-2012.**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| ***Specific Individual Average Effects*** | | | | | | |
| **Sex** | | | | | | |
| Men | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Women | 0.66 | 0.61-0.70 | 0.62 | 0.57-0.67 | 0.62 | 0.57-0.67 |
| **Age** | | | | | | |
| 15-24 | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| 25-34 | 0.70 | 0.57-0.85 | 0.65 | 0.53-0.81 | 0.65 | 0.52-0.80 |
| 35-44 | 0.45 | 0.38-0.54 | 0.40 | 0.33-0.48 | 0.40 | 0.32-0.48 |
| 45-54 | 0.29 | 0.24-0.35 | 0.24 | 0.20-0.30 | 0.24 | 0.20-0.30 |
| 55-64 | 0.19 | 0.16-0.23 | 0.14 | 0.12-0.18 | 0.14 | 0.12-0.18 |
| 65-74 | 0.15 | 0.13-0.18 | 0.12 | 0.09-0.14 | 0.12 | 0.10-0.14 |
| ≥75 | 0.17 | 0.14-0.20 | 0.13 | 0.10-0.16 | 0.13 | 0.11-0.16 |
| **Educational level** | | | | | | |
| Primary or less | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Secondary 1st level | 0.77 | 0.70-0.84 | 0.80 | 0.72-0.89 | 0.81 | 0.73-0.91 |
| Secondary 2nd level | 0.72 | 0.65-0.80 | 0.74 | 0.65-0.83 | 0.76 | 0.67-0.86 |
| University | 0.61 | 0.54-0.68 | 0.61 | 0.53-0.70 | 0.63 | 0.55-0.73 |
| **Household income** | | | | | | |
| Low | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Medium | 0.74 | 0.68-0.81 | 0.77 | 0.69-0.85 | 0.78 | 0.70-0.86 |
| High | 0.74 | 0.67-0.82 | 0.79 | 0.70-0.89 | 0.81 | 0.72-0.91 |
| Not available | 0.97 | 0.88-1.06 | 0.95 | 0.85-1.06 | 0.97 | 0.86-1.08 |
| **Municipality of residence** | | | | | | |
| Urban | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Rural | 0.80 | 0.75-0.87 | 0.81 | 0.71-0.93 | 0.76 | 0.67-0.87 |
| **Country of birth** | | | | | | |
| Spain | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Other | 1.14 | 1.00-1.30 | 1.16 | 1.00-1.34 | 1.17 | 1.01-1.35 |
| ***Specific Contextual Average Effects*** | | | | | | |
| **Privation Index** | | | | | | |
| Q1 least privation | | | | | 1 (ref) | |
| Q2 | | | | | 0.98 | 0.84-1.15 |
| Q3 | | | | | 1.11 | 0.95-1.30 |
| Q4 greatest privation | | | | | 1.35 | 1.14-1.60 |
| ***General Contextual Effects*** | | | | | | |
| Census tract variance | | | 0.91 | 0.80-1.03 | 0.90 | 0.79-1.02 |
| PCV (%) | | | | | -1 | |
| VPC (%) | | | 21.6 | 19.6-23.8 | 21.5 | 19.4-23.6 |
| AUC (%) | 68.3 | 67.5-69.0 | 82.3 | 81.7-82.9 | 82.3 | 81.7-82.9 |
| AUC Change | | | 14 | | 0 | |

AUC, Area under the curve; AUC Change (model 3 vs model 1; model 4 vs model 3); PCV, proportional change of the variance (model 4 vs model 3; Q, Quartiles; VPC, Variance Partition Coefficient

**Table 4. Individual and Contextual factors associated with leisure-time sedentarism. Population 15 years of age and older, Spain 2011-2012.**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| ***Specific Individual Average Effects*** | | | | | | |
| **Sex** | | | | | | |
| Men | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Women | 1.58 | 1.49-1.68 | 1.68 | 1.57-1.79 | 1.68 | 1.57-1.79 |
| **Age** | | | | | | |
| 15-24 | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| 25-34 | 1.46 | 1.28-1.67 | 1.47 | 1.27-1.70 | 1.46 | 1.26-1.68 |
| 35-44 | 1.62 | 1.43-1.83 | 1.69 | 1.47-1.94 | 1.68 | 1.47-1.93 |
| 45-54 | 1.62 | 1.42-1.84 | 1.69 | 1.47-1.94 | 1.69 | 1.47-1.94 |
| 55-64 | 1.40 | 1.23-1.60 | 1.47 | 1.28-1.70 | 1.47 | 1.28-1.70 |
| 65-74 | 1.32 | 1.15-1.52 | 1.41 | 1.21-1.63 | 1.42 | 1.22-1.65 |
| ≥75 | 2.59 | 2.26-2.97 | 3.00 | 2.58-3.50 | 3.04 | 2.61-3.54 |
| **Educational level** | | | | | | |
| Primary or less | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Secondary 1st level | 0.80 | 0.74-0.87 | 0.78 | 0.71-0.86 | 0.79 | 0.72-0.87 |
| Secondary 2nd level | 0.59 | 0.54-0.65 | 0.57 | 0.52-0.63 | 0.59 | 0.53-0.65 |
| University | 0.45 | 0.40-0.50 | 0.43 | 0.38-0.49 | 0.45 | 0.40-0.51 |
| **Household income** | | | | | | |
| Low | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Medium | 0.93 | 0.85-1.00 | 0.91 | 0.83-0.99 | 0.92 | 0.84-1.00 |
| High | 0.79 | 0.72-0.86 | 0.79 | 0.72-0.88 | 0.81 | 0.74-0.90 |
| Not available | 1.06 | 0.98-1.15 | 1.01 | 0.92-1.11 | 1.03 | 0.93-1.13 |
| **Municipality of residence** | | | | | | |
| Urban | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Rural | 1.00 | 0.93-1.07 | 1.01 | 0.90-1.12 | 0.95 | 0.85-1.06 |
| **Country of birth** | | | | | | |
| Spain | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Other | 1.28 | 1.16-1.42 | 1.37 | 1.22-1.53 | 1.37 | 1.22-1.53 |
| ***Specific Contextual Average Effects*** | | | | | | |
| **Privation Index** | | | | | | |
| Q1 least privation | | | | | 1 (ref) | |
| Q2 | | | | | 1.12 | 0.99-1.27 |
| Q3 | | | | | 1.27 | 1.11-1.44 |
| Q4 greatest privation | | | | | 1.31 | 1.14-1.50 |
| ***General Contextual Effects*** | | | | | | |
| Census tract variance | | | 0.56 | 0.49-0.64 | 0.55 | 0.48-0.63 |
| PCV (%) | | | | | -1.8 | |
| VPC (%) | | | 14.5 | 13.0-16.2 | 14.3 | 12.8-16.0 |
| AUC (%) | 64.1 | 63.4-64.9 | 77.2 | 76.6-77.9 | 77.2 | 76.5-77.8 |
| AUC Change | | | 13.1 | | 0 | |

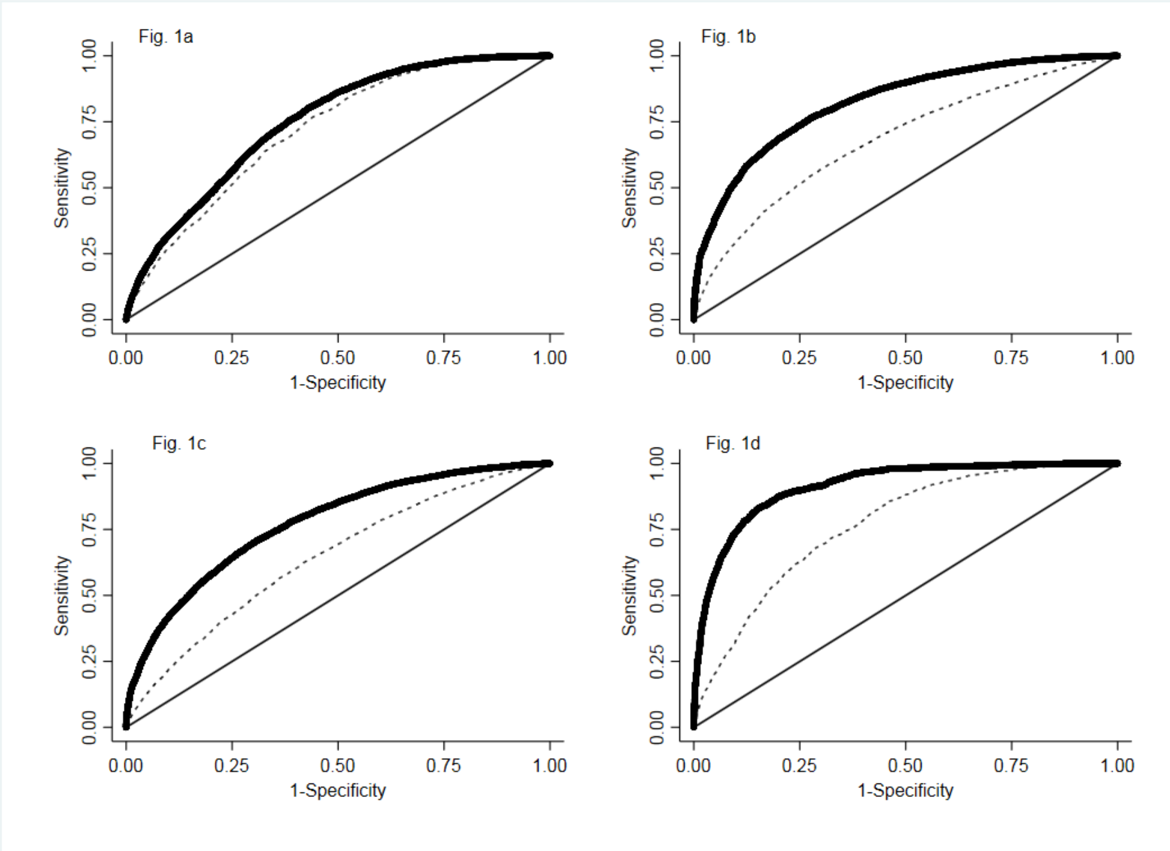
AUC, Area under the curve; AUC Change (model 3 vs model 1; model 4 vs model 3); PCV, proportional change of the variance (model 4 vs model 3; Q, Quartiles; VPC, Variance Partition Coefficient

**Table 5. Individual and Contextual factors associated with at-risk alcohol consumption. Population 15 years of age and older, Spain 2011-2012.**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| ***Specific Individual Average Effects*** | | | | | | |
| **Sex** | | | | | | |
| Men | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Women | 0.31 | 0.27-0.36 | 0.27 | 0.23-0.32 | 0.27 | 0.23-0.32 |
| **Age** | | | | | | |
| 15-24 | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| 25-34 | 0.66 | 0.53-0.83 | 0.64 | 0.49-0.82 | 0.64 | 0.50-0.82 |
| 35-44 | 0.37 | 0.30-0.47 | 0.34 | 0.26-0.44 | 0.34 | 0.26-0.44 |
| 45-54 | 0.33 | 0.26-0.42 | 0.29 | 0.22-0.38 | 0.29 | 0.22-0.38 |
| 55-64 | 0.39 | 0.30-0.50 | 0.35 | 0.26-0.45 | 0.35 | 0.26-0.45 |
| 65-74 | 0.25 | 0.19-0.34 | 0.21 | 0.15-0.29 | 0.21 | 0.15-0.29 |
| ≥75 | 0.14 | 0.10-0.20 | 0.10 | 0.07-0.16 | 0.10 | 0.07-0.16 |
| **Educational level** | | | | | | |
| Primary or less | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Secondary 1st level | 0.92 | 0.75-1.13 | 0.88 | 0.70-1.11 | 0.87 | 0.69-1.10 |
| Secondary 2nd level | 1.17 | 0.94-1.44 | 1.13 | 0.89-1.44 | 1.11 | 0.87-1.42 |
| University | 1.35 | 1.06-1.73 | 1.30 | 0.99-1.72 | 1.28 | 0.97-1.69 |
| **Household income** | | | | | | |
| Low | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Medium | 1.32 | 1.09-1.60 | 1.33 | 1.08-1.65 | 1.32 | 1.07-1.63 |
| High | 1.40 | 1.15-1.71 | 1.39 | 1.11-1.74 | 1.37 | 1.09-1.71 |
| Not available | 1.10 | 0.90-1.35 | 1.10 | 0.88-1.38 | 1.09 | 0.87-1.37 |
| **Municipality of residence** | | | | | | |
| Urban | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Rural | 1.27 | 1.09-1.47 | 1.30 | 1.05-1.62 | 1.34 | 1.07-1.67 |
| **Country of birth** | | | | | | |
| Spain | 1 (ref) | | 1 (ref) | | 1 (ref) | |
| Other | 0.88 | 0.70-1.11 | 0.82 | 0.64-1.07 | 0.82 | 0.63-1.06 |
| ***Specific Contextual Average Effects*** | | | | | | |
| **Privation Index** | | | | | | |
| Q1 least privation | | | | | 1 (ref) | |
| Q2 | | | | | 0.99 | 0.76-1.28 |
| Q3 | | | | | 0.99 | 0.76-1.29 |
| Q4 greatest privation | | | | | 0.88 | 0.66-1.16 |
| ***General Contextual Effects*** | | | | | | |
| Census tract variance | | | 1.41 | 1.15-1.74 | 1.41 | 1.14-1.74 |
| PCV (%) | | | | | 0 | |
| VPC (%) | | | 30.0 | 25.8-34.6 | 30.0 | 25.8-34.5 |
| AUC (%) | 76.8 | 75.5-78.1 | 91.3 | 90.5-92.2 | 91.3 | 90.5-92.1 |
| AUC Change | | | 14.5 | | 0 | |

AUC, Area under the curve; AUC Change (model 3 vs model 1; model 4 vs model 3); PCV, proportional change of the variance (model 4 vs model 3; Q, Quartiles; VPC, Variance Partition Coefficient

Figure 1. Area Under the Curve (AUC) for: 1a. Tobacco consumption; 1b. Unbalanced diet; 1c. Leisure-time sedentarism; 1d. At-risk alcohol consumption. Population 15 years of age and older, Spain 2011-2012.




-------- Model 1 adjusted only for individual-level variables

▬ Model 2 with additional adjustment for census tract of residence