

## **Covid-19 restrictions**

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# Covid-19 restrictions: An opportunity to highlight the effect of neighbourhood deprivation on individuals' health-related behaviours

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## ABSTRACT

**Rationale:** Neighbourhood socio-economic deprivation is strongly related to health-risk behaviours, which are predictors of overall health and mortality. During the Covid-19 pandemic, individuals have been forced to spend more time within their residential areas, which might have had an effect on health-risk behaviours.

**Objective:** We assess the consequences of living in a more or less deprived neighbourhood during the pandemic on individual behavioural changes in four health-related outcomes: smoking, drinking, physical activity and healthy eating. We hypothesise that the pandemic and related lock-downs had negative effects on health-related behaviours, but that this negative effect had been stronger for people living in more deprived areas. We additionally explore sex and ethnicity as sources of heterogeneity in these effects.

**Methods:** We use data from four nationally representative cohort studies in England. We perform longitudinal individual and neighbourhood fixed effects estimations focusing on comparing the pre-pandemic period with the first lockdown (May 2020) period and up to one year after the outbreak of the pandemic (March 2021).

**Results:** During the first lockdown, as compared to pre-pandemic levels, on average, people smoked more, drank more and did more physical activity. However, compared to people in less deprived neighbourhoods, people living in more deprived areas showed a smaller increase in their levels of physical activity, consumed less fruit and vegetables and increased the number of cigarettes smoked. We additionally find that the combined effect of Covid-19 and area deprivation varies significantly by both sex and ethnicity.

**Conclusion:** Results add to evidence on the impact of the Covid-19 pandemic and associated lockdowns on health-risk behaviours, highlighting the relative contribution of the neighbourhood environment and individual characteristics. We argue that reducing levels of neighbourhood deprivation may contribute to positively influence behaviours, especially for some sub-groups of the population, leading to a reduction of social inequalities in health.

## 1. Introduction

Social inequalities in health have increased in recent decades, with the Covid-19 pandemic further accelerating this trend (Mackenbach et al., 2018; Bambra et al., 2020). Studies increasingly emphasise the importance of modifiable health-risk behaviours such as drinking, smoking, diet habits or physical exercising, for the understanding of health outcomes (Marteau et al., 2021). Reducing social inequalities related to these behaviours has therefore become an important concern

in public health (Marteau et al., 2021).

It is widely accepted that neighbourhood deprivation contributes to the socio-economic gradient in health-risk behaviours and, by consequence, overall health and mortality (Diez Roux and Mair, 2010). In England, a recent review has highlighted how the gap in life expectancy at birth between those living in the least and most deprived areas significantly increased between 2010 and 2018 (Marmot, 2020). The outbreak of Covid-19 has made even more salient the need to focus on the relationship between the neighbourhood environment and

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health-risk behaviours. On the one hand, rare and extreme events such as the Covid-19 pandemic can be viewed as a major disruptor, affecting key health behaviours associated with longer-term health outcomes for populations (Mazidii et al., 2021). On the other hand, the pandemic represents a unique form of natural experiment which allows the identification of causal effects on health behaviour outcomes (Bonomi Bezzo et al., 2021; Campbell et al., 2021). The enforced lockdowns can be seen as an exogenous shock, which provides researchers with the opportunity to understand the role of the residential area on the unfolding of health behaviours more in detail. The lockdowns have forced people to spend more time within the boundaries of their neighbourhoods, thus potentially increasing the negative effects of living in the most deprived areas.

Previous work in the UK has explored the consequences of the pandemic on individual changes in health-risk behaviours (see for example Bann et al., 2021; Villadsen et al., 2021; Niedzwiedz et al., 2021; McBride et al., 2021). Authors have also assessed, although marginally and with inconsistent findings, the extent to which the level of deprivation of the residential area has had an influence on these changes (Naughton et al., 2021; McCarthy et al., 2021). In this paper, we build upon this literature by making three main contributions.

First, we provide a comprehensive analysis on how neighbourhood socio-economic deprivation influences the unfolding of health-risk behaviours. Previous works have mostly leveraged data from non-representative or convenience samples, gathered for example from the daily use of smartphone apps (Mazidii et al., 2021; McCarthy et al., 2021) or specific target populations (Naughton et al., 2021; Quirk et al., 2022), which may raise concerns related to selection and generalisability. In contrast, we leverage unique information from four British representative cohorts and adopt a longitudinal individual and neighbourhood fixed effects approach to provide robust findings.

Second, we investigate both the short and the long-term effects of the neighbourhood and Covid-19 on health-risk behaviours. Similar to previous work, we focus on effects of the first lockdown, which took place in May 2020, and compare it to pre-pandemic periods. We additionally test whether our findings change when considering a longer time span up to March 2021, a period that includes the release of lockdown restrictions and then a further, although more relaxed, period of restrictions.

Finally, the pandemic has likely not affected all individuals in the same way. Thus, we focus on within-individual changes and investigate sex and ethnicity as sources of heterogeneity. We investigate which individuals living in less or more deprived areas have had more or less severe consequences in terms of health-risk behaviours.

## 2. Background

### 2.1. Social inequalities in health-risk behaviours

Health-risk behaviours can be defined as those behaviours or actions that a) influence individual health in the short or long term and b) that also include a component of risk, meaning that they are proven to be associated with increased susceptibility to a specific disease or ill-health (Andersen, 2013). Typically, this category thus includes alcohol, tobacco and substance use, dietary choices, and a lack of physical activity (Algren et al., 2015). It is well documented that health-risk behaviours are important predictors of overall health (Marteau et al., 2021). They have been associated with severe consequences in health and mortality and, thus, they contribute to widen existing inequalities in health (Marmot, 2020). For example, according to Khaw et al. (2008), individuals who engage in four healthy behaviours (fruit and vegetable intake of at least five servings per day, non-smoking, moderate alcohol intake (1–14 units per week), and physically active) have a life expectancy that is, on average, 14 years longer than that of individuals who do not engage in any of these healthy behaviours.

Health-risk behaviours also represent one of the main channels through which socio-economic status (SES) inequalities influence

overall health outcomes (Glymour et al., 2014; Petrovic et al., 2018). Research has repeatedly highlighted the existence of a strong socio-economic gradient, for which individuals with lower SES are more likely to display health-risk behaviours than individuals with higher SES (Lynch et al., 1997; Adler et al., 1994).

### 2.2. Neighbourhood deprivation and health-related behaviours

Among the predictors of health-risk behaviours, neighbourhood SES has attracted increasing interest among scholars (Diez Roux and Mair, 2010; Ribeiro, 2018). As these behaviours tend to cluster in lower socioeconomic groups, their main underlying determinants are most likely to be found among factors to which socioeconomic groups are differentially exposed, such as living in deprived neighbourhoods (Algren, 2017). Various studies have confirmed that health-risk behaviours are more prevalent among residents of deprived neighbourhoods than among those of non-deprived neighbourhoods, net of individual level sociodemographic and socioeconomic characteristics (Algren et al., 2015). In general, a higher level of area deprivation has been associated with less physical activity (Riva et al., 2007; Algren et al., 2015), and with more unhealthy dietary habits (Riva et al., 2007; Lakshman et al., 2011). Living in low-SES areas has also been associated with a higher likelihood of smoking (Lakshman et al., 2011; Algren et al., 2015; Morris et al., 2018; Pan et al., 2022). Finally, evidence on the relationship between the neighbourhood context and drinking behaviour is inconclusive, mostly depending on the type of behaviour being observed. Living in more deprived areas is normally associated with a lower likelihood of drinking, but a higher likelihood to engage in heavy episodic drinking (Jefferis et al., 2007; Fone et al., 2013; Ng Fat et al., 2017).

Underpinning the different explanations of the mechanisms through which the neighbourhood environment might affect health-risk behaviour, two main approaches have been proposed; a functionalist (Goldberg, 2012) and a sociological cultural explanation (Bourdieu, 1984). The former emphasises the different material conditions experienced by low-SES individuals as compared to high-SES ones, stressing that individuals with fewer “resources” are less “able” of achieving good socio-economic levels and, by consequence, also display less “self-control” and “ability” to understand the benefits/risks of behaviours. The latter instead posits that health-risk behaviours represent tools for the identification and belonging to social groups, thus are perpetuated by individuals in different socio-economic conditions due to their symbolic and cultural meaning.

Authors have similarly emphasised that neighbourhoods might exert an influence via their physical or social characteristics (Macintyre et al., 1993; Pickett and Pearl, 2001; Kawachi and Berkman, 2003; Diez Roux and Mair, 2010). On the one hand, the physical neighbourhood environment can affect health behaviour through environmental exposures, food and recreational resources, the built environment, aesthetic quality/natural spaces, services and quality of housing (Kärmeniemi et al., 2018). On the other hand, the neighbourhood environment can affect residents’ health through factors related to safety/violence, social connections/cohesion, local institutions and norms. A key mechanism linking poor physical and social neighbourhood conditions with health related behaviours is stress. Stress theory emphasises how characteristics of more deprived areas, such as poor housing conditions, perceived unsafety, lack of public services and of social support, can trigger feelings of stress (Steptoe and Feldman, 2001). Authors have found indeed that individuals living in deprived areas are at higher risk of perceiving stress compared to residents of non-deprived ones (Pickett and Pearl, 2001; Algren et al., 2018). Stress is in turn associated with worse health-related behaviours, since individuals tend to cope with stress by engaging in riskier behaviours, such as eating high-fat foods, drinking alcohol or smoking more, and reducing the time they dedicate to physical activity (Algren et al., 2018; Ng and Jeffery, 2003).

The outbreak of the Covid-19 pandemic has provided a new context to investigate the role of the residential area on promoting or hindering

health-risk behaviours. Lockdown measures imposed in the United Kingdom and many countries worldwide, enforced significant changes and constraints on daily living, which are likely to have driven behavioural change. Previous research has investigated the extent to which the rise of Covid-19 has affected individual mental health and well-being (Bonomi Bezzo et al., 2021; Akinin et al., 2022; Pierce et al., 2021; Manchia et al., 2022; McPherson et al., 2021) as well as health-related behaviours (Wilson et al., 2022; McBride et al., 2021; Bann et al., 2021; Villadsen et al., 2021; McCarthy et al., 2021; Mazidii et al., 2021; Bell et al., 2021; Garnett et al., 2021). In the UK, most papers do not use nationally representative samples and instead recruit participants via snowballing techniques, targeted recruitment, advertising on social media or media outlets, although some exceptions exist (Bann et al., 2021; Niedzwiedz et al., 2021). Detailed information on sampling strategies adopted by empirical studies a) based in the UK and b) focused on health-related behaviour is presented in Table A1 of the Appendix. Overall, across pre-lockdown and first lockdown period, Bann et al. (2021) find that the pandemic has amplified existing behavioural gaps, further enlarging the difference between individuals reporting high and low sleep, physical exercise, and alcohol consumption. In other words, those who used to drink more, ended up drinking even more and those who used to drink less ended up drinking even less (i.e. Bann et al., 2021; Niedzwiedz et al., 2021). Covid-19 has also been shown to have led to eating less healthy than usual (McAtamney et al., 2021; Herle et al., 2021). A study by Naughton et al. (2021) indicates that people have consumed on average one portion of fruit and vegetables less per day than before the pandemic. Overall, the majority of studies in the UK also found support for a reduction in physical activity during the Covid-19 pandemic (Rogers et al., 2020; Niedzwiedz et al., 2021; Stockwell et al., 2021; Naughton et al., 2021; Strain et al., 2022), although one survey found that 57% of people had either maintained or increased their levels of physical activity during the lockdowns (Spence et al., 2021). Concerning alcohol consumption and smoking behaviour, the pandemic has been associated with an increase in adverse alcohol use (Niedzwiedz et al., 2021; Naughton et al., 2021; Duffy, 2020) and, on the contrary, a null effect (Naughton et al., 2021) or a decrease in smoking (Niedzwiedz et al., 2021). For the latter, a possible explanation is that, being the Covid-19 a respiratory disease, since the very beginning of the pandemic it became evident that smokers were more likely to end up in intensive care.

The few studies that investigate the effects of Covid-19 on health behaviour in the UK, and include information on neighbourhood SES, provide inconsistent results and have mostly focused on physical activity. Considering a variety of health-risk behaviours, Mazidii et al. (2021) build a composite indicator of behaviour disruption (that includes information on diet, alcohol use frequency, physical activity and sleep duration) and find that living in a socioeconomically deprived area predicts a greater disruption of individuals' routine health-risk behaviours as compared to living in a less deprived one. Naughton et al. (2021) compare baseline values with daily self-reported measures of health behaviours across 30 days of April 2020. They find that the level of deprivation of the residential area is associated with a higher number of cigarettes smoked per day and with reduced physical activity, but not with changes in alcohol consumption or dietary choices. Quirk et al. (2022) also find that individuals living in low-SES areas reduced their physical activity much more compared to individuals in high-SES areas. However, McCarthy et al. (2021) and Strain et al. (2022), who focus specifically on physical activity, find no association between the deprivation of the residential area and changes in behaviour across the lockdowns.

### 2.3. Previous evidence on heterogeneous effects by sex and ethnicity

There is no robust evidence on the extent to which living in a more or less deprived area throughout the unfolding of the pandemic has differently affected health-related behaviours depending on sex or

ethnicity. Nonetheless, there is no doubt that certain groups have been more strongly impacted by the stress imposed by Covid-19 as well as the policy measures. In the US, women have been found to suffer more than men have from Covid-19-related economic downturn (Alon et al., 2020) and in the UK authors have emphasised how women have been more vulnerable than men to poorer mental health as a consequence of Covid-19-related stressors (Dal Santo et al., 2022; Pierce et al., 2021). Research in the UK has highlighted that females have experienced a greater disruption in terms of health-related behaviours than males (Mazidii et al., 2021), although estimates on the effect differ depending on the studies and on the outcome. Many studies over time have depicted a great cultural variance in patterns of alcohol use among men and women (Hemstrom et al., 2002; Holmila and Raitasalo, 2005). Gender differences in drinking behaviour continue to be considerable and social studies have suggested that men's drinking control is more externalized than women's, making the former more prone to binge-drinking in situations in which the external control is looser than usual or when a situation is defined as 'time out' and, therefore, outside normal controls (Alasuutari, 1990). Naughton et al. (2021) find that being female is independently associated with a decline in diet quality and an increase in alcohol consumption, but that sex has no significant relationship with changes in physical activity or smoking behaviour. However, McCarthy et al. (2021) and Quirk et al. (2022) both find that being female significantly predicts Covid-19 induced reduction in physical activity. But Bann et al. (2021) then find that more women than men report increased exercise levels during the lockdown compared with before. Furthermore, they also found that women had a lower alcohol consumption and higher fruit and vegetable intake than men, with the gap slightly narrowing during the pandemic as compared to before. Robinson et al. (2021) also find support for a higher diet quality during lockdown for females as compared to males.

Ethnic minorities have also been amongst the most severely affected by the pandemic (Katikireddi et al., 2021). Ethnic minority individuals are often concentrated in low-SES and deprived neighbourhoods, and previous research has highlighted how neighbourhood disadvantage has contributed to increase the rate of infection and mortality rates during the health crisis for this group (Razieh et al., 2021). Concerning health-related behaviours, after the outbreak of Covid-19, ethnic minorities reported lower exercise levels (Bann et al., 2021; Robinson et al., 2021) and no change in (Herle et al., 2021) or healthier eating habits (Robinson et al., 2021; Bell et al., 2021; Bann et al., 2021). In contrast, authors have emphasised that, as compared to main category of white individuals, ethnic minorities reported lower alcohol consumption (Bann et al., 2021; Niedzwiedz et al., 2021). This is coherent with research that shows how there is a specific value linked to the culture of drinking being commonly associated with the "British pride" since the industrial revolution (Jayne et al., 2008; Hemstrom et al., 2002; Fletcher and Karl Spracklen, 2014). In recent years in particular, dynamics of 'drinkainment' (Bell, 2005) have further escalated to become one of the cornerstones of urban regeneration attempts, by increasingly highlighting the economic relevance of night life (Chatterton and Hollands, 2003). Previous research has found a gradient between white and non-white British in more deprived neighbourhoods because of the higher salience of cultural differences caused by higher ethnic segregation in these areas (Demireva and Heath, 2014), lower integration in the British culture, and a stronger, defensive, embracement of the British "pride of drinking" by white-British residents (Mutz, 2018).

Building on the above literature review, we have formulated two research questions: Did experiences of neighbourhood deprivation during the lockdown period influence health-related behaviours? And if any effect could be detected, did it differ by sex and/or ethnicity? We hypothesise that the Covid-19 pandemic had negative effects on health related behaviours but that this negative effect has been stronger for people living in more deprived areas, with even more severe effects for females and people belonging to ethnic minorities.

### 3. Data and methods

In order to answer the two research questions, we use longitudinal data from four British national cohort studies, including people born respectively in 1958, 1970, 1989 and 2000. The National Child Development Study (NCDS) is the oldest cohort, following the lives of an initial 17,415 people born in 1958 (Power and Elliott, 2006). The 1970 British Cohort Study (BCS70) is based on initially 17,196 cohort members born in 1970 (Elliott and Shepherd, 2006). The Next Steps cohort is born in 1989 starting with 15,770 cohort members (Calderwood et al., 2016). Finally, the youngest cohort, the Millennium Cohort Study (MCS), began with an original sample of 18,818 born in 2001 (Joshi and Fitzsimons, 2016). We use data from the special Covid-19 survey, available from the UK Data Service. We combine this data with demographic information gathered in the main surveys in previous years. The Covid-19 study consists in three waves of study and all cohort members for whom an email address was held were selected for issue, provided that they a) had not permanently withdrawn from the study b) were not ‘permanently untraced’ and c) were not known to have died (University College London, 2021). The survey for Wave 1 was carried out at the height of first lockdown restrictions in May 2020 and focused mainly on how participants’ lives had changed from just before the outbreak of the pandemic in March 2020 until then. Wave 2 was conducted in September/October 2020 and focused on the period between the easing of restrictions in June through the summer into the autumn. Wave 3 took place in February/March 2021, during the third UK lockdown. Number respondents amounted to respectively  $N = 16,784$ ,  $N = 24,247$  and  $N = 26,531$  in each wave. Wave 1 and Wave 2 were conducted purely online while in Wave 3 participants were initially invited to take part online but a subset of web-survey non-respondents were followed up and invited to take part via telephone. Retrospective information was collected, for each relevant variable, during the wave in which the participant first entered the survey. We use this data to build a pre-Covid wave, defined as Wave 0.

#### 3.1. Sample selection

Overall, 34,218 individuals participated in at least one of the three waves across the whole UK. We restrict our analysis to England because this is the only country for which neighbourhood deprivation information are homogeneously available for all cohorts, reducing the sample to 25,541 observations. We additionally exclude individuals with missing neighbourhood information and with a non-missing value in our outcomes of interest, which brings the sample to 19,925. Finally, in order to focus on the effect of prolonged exposure to the neighbourhood, we only included those who have remained in the same neighbourhood in the observed period across the pandemic, i.e. from before the outbreak of the pandemic up to March 2021. After this restriction, we are left with 18,577 individual observations, which become 18,438 when we remove those who a non-positive sampling and attrition weight. It is important to note that the majority of individuals lost in applying the residential mobility restriction belong to the MCS cohort (21%), while the other samples remain rather stable (between 4 and 10%).

Table 1 below shows the percentage for each cohort.

**Table 1**  
Sample descriptive statistics.

Cohort	Freq.	Percent
NCDS (age 64)	5599	32.34
BCS70 (age 52)	5235	29.93
Next Steps (age 32)	4076	22.38
MCS (age 22)	3528	15.36
Total	18,438	100

Notes: author’s own calculations based on CLS Covid-19 survey.

#### 3.2. Dependent variables

The survey includes repeated information on four aspects of health behaviour: *smoking* (count, number of cigarettes smoked per day, 0–99); *drinking* (count, times per month, 0, 1, 3, 10, 16); *healthy eating* (count, number of portions of fresh fruits and vegetables per day, 0–150); *physical activity* (count, number of days in a week did 30 min exercise in the previous month, 1–7). Fig. 1 below shows the variation in the mean value of each outcome across the periods of interest. To be more precise, two further clarifications are needed: i) smoking varies little across the observation period (particularly with few people who either start or quit) leading to much smaller sample sizes in the longitudinal models; ii) drinking is not strictly speaking a count variable, for homogeneity we have considered it as count. We have tried an alternative specification considering it as a discrete variable and the results do not change. On a theoretical level we acknowledge that our drinking variable only measures the monthly frequency of drinking and not the amount. This is naturally important in terms of interpretation of the results since it has been shown that people from low social class and/or living in more deprived areas have a lower likelihood of drinking, but a higher likelihood to binge drinking (Fone et al., 2013).

We observe a similar trend in drinking and physical activity, where we observe a peak during the first, stricter, lockdown, followed by a significant decline and a slower increase. Smoking does not significantly vary between the pre-pandemic wave and March 2020, while it increases over the summer and decreases in winter (March 2021) reaching to even lower values than before the outbreak of Covid. We observe an overall gradual increase in the mean value of healthy eating over time.

#### 3.3. Independent variable

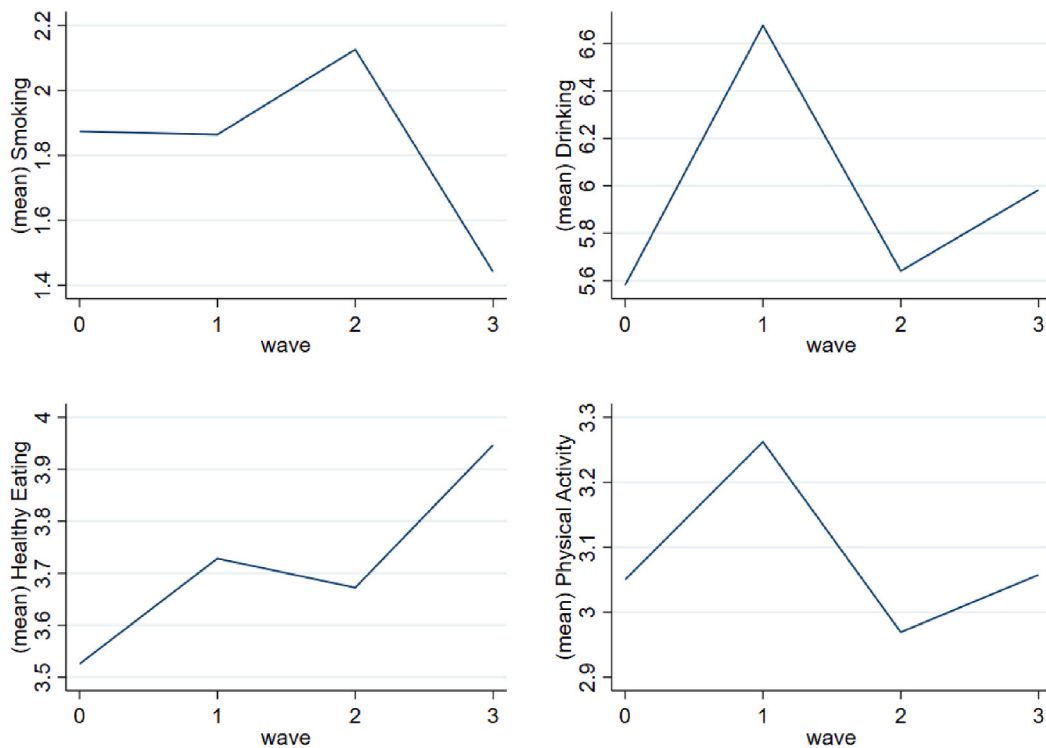
To measure the degree of deprivation of the neighbourhood our respondents live in, we use the 2019 Index of Multiple Deprivation (IMD) released by the Office for National Statistics (ONS) at Lower Layer Super Output Area (LSOA) level. LSOAs are very granular, in fact each of them contains between 1000 and 3000 people.

The IMD is a weighted average of nine domains (Income, Employment, Education Skills and Training, Health and Disability, Crime, Barriers to Housing and Services, Living Environment) and allow us to better capture the multi faced nature of deprivation experienced by the individuals in their local area of residence. We prefer the use of the IMD to alternative measures like, for instance, the Townsend index, which incorporates four variables, three of which are also included in the IMD (unemployment, non-home ownership, and household overcrowding), and the fourth of which no longer seems relevant to contemporary measures of deprivation (non-car ownership). The multidimensional nature of the IMD and its frequent updating render it very suitable to capture the multiple sources of deprivation at the neighbourhood level. While it is true that the Townsend index is still the most homogenous index for analysis the whole of the UK, we think that, while focusing on England alone, the IMD is a preferable measure.

The higher the IMD score, the more deprived is the area. To reduce the risk of disclosure, in agreement with the data provider, all England scores were rounded to 0 decimal places. We standardize the value on our final sample to ease the interpretation. Fig. 2 stratifies changes in the four outcome variables by IMD quintile, depicting the trend for the least and most deprived quintile. While we observe overall similar trends in drinking and healthy eating, differential patterns emerge for smoking and physical activity.

#### 3.4. Moderators

Self-reported biological sex (male or female) and ethnicity (white or non-white). In some specifications, we have also tried to further disentangle the non-white category into Indian, Bangladeshi & Pakistani, Black, Black British, Caribbean or African, Other & mixed. However, due



Notes: author's own calculations based on CLS Covid-19 survey.

Fig. 1. Mean value in the four dependent variables across pre-Covid and post-Covid waves. Notes: author's own calculations based on CLS Covid-19 survey.

to the very limited group size, no significant results emerge.

### 3.5. Control variables

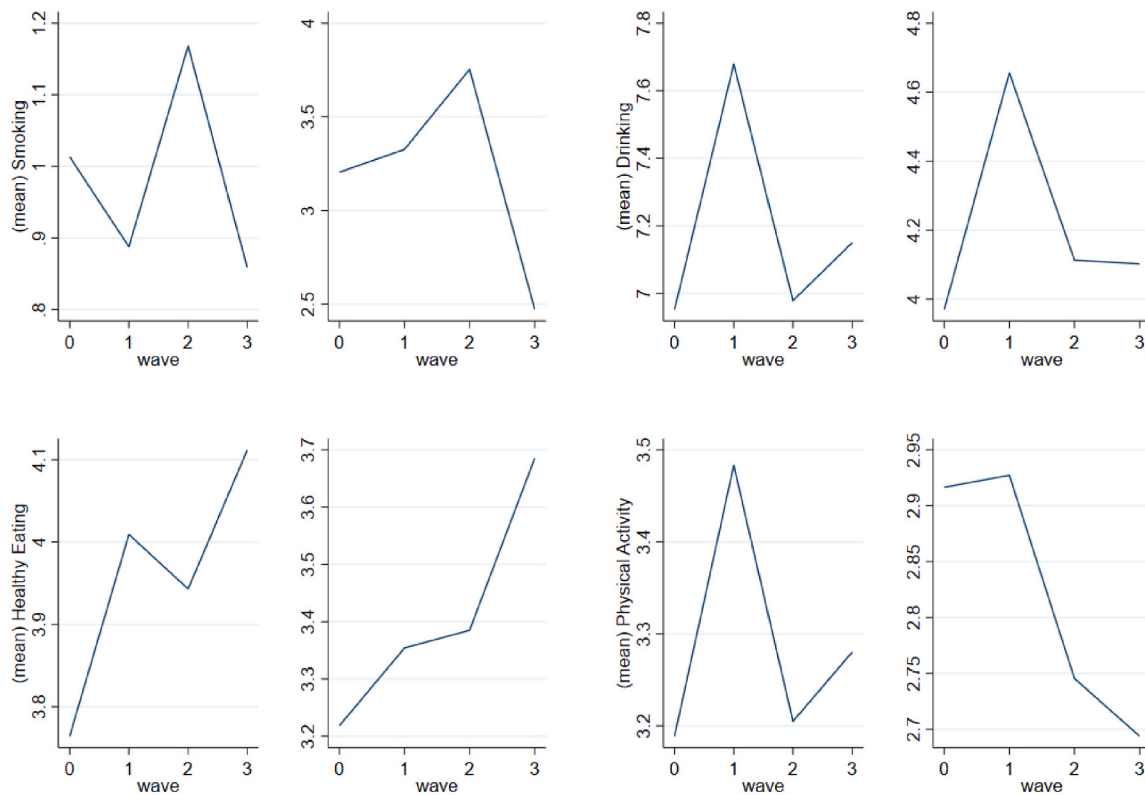
Cohort (i.e. age), health conditions (good or excellent [reference category], fair, poor), educational attainment (no academic qualification [RC], secondary vocational, secondary non-vocational, degree/higher), employment status (working [RC], not working (including furlough), unemployed, in education, other); living with a partner (no, yes [RC]), number of children living in the household (0–10), housing tenure (own [RC], rent, rent free, squatting and other), combined household social class (Higher managerial, administrative and professional occupations [RC], Intermediate occupations, Small employers and own account workers, Lower supervisory and technical occupations, Semi-routine and routine occupations), subjective financial assessment (Living comfortably [RC], doing all right, just about getting by, finding it quite difficult). In the longitudinal analysis reported in the main text, time invariant controls are dropped (Table A2 in Supplementary Material includes descriptive statistics for the sample, depending on the outcome and the reference time-frame, short vs. long-term).

### 3.6. Empirical framework

The empirical analysis is structured around three periods, baseline (wave 0), first lockdown period (wave 1), full Covid period (waves 1 to 3). We perform, first, a) 12 (wave 0, wave 1 and wave 3, for each of the four dependent variables) cross-sectional models in which we look at how correlations change over time. Results for the cross-sectional models are presented in the Supplementary Material, Tables A3-A6. Next, we investigate the short-term effects between wave 0 and wave 1 and the long-term effect between wave 0 and the average over the three Covid waves. We thus estimate: b) four short-term longitudinal fixed-effect models (one for each outcome); c) four short-term longitudinal fixed-effect models that test any additional heterogeneity driven by

individual sex; d) four short-term longitudinal fixed-effect models that test any additional heterogeneity driven by individual ethnicity; d) four long-term longitudinal fixed effect models; e) four long-term longitudinal fixed effect models testing heterogeneity by sex; and f) four long-term longitudinal fixed effect models testing heterogeneity by ethnicity. In the longitudinal analyses, the main variables of interest are the interaction term between the Covid-19 dummy and the standardised (mean 0 and standard deviation 1) IMD and, in models c-d and e-f, the triple interaction between the Covid-19 dummy, the standardised IMD, and the moderator.

Given the skewed distribution of our variables, with a natural large proportion of zeros, we use Poisson models, and, in the longitudinal specifications, we adopt individual and neighbourhood fixed effects models. The main advantage of using fixed-effect models is that it removes the potential unobserved confounding effects at the higher level of the analysis where individuals may be nested. This feature of fixed-effect modelling increases the reliability of causal interpretation which would be otherwise tempered down when using other approaches which would necessitate to assume, for example, that people are randomly allocated to neighbourhoods (Wooldridge, 2021). To account for the fact that individuals living in the same area may be not independent observations, i.e. the error terms may be correlated, we cluster the standard errors at the neighbourhood level (LSOA). Instead of clustering at the individual level we cluster at the neighbourhood level, because as we identify the neighbourhood at LSOA level, we want to avoid within-cluster correlation biases at the treatment level (Cameron & Miller, 2014). The data owner released study specific PSU, stratum and design weight to account for the difference structure of each cohort study. For our analysis we derive a crude non-response weight by taking the mean, within each individual, of the COVID-19 Survey non-response weight (COMBWT), which already incorporates the sample design structure. To be sure that our use of the weights did not bias our results, we also run the models, separately for each cohort, with the STATA svy command to also consider the different PSU and stratum. Results do not



or each outcome, the graph on the left represents the "Least Deprived Neighbourhood Quintile", while the graph on the right the "Most Deprived Neighbourhood Quintile"

Notes: author's own calculations based on CLS Covid-19 survey.

Fig. 2. Mean value in the four dependent variables across pre-Covid and post-Covid waves, for the least (left graph) and most (right graph) deprived quintile of IMD. Notes: author's own calculations based on CLS Covid-19 survey.

change. However, since we are not specifically interested in analysing the different cohorts separately, once reassured about the use of the crude weight, we pool the cohorts together instead of running a meta-analysis for neater results.

#### 4. Results

The first observation regarding the regression results is that all models have a high Pseudo R-square; especially the models with Smoking and Drinking as dependent variables explain more than 50% of the total variance with no models below 20%. Table 2 reports the effects of neighbourhood deprivation during the first lockdown on the four behavioural outcome variables. Full results, including estimates on control variables, are available in Supplementary Material, table A7.

We can see that the first lockdown, on average, has induced people to smoke more, drink more and do more physical activity. However, those living in more deprived areas have been more negatively affected by the pandemic concerning healthy eating, physical activity and smoking (although only at 10% significance level). Living in a one standard deviation more deprived neighbourhood during the first lockdown has led to a decrease of 1.5% in physical activity and in eating about 1% less portions of fruit and vegetables than people in less deprived areas (with a deprivation scale ranging from -1.27 to 5.62, suggesting that the difference between two people living in the most and least deprived neighbourhood is respectively 9% and 7%). Statistics from the full table A7 in the Supplementary Material additionally show some additional interesting patterns on individual time-varying socio-economic characteristics such as employment and income. As compared to employed individuals, students tend to drink more and eat less healthy. Furthermore, as compared to the group of individuals who find their financial

Table 2 Short-term effect of Covid-19 and neighbourhood deprivation.

VARIABLES	(1)	(2)	(3)	(4)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown
Covid-19	0.091*** (0.022)	0.116*** (0.011)	0.007 (0.006)	0.047*** (0.014)
Covid-19*Nhb Deprivation	0.024+ (0.013)	0.012 (0.011)	-0.015* (0.006)	-0.033** (0.012)
Constant	2.504*** (0.135)	2.272*** (0.045)	1.419*** (0.027)	1.312*** (0.066)
Individual observations	959	7757	8833	7881
Observations	1918	15,514	17,666	15,762
Pseudo R <sup>2</sup>	0.55	0.51	0.24	0.22

Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.

situation difficult, individuals who are more financially secure tend overall to eat more fruit and vegetable (although the significance level is only 10%).

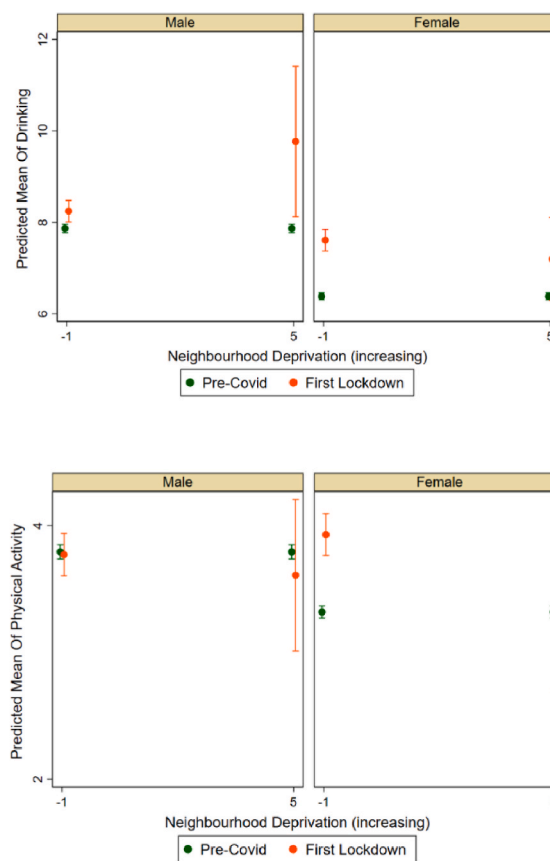
When we look at whether the effect of neighbourhood deprivation differs by sex (Table 3 and Fig. 3) and ethnicity (Table 4 and Fig. 4) we find that it actually does.

Females living in more deprived neighbourhoods do even less physical activity (-5.5%) than males living in deprived areas, but they

**Table 3**  
Short-term effect of Covid-19 and neighbourhood deprivation, interacted by sex.

VARIABLES	(1)	(2)	(3)	(4)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown
Covid-19	0.060* (0.026)	0.075*** (0.014)	0.015* (0.007)	-0.013 (0.017)
Covid-19*Nhb Deprivation	0.020 (0.016)	0.028+ (0.016)	-0.018* (0.009)	-0.007 (0.017)
Covid-19*Female*Deprivation	0.009 (0.026)	-0.038+ (0.020)	0.005 (0.013)	-0.055* (0.025)
Constant	2.500*** (0.143)	2.264*** (0.045)	1.419*** (0.027)	1.306*** (0.064)
Individual observations	959	7757	8833	7881
Observations	1918	15,514	17,666	15,762
Pseudo R <sup>2</sup>	0.55	0.51	0.25	0.22

Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.



Notes: author’s own calculations based on CLS Covid-19 survey, representing interactions from models reported in Table 3

**Fig. 3.** Short-term effect of Covid-19 and neighbourhood deprivation, by sex. Notes: author’s own calculations based on CLS Covid-19 survey, representing interactions from models reported in Table 3.

also consume fewer alcoholic drinks (-3.8%). Regarding drinking alcohol, we find that when we introduce an interaction with ethnicity, white residents are more negatively affected by spending the lockdown in more deprived neighbourhoods, drinking and smoking, respectively 10% and 7%, more than people who belong to ethnic minorities living in more deprived neighbourhoods.

Moving to the long-term effects, first we can see that the Covid-19 pandemic has had a long-lasting overall negative effect on smoking

and drinking but also a positive effect on healthy eating and physical activity. However, although the neighbourhood deprivation gradients in the long-term seem reduced, still, after the pandemic, those living in a more deprived neighbourhood, tend to do 2.8% less physical activity than people living in a one standard deviation more advantaged areas (Table 5) which translates to a difference between those living in the most and least deprived neighbourhood of 18%. Table A8 in Supplementary Material provides full results.



**Table 4**  
Short-term effect of Covid-19 and neighbourhood deprivation, interacted by ethnic background.

VARIABLES	(1)	(2)	(3)	(4)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown	Pre and First Lockdown
Covid-19	0.086*** (0.023)	0.116*** (0.011)	0.009 (0.006)	0.049*** (0.014)
Covid-19*Nhb Deprivation	0.027* (0.071)	0.015 (0.083)	-0.014* (0.029)	-0.030* (0.063)
Covid-19*Ethnic Minority*Nhb Deprivation	-0.075* (0.035)	-0.104* (0.047)	0.009 (0.023)	0.014 (0.053)
Constant	2.509*** (0.135)	2.273*** (0.045)	1.420*** (0.028)	1.313*** (0.066)
Individual observations	959	7757	8833	7881
Observations	1918	15,514	17,666	15,762
Pseudo R <sup>2</sup>	0.55	0.51	0.25	0.22

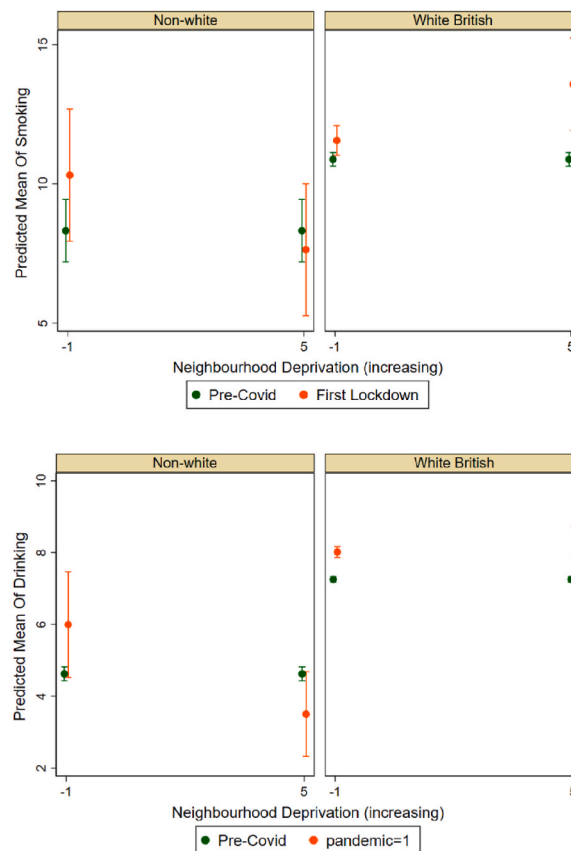
Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.

We find similar effects as in the short term of time-varying employment status. Not working and studying are associated with a greater number of drinks per week. Not working is also associated with increased physical activity. In contrast with the short term, we observe no relevant effect of individual changes in financial subjective

**Table 5**  
Long-term effect of Covid-19 and neighbourhood deprivation.

VARIABLES	(1)	(2)	(4)	(5)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre-Covid and Long Term	Pre-Covid and Long Term	Pre-Covid and Long Term	Pre-Covid and Long Term
Covid-19	0.117*** (0.021)	0.015** (0.006)	0.033*** (0.005)	0.012* (0.006)
Covid-19*Nhb Deprivation	0.010 (0.014)	0.003 (0.006)	0.001 (0.005)	-0.028*** (0.007)
Constant	2.433*** (0.135)	2.289*** (0.024)	1.434*** (0.024)	1.288*** (0.028)
Individual observations	1463	10,158	11,695	10,975
Observations	4914	35,652	40,699	38,366
Pseudo R <sup>2</sup>	0.50	0.50	0.18	0.21

Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.



Notes: author’s own calculations based on CLS Covid-19 survey, representing interactions from models reported in Table 4

**Fig. 4.** Short-term effect of Covid-19 and neighbourhood deprivation, by ethnicity. Notes: author’s own calculations based on CLS Covid-19 survey, representing interactions from models reported in Table 4.

assessment. Similarly, in the long-term, the different effect by sex and ethnicity also seems to disappear (Table 6 and Table 7).

5. Discussion and conclusion

This paper investigated the consequences of living in a more or less deprived neighbourhood during the Covid-19 pandemic in England, for individual behavioural changes in four health-related outcomes: smoking, drinking, physical activity and healthy eating. We focused specifically on differences in outcomes by sex and ethnicity.

The results showed that there has been an overall significant effect of Covid-19 on health-related behaviours, with people drinking and smoking more, but also doing more physical activity and consuming more healthy food. However, the imposed restrictions during the pandemic seemed to have also widened the gap between more and less deprived areas: people living in the more deprived neighbourhoods smoked even more, ate less fruit and vegetables and increased the amount of physical activity to a lower extent than those in less deprived areas. At a first glance we might have expected a more marked effect of the neighbourhood on individuals living in better off areas than in more deprived ones, since their geographic mobility patterns have likely changed the most due to the pandemic. People in better off neighbourhoods were more likely to have jobs which allowed them to work from home during the pandemic, which translated in more time spent in the neighbourhood. However, while individuals living in more deprived areas might have experienced a smaller disruption to their daily habits, especially when it comes to specific groups, such as those working in supermarkets, public transport, or care workers who continued to commute to work during the pandemic, the opportunities they had to “escape” their neighbourhood besides work also reduced significantly. At the same time, individuals living in better off areas tend to be even more spatially segregated than individuals living in more deprived areas – thus it may be that their daily habits after all have not been that much disrupted, and that they were mostly exposed to their own high quality neighbourhood.

Several mechanisms could explain why those in the most deprived neighbourhoods were most affected. While we are not able to test them due to data constraints, we can here speculate on the physical and social dimensions of the neighbourhood that might account for these results. Stress theory suggests that individuals might translate feelings of stress and anxiety into smoking or drinking behaviours. It could thus be that people living in deprived areas might have perceived as even more challenging the difficulties posed by the pandemic than individuals living in less deprived ones, and this could have triggered a more marked increase in smoking patterns. For example, overcrowding conditions could have raised health-related concerns and anxiety. Moreover, individuals living in deprived areas were also much more likely to use

Table 7

Long-term effect of Covid-19 and neighbourhood deprivation, interacted by ethnic background.

VARIABLES	(1)	(2)	(3)	(4)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre and Long Term	Pre and Long Term	Pre and Long Term	Pre and Long Term
Covid-19	0.119*** (0.021)	0.017** (0.006)	0.031*** (0.005)	0.013+ (0.007)
Covid-19*Nhb Deprivation	0.001 (0.014)	0.006 (0.007)	0.001 (0.005)	-0.028*** (0.007)
Covid-19*Ethnic Minority*Deprivation	0.164 (0.122)	-0.033 (0.034)	0.008 (0.017)	0.044 (0.027)
Constant	2.440*** (0.135)	2.288*** (0.023)	1.433*** (0.024)	1.291*** (0.028)
Individual observations	1463	10,158	11,695	10,975
Observations	4914	35,652	40,699	38,366
Pseudo R2	0.50	0.50	0.18	0.21

Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.

public transport and make more visits to essential shops compared to those in more affluent areas, which again might have increased the risk of infection. Those living in deprived neighbourhoods were also more likely to work in risky jobs with regard to potential Covid-19 infections, leading to extra stress. Furthermore, the deterioration of the general economic situation might have also led individuals to experience negative feelings, not only in relation to each individual’s socio-economic position but also assuming that individuals living in more deprived areas tend to be more exposed to peers at risk of job loss or in disadvantaged economic conditions. At the same time, we could expect physical characteristics of the neighbourhood, such as the presence of health food shops and quality supermarkets, to affect the reduction in consumption of fruit and vegetables. Data from Public Health England (PHE) highlight how deprived areas host five times more fast food outlets than non-deprived ones. Such outlets provide tasty and cheap food, and local residents might be tempted to resort to this kind of food, readily available in the area, during a lockdown in a pandemic. Possible feelings of stress and uncertainty over future conditions here might also play a role, leading individuals to lose their self-control and adopt riskier eating behaviours.

We found that women living in deprived areas have been more affected, i.e. showing less physical activity, by the first lockdown than men residing in areas characterised by the same level of deprivation. When it comes to physical activity, again many characteristics of a

Table 6

Long-term effect of Covid-19 and neighbourhood deprivation, interacted by sex.

VARIABLES	(1)	(2)	(3)	(4)
	Smoking	Drinking	Healthy Eating	Physical Activity
	Pre and Long Term	Pre and Long Term	Pre and Long Term	Pre and Long Term
Covid-19	0.066* (0.029)	-0.007 (0.008)	0.041*** (0.009)	-0.030*** (0.009)
Covid-19*Nhb Deprivation	0.020 (0.021)	0.004 (0.009)	0.004 (0.008)	-0.025** (0.008)
Covid-19*Female*Deprivation	-0.025 (0.029)	-0.003 (0.013)	-0.004 (0.010)	-0.006 (0.013)
Constant	2.426*** (0.139)	2.288*** (0.024)	1.434*** (0.024)	1.288*** (0.028)
Individual observations	1463	10,158	11,695	10,975
Observations	4914	35,652	40,699	38,366
Pseudo R2	0.50	0.50	0.18	0.21

Notes: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, + p < 0.1. Individual and neighbourhood fixed effects. Standard error clustered at the neighbourhood level. Additional time-varying controls: economic activity, health status, tenure, financial subjective assessment.

neighbourhood, such as the availability of sport infrastructure and/or walkable space might play a significant role. Moreover, it could be that women living in more deprived neighbourhoods felt less secure than women in less deprived ones to go out exercising in the context of lockdown restrictions, which reduced the number of people on the street. Furthermore, previous evidence (Borkowska and Laurence, 2021) showed that, in the UK, the pandemic has significantly lowered perception of local community cohesion in more deprived areas. Since women tend to have greater caring responsibilities than men, of both children and neighbours (Zangger, 2021), a reduction in cohesion might have meant lower care sharing and therefore might have more negatively affected them as compared to men.

Finally, white British living in more deprived areas consumed more alcohol and smoked more than non-white British living in areas similarly deprived. Previous research found that people belonging to ethnic minorities were more likely to drink less than usual because of higher general health concerns in the context of the pandemic (CGA, 2020). This could be extended to smoking, especially considering that Covid-19 originates as a respiratory disease. Additionally, the culture of drinking has been a common feature of Britain since the industrial revolution (Jayne et al., 2008; Fletcher and Karl Spracklen, 2014), with dynamics of 'drinkertainment' (Bell, 2005) at the centre of post-industrial British cities. The stronger difference between white and non-white British in more deprived neighbourhoods could thus be explained by the higher salience of these cultural difference caused by higher ethnic segregation in these areas (Demireva and Heath, 2014), lower integration in the British culture, and stronger embracement of the British "pride of drinking" by white-British residents.

Both the overall gap between more and less deprived areas and the gender and ethnicity differences are particularly evident in the period covering the first lockdown. The only effect that remains significant in the long-term is that individuals living in more deprived areas tend to exercise less than individuals in advantageous ones. In the long term, we do not detect any significant ethnic or gender differences. At first sight, it may seem that the negative gradients between more and less deprived areas, and the gender and ethnic ones, disappear with time, although not for physical activity. However, we think that this trend is caused partly by the fact that, since the first lockdown was more stringent and respected than the following ones (Brown and Kirk-Wade, 2021), only in that period people really had to spend time in their neighbourhood while in the other periods people had more freedom to visit other neighbourhoods.

Overall, we argue that the first lockdown has thus been a powerful highlighter and amplifier of pre-existing neighbourhood inequalities, that in non-pandemic times might be hidden. The first lockdown really constrained people to spend more time in their home and the immediate surroundings of where they live. Results thus suggest that only during the first lockdown we may have seen the neighbourhood effect genuinely at work. The fact that we only find significant results in the short-term is important for the wider neighbourhood effects literature, as it has been suggested than neighbourhood effects only work in the long term, while in this paper we see the opposite. From a policy perspective, there are several lessons to be learned from this study. Especially during a lockdown it is important to make people aware of the potential negative effects of lockdowns on smoking and drinking behaviour. And although we saw more physical activity and healthier eating habits during the lockdowns, these positive effects could be stimulated more by creating more awareness that healthy behaviour can compensate for some of the negative effects of lockdowns. The fact that those living in deprived neighbourhoods started to smoke more, eat less healthy, and showed a lower increase in physical activity suggests that policy should especially target these neighbourhoods. An obvious suggestion would be to reduce spatially concentrated poverty, and reduce the level of inequality in society. Policy specifically targeting the most deprived neighbourhoods could include improving outdoor spaces to stimulate being physically active, and policy which alerts people to the fact that

smoking could actually increase the health risks of being infected with Covid-19.

### Credit author statement

Laura Silva: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing; Franco Bonomi Bezzo: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing; Maarten Van Ham: Conceptualization, Supervision, Writing – review & editing.

### Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

The authors do not have permission to share data.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.socscimed.2023.115917>.

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