Role of individual deprivation and community-level deprivation on suicidal behaviors: Insights from the UK Biobank study

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A B S T R A C T

Introduction: This study aimed to investigate the impact of individual- and community-level deprivation on suicidal behaviors among community members.
Methods: Data from 350,884 UK Biobank participants were employed to construct an individual deprivation index. Absolute poverty was defined as a pre-tax annual household income below £18,000. Predictors for absolute poverty incorporated variables such as sex, ethnicity, type of accommodation, tenure status, number of vehicles owned, educational qualifications, current employment status, and subjective health rating. The individual deprivation index was constructed using a logistic regression model to predict absolute poverty. Townsend Deprivation Index (TDI) was employed to represent community-level deprivation. The associations between the individual deprivation index, TDI, and suicidal behaviors were examined through multivariate linear regression. Interaction analyses were conducted to investigate effect modification.
Results: The logistic regression model demonstrated high predictive accuracy for absolute poverty (area under the receiver operating curve = 0.840). The associations between individual deprivation index and suicidal behaviors were observed to be more substantial than those between TDI and suicidal behaviors. A positive interaction between the individual deprivation index and TDI was detected, indicating an amplifying effect of community-level deprivation on the impact of individual-level deprivation on suicidal behaviors.
Conclusion: Our study successfully constructed a comprehensive individual deprivation index that could be applied widely to measure individual-level deprivation. Our findings revealed that individual-level deprivation and community-level deprivation have a synergistic effect on suicidal behaviors, underscoring the importance of multilevel interventions in suicide prevention.

1. Introduction

Suicide is a serious public health problem that affects individuals, families, and communities across the globe. Recent evidence from the Global Burden of Disease (GBD) study showed that around 759,000 deaths were attributable to self-harm, being ranked as the 22nd leading cause of death among 369 diseases and injuries (Vos et al., 2020). Although there had been rigorous attempts to prevent suicide which had

led to substantial decrease in suicide prevalence (Zheng et al., 2022), it is still one of the most serious public health issues that imposes heavy disease burden.

It is well understood that social deprivation is a major risk factor of suicidal behaviors. Although there is a certain degree of variance in the magnitude of association, previous evidence agrees that deprived individuals have higher risk of attempting suicidal behaviors (Burrows et al., 2011; Xi et al., 2023; Yeung et al., 2022). The mechanisms through

which social deprivation promotes suicidal behaviors include lack of socioeconomic capacity for managing distress (Martikainen et al., 2004), increased risk of developing mental disorders (Visser et al., 2021), and negative neighborhood effects (Jakobsen & Lund, 2022).

It should be noted, however, that the multiple facets of social deprivation provides challenges in interpreting health effects of social deprivation. As Berkman et al. and other researchers had previously theorized, measurement of social aspects of health should incorporate both macro-level and micro-level approaches, which deal with individual-level, community-level, and nation-level pathways of action (Berkman et al., 2000; Whelan et al., 2004). Micro-level exposure, such as individual-level deprivation, directly triggers psychological pathway, such as mood and self-efficacy, as well as health behavior pathways including physical activity and help-seeking behavior. Meanwhile, macro-level exposures condition the exposure and nature of pathways, acting as indirect causes of suicidal behaviors (Berkman et al., 2000; Jakobsen & Lund, 2022; Pak & Choung, 2020; Yeung et al., 2022).

There have been a few studies that attempted to analyze the effects of each hierarchical level separately (Li et al., 2016; Xi et al., 2023; Yeung et al., 2022), but just as there are numerous indicators of both micro-level and macro-level deprivation, so are the methods of constructing indices for measurement of social deprivation (Bossert & d'Ambrosio, 2007; Labbe et al., 2015; Salmond et al., 2006). This is especially true for individual-level deprivation, which had been measured differently throughout numerous studies, compared to community-level deprivation. In the present study, we tried to investigate the association between social deprivation, both individual-level and community-level, and suicidal behaviors by utilizing the UK Biobank database. To address the various factors that constitute social deprivation, we have developed a deprivation index that could provide comprehensive information on individual-level deprivation. Additionally, we utilized the Townsend Deprivation Index as an index for community-level deprivation and tested the association between both levels of deprivation and suicidal behaviors.

2. Methods

2.1. Study population

The UK Biobank is a population-based prospective study constructed for detailed investigations of health determinants of middle-aged and elderly populations. A total number of 502,420 participants were recruited from 22 assessment centers across the United Kingdom between 2006 and 2010, and all participants had provided electronic informed consent for the assessment. The UK Biobank database consists of results from clinical examinations, biological sample assessments, self-reported health behaviors, sociodemographic information of participants, and information on other health determinants. Detailed study protocols are available on the UK Biobank Website (https://www.ukbiobank.ac.uk) (Sudlow et al., 2015).

Although the UK Biobank is one of the most widely used cohort databases from UK, there have been some concerns on the representativeness of the database, as only participants aged 40–69 years are recruited (Fry et al., 2017; Swanson, 2012). To overcome this limitation, several studies have tested the generalizability of evidence from the UK Biobank to general population, and concluded that valid assessment of exposure-outcome association could be widely generalized due to its large size and heterogeneity of exposure measures (Batty et al., 2020; Ebrahim & Davey Smith, 2013; Fry et al., 2017).

We used the baseline assessment data for constructing individual deprivation index. Among 502,240 participants, we excluded participants whose information on either one of age, ethnic background, type of accommodation, tenure type, number of vehicles, qualifications, current employment status, or overall subjective health rating was missing, leaving 350,884 participants for analysis. After developing the individual deprivation index, we assessed how individual- and area-

based deprivation affects suicidal behaviors. For complete-case analysis, we included participants who had completed the mental health questionnaire included in the online follow-up assessment, with no missing information on suicidal behaviors, depressive symptoms, anxiety, and experiences on traumatic events, which left us with 119,585 participants. For sensitivity analysis, we imputed missing values in participants who completed mental health assessment by multiple imputation (Berglund & Heeringa, 2014).

2.2. Developing individual deprivation index

We tried to develop an individual deprivation index than can provide comprehensive information on multiple aspects of socioeconomic deprivation. After reviewing previous research that had attempted to develop an individual deprivation index, we selected the sociodemographic factors that are hypothesized to be strongly associated with socioeconomic deprivation as predictors of objective poverty from the UK Biobank database: biological sex, housing condition, number of vehicles, educational qualification, current employment status, and overall subjective health rating (Brown et al., 2023; Labbe et al., 2015; Moussaoui et al., 2022). As we tried to develop an indicator that could be applied to a wide range of database, we included indicators that are commonly used and can be easily assessed into the prediction model.

According to research briefing publication produced by the House of Commons Library of UK, relative low income is defined as 'living in households with income below 60% of the median in that year', and absolute low income is defined as 'living in households with income below 60% of inflation-adjusted median income in a certain base year' (Hanandita & Tampubolon, 2014). In the year 2011, the median equivalized net household income was £419 per week before housing cost (Cribb et al., 2012). Information on pre-taxed household income per week was provided only in a categorical form: <£346, £346 - £576, £577 - £999, £1000 - £1,923, and >£1923. Therefore, we defined objective poverty as 'having pre-taxed household income of less than £346 per week'. All sociodemographic variables were assessed at baseline study. Multivariate logistic regression was conducted to test the association between sociodemographic characteristics and objective poverty and to estimate coefficients of each predictor. Regression coefficients obtained from multivariate logistic regression model were used to construct the individual deprivation index. The area under the receiver-operator curve was calculated to assess the predictability of individual deprivation index.

2.3. Effect of individual deprivation and community-level deprivation on suicidal behaviors

After the development of individual deprivation index, we assessed the role of individual deprivation and community-based deprivation on suicidal behaviors. Information on suicidal behaviors, including suicidal ideation, self-harm, and suicide attempt was collected through online mental health survey. Information on mental health variables related to suicidal behaviors, such as depressive symptoms (Casey et al., 2015; Melhem et al., 2019; Rihmer, 2011; Rotenstein et al., 2016; Sullivan et al., 2015), anxiety (Kanwar et al., 2013; Lee et al., 2022; Mann & Rizk, 2020; Moitra et al., 2021; Valentiner et al., 2002), and traumatic events (O'Neill et al., 2014; Wang et al., 2018), was also assessed during online mental health survey. Depressive symptoms were measured by the Patient Health Questionnaire-9 (PHQ-9) (Kroenke et al., 2001), while anxiety was measured by the Generalized Anxiety Disorder-7 (GAD-7) questionnaire (Spitzer et al., 2006).

We used the individual deprivation index constructed from our analysis as an indicator of individual deprivation, and the Townsend Deprivation Index (TDI) as an indicator of community-level deprivation. Both indices were standardized before analysis for comparability. Multivariate logistic regression model was constructed to test the association between individual deprivation, community-level deprivation,

and suicidal behaviors. All models were adjusted for age, PHQ-9 score, GAD-7 score, and traumatic events. We did not include sex in this model since sex was included in the construction of individual deprivation index. Additionally, we assessed the interaction between individual deprivation and community-level deprivation by introducing interaction term to the model. Both linear interaction model and non-linear interaction model were used for interaction assessment. For non-linear interaction, polynomial splining with a degree of 5 was performed with knots at 5p, 25p, 50p, 75p, and 95p of indices. For sensitivity analyses to test the effect of missing variables, same analyses were repeated on multiply imputed dataset, and the results from main and sensitivity analyses were compared. All analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary NC, USA).

3. Results

3.1. Characteristics of participants

For the construction of individual deprivation index, data from 350,884 participants were used. Among them, 58,648 participants (16.20%) had household income of 'less than £18,000' before taxation and were categorized as 'participants in objective poverty'. The proportion of men among participants in objective poverty was significantly lower than that among participants not in objective poverty. The proportion of participants with non-white ethnic background was larger in 'objective poverty' group as well. Other socioeconomic factors, including educational qualifications, occupational status, and accommodation status, were also positively associated with objective poverty (Table 1).

For analyzing the effect of deprivation on suicidal behaviors, data from 119,585 participants were used. Among them, 13,230 participants (11.06%) were in objective poverty. Similar trends of association between sociodemographic factors and objective poverty were also detected in this database. In addition, differences in psychological factors between participants were also detected. Participants in objective poverty had higher average PHQ-9 score and GAD-7 score, and they were more likely to have been exposed to traumatic events and had higher incidence of suicide behaviors (Table 2).

3.2. Individual deprivation, community-level deprivation, and suicidal behaviors

Table 3 shows the regression coefficient for objective poverty of the variables included in the construction of individual deprivation index. We included sex, ethnicity, type of accommodation, number of vehicles in household, educational qualifications, current employment status, and subjective health status as predictors of objective poverty. The surface area under the receiver operator curve was 0.840, suggesting high predictive ability of the model. The constructed individual deprivation index was included in the analysis model as an independent variable (Fig. 1). Results from multiply imputed database did not differ significantly from the original analyses (Supplemental Material 1).

Both individual- and community-level deprivation were positively associated with suicidal ideation, self-harm, and suicide attempt, but the regression coefficient by 1 standard deviation was larger in individual deprivation (Table 4). When interaction term (individual deprivation index × Townsend deprivation index) was added to the model, no linear interaction was detected in any analysis (Table 4, Fig. 2-A). However, when non-linear interactions were tested by polynomial splining, we detected positive interaction between individual deprivation index and Townsend deprivation index (Fig. 2-B). This result suggests that highly deprived community environment acts as an aggravating factor which amplifies the association between individual deprivation and suicidal behaviors. Results from multiply imputed dataset did not significantly differ from complete case analysis (Supplemental Materials 2–3).

Table 1

Characteristics of individuals included in constructing individual deprivation index (N = 353,105).

	Not in objective poverty [a] (N = 293,841)	In objective poverty [a] (N = 59,264)	p-value
Age at baseline, mean (SD)	54.77 (7.93)	58.34 (7.97)	**<0.001**
Male, N (%)	142,366 (48.45)	23,636 (39.88)	**<0.001**
Ethnic background, N (%)			**<0.001**
White	281,389 (95.76)	54,833 (92.51)	
Mixed	1656 (0.56)	444 (0.75)	
Asian or Asian British	5199 (1.77)	1680 (2.84)	
Black or Black British	3650 (1.24)	1500 (2.53)	
Other ethnic groups	1.947 (0.66)	814 (1.37)	
Type of accommodation lived in, N (%)			**<0.001**
A house or bungalow	271,577 (92.42)	47,880 (80.79)	
A flat, maisonette or apartment	22,115 (7.53)	11,190 (18.88)	
Mobile or temporary structure (e.g., caravan)	149 (0.05)	194 (0.33)	
Tenure type, N (%)			**<0.001**
Own outright	140,698 (47.88)	33,902 (57.21)	
Own with a mortgage	138,307 (47.07)	11,540 (19.47)	
Rent from local authority, local council or housing association	5338 (1.82)	9238 (15.59)	
Rent from private landlord or letting agency	6882 (2.34)	3768 (6.36)	
Pay part rent and part mortgage (shared ownership)	785 (0.27)	280 (0.47)	
Live in accommodation rent-free	1831 (0.62)	536 (0.90)	
Number of vehicles, mean (SD)	2.73 (0.83)	2.00 (0.71)	**<0.001**
Educational qualifications, N (%)			**<0.001**
College or University degree	131,527 (44.76)	13,845 (23.36)	
Other professional qualifications	16,331 (5.56)	4751 (8.02)	
A levels/AS levels or equivalent	40,820 (13.89)	7450 (12.57)	
O levels/GCSEs or equivalent	68,494 (23.31)	20,020 (33.78)	
CSEs or equivalent	16,818 (5.72)	5615 (9.47)	
NVQ or HND or HNC or equivalent	19,851 (6.76)	7583 (12.80)	
Current employment status, N (%)			**<0.001**
In paid employment or self-employed	211,062 (71.83)	19,796 (33.40)	
Retired	70,023 (23.83)	29,145 (49.18)	
Looking after home and/or family	7041 (2.40)	1779 (3.00)	
Unbale to work because of sickness or disability	2613 (0.89)	5186 (8.75)	
Unemployed	2038 (0.69)	2910 (4.91)	
Doing unpaid or voluntary work	1064 (0.36)	448 (0.76)	
Overall subjective health rating, N (%)			**<0.001**
Excellent	58,245 (19.82)	6963 (11.75)	
Good	177,791 (60.51)	31,246 (52.72)	
Fair	50,596 (17.22)	15,909 (26.84)	
Poor	7209 (2.45)	5146 (8.68)	

SD: standard deviation; GCSE: General Certificate of Secondary Education; CSE: Certificate of Secondary Education; NVQ: National Vocational Qualification; HND: Higher National Diploma; HNC: Higher National Certificate.

[a] Objective poverty was defined as having household income before tax of "less than £18,000."

4. Discussion

Our study contributes significantly to the understanding of the interplay between individual- and community-level deprivation and

Table 2

Characteristics of individuals included in analyzing the effect of deprivation on suicidal behaviors (N = 119,585).

	Full population (N = 119,585)	Not in objective poverty (N = 106,355)	In objective poverty (N = 13,230)	p-value
Age at timepoint of mental health assessment, mean (SD)	63.24 (7.70)	62.86 (7.64)	66.30 (7.48)	<0.001
Male, N (%)	53,937 (45.10)	49,173 (46.23)	4764 (36.01)	<0.001
Ethnic background, N (%)				<0.001
White	116,438 (97.37)	103,629 (97.44)	12,809 (96.82)	
Mixed	616 (0.52)	531 (0.50)	85 (0.64)	
Asian or Asian British	1141 (0.95)	1008 (0.95)	133 (1.01)	
Black or Black British	800 (0.67)	693 (0.65)	107 (0.91)	
Other ethnic groups	590 (0.49)	494 (0.46)	96 (0.73)	
Type of accommodation lived in, N (%)				<0.001
A house or bungalow	109,044 (91.19)	98,025 (92.17)	11,019 (83.29)	
A flat, maisonette or apartment	10,453 (8.74)	8284 (7.79)	2169 (16.39)	
Mobile or temporary structure (i.e. caravan)	88 (0.07)	46 (0.04)	42 (0.32)	
Tenure type, N (%)				<0.001
Own outright	63,271 (52.91)	54,632 (51.37)	8639 (65.30)	
Own with a mortgage	49,889 (41.72)	47,427 (44.59)	2462 (18.61)	
Rent from local authority, local council or housing association	2537 (2.12)	1250 (1.18)	1287 (9.73)	
Rent from private landlord or letting agency	2801 (2.34)	2125 (2.00)	676 (5.11)	
Pay part rent and part mortgage (shared ownership)	320 (0.27)	263 (0.25)	57 (0.43)	
Live in accommodation rent-free	767 (0.64)	658 (0.62)	109 (0.82)	
Number of vehicles, mean (SD)	2.64 (0.83)	2.72 (0.82)	2.06 (0.69)	<0.001
Educational qualifications, N (%)				<0.001
College or University degree	61,073 (51.07)	56,990 (53.58)	4083 (30.86)	
Other professional qualifications	6175 (5.16)	5247 (4.93)	928 (7.01)	
A levels/AS levels or equivalent	17,321 (14.48)	15,273 (14.36)	2048 (15.48)	
O levels/GCSEs or equivalent	24,405 (20.41)	20,127 (18.92)	4278 (32.34)	
CSEs or equivalent	4401 (3.68)	3602 (3.39)	799 (6.04)	
NVQ or HND or HNC or equivalent	6210 (5.19)	5116 (4.81)	1094 (8.27)	
Current employment status, N (%)				<0.001
In paid employment or self-employed	81,111 (67.83)	76,441 (71.87)	4670 (35.30)	
Retired	32,306 (27.02)	25,603 (24.07)	6703 (50.67)	
Looking after home and/or family	2957 (2.47)	2572 (2.42)	385 (2.91)	

Table 2 (*continued*)

	Full population (N = 119,585)	Not in objective poverty (N = 106,355)	In objective poverty (N = 13,230)	p-value
Unbale to work because of sickness or disability	1340 (1.12)	598 (0.56)	742 (5.61)	
Unemployed	1263 (1.06)	662 (0.62)	601 (4.54)	
Doing unpaid or voluntary work	608 (0.51)	479 (0.45)	129 (0.98)	
Overall subjective health rating, N (%)				<0.001
Excellent	27,942 (23.37)	25,792 (24.25)	2150 (16.25)	
Good	71,797 (60.04)	64,217 (60.38)	7580 (57.29)	
Fair	17,352 (14.51)	14,603 (13.73)	2749 (20.78)	
Poor	2494 (2.09)	1743 (1.64)	751 (5.68)	
PHQ-9 score, mean (SD)	2.73 (3.63)	2.62 (3.48)	3.63 (4.56)	<0.001
GAD-7 score, mean (SD)	4.59 (2.88)	4.56 (2.82)	4.84 (3.35)	<0.001
Information on traumatic events during childhood, N (%)				
Felt hated by a family member as a kid	10,941 (9.15)	9232 (8.68)	1709 (12.92)	<0.001
Physically abused by family as a child	9362 (7.83)	8020 (7.54)	1342 (10.14)	<0.001
Felt loved as a child	93,596 (78.27)	84,070 (79.05)	9526 (72.00)	<0.001
Sexually molested as a child	4888 (4.09)	4107 (3.86)	781 (5.90)	<0.001
Someone to take to doctor when needed as a child	114,064 (95.38)	101,880 (95.79)	12,184 (92.09)	<0.001
Information on traumatic events during adulthood, N (%)				
Belittlement by partner or ex-partner	17,199 (14.38)	14,357 (13.50)	2842 (21.48)	<0.001
Been in a confiding relationship	84,042 (70.28)	76,875 (72.28)	7167 (54.17)	<0.001
Physical violence by partner or ex-partner	7476 (6.25)	6025 (5.66)	1451 (10.97)	<0.001
Sexual interference by partner or ex-partner without consent	2954 (2.47)	2284 (2.15)	670 (5.06)	<0.001
Able to pay rent/mortgage as an adult	84,042 (70.28)	76,875 (72.28)	7167 (54.17)	<0.001
Suicidal behaviors, N (%)				
Suicidal ideation (N = 119,253)	37,264 (31.25)	32,308 (30.46)	4956 (37.58)	<0.001
Self-harm (N = 119,482)	5351 (4.48)	4420 (4.16)	931 (7.04)	<0.001
Suicide attempt (N = 119,482)	2711 (2.27)	2116 (1.99)	595 (4.50)	<0.001

SD: standard deviation; GCSE: General Certificate of Secondary Education; CSE: Certificate of Secondary Education; NVQ: National Vocational Qualification; HND: Higher National Diploma; HNC: Higher National Certificate; PHQ-9: Patient Health Questionnaire-9; GAD-7: Generalized Anxiety Disorder-7.

*Objective poverty was defined as having household income before tax of "less than £18,000" or "£18,000 – £30,999."

suicidal behaviors. We have developed and utilized a comprehensive individual-level deprivation index that encapsulates a variety of socio-economic and health-related factors, providing a holistic understanding of an individual's circumstances. This novel index has demonstrated its efficacy in the context of this study and could be further employed in future research on socioeconomic deprivation and its consequences.

Our findings suggest the hierarchical structure of socioeconomic deprivation and its effect on suicidal behaviors. The construction and

Table 3
Logistic regression coefficients between objective poverty and sociodemographic factors (N = 353,105).

Predictors of objective poverty	β	SE	OR	95% CI
Women vs. Men	0.369	0.011	1.45	1.42–1.48
Ethnic minority vs. White	0.405	0.023	1.50	1.43–1.57
Temporary accommodation vs. Permanent accommodation	1.838	0.132	6.28	4.85–8.14
Tenure type: Rent vs. Own (outright or with mortgage)	1.159	0.016	3.19	3.09–3.29
Number of vehicles in household	−1.134	0.008	0.32	0.32–0.33
Educational qualifications (O level/ GCSEs or lower vs. A level/AS level or higher)	0.864	0.011	2.37	2.32–2.42
Current employment status				
In paid employment or self-employed	ref		ref	
Retired	1.590	0.012	4.91	4.80–5.02
Unemployed or doing unpaid or voluntary work	1.763	0.018	5.83	5.62–6.04
Overall health rating, vs. Excellent				
Excellent	ref		ref	
Good	0.213	0.016	1.24	1.20–1.28
Fair	0.537	0.018	1.71	1.65–1.77
Poor	0.853	0.027	2.35	2.22–2.48

SE, standard error; OR, odds ratio; CI, confidence interval; ref: reference; GCSE: General Certificate of Secondary Education.

deployment of the individual deprivation index have broadened our understanding of how multifaceted individual-level socioeconomic deprivation can influence suicidal tendencies. These findings dovetail with previous research that underscored the importance of individual-level factors, including health status, sociodemographic factors, and economic and lifestyle conditions (Favril et al., 2022; Yoshimasu et al., 2008).

Our results indicate that individual-level deprivation and community-level deprivation are both associated with increased risk of suicidal behaviors, both independently and interactively. Numerous previous studies have reported on individual socioeconomic status and neighborhood-level/community-level deprivation separately (Kashem et al., 2019; Lang et al., 2009; Verhaeghe & Tampubolon, 2012). As Berkman et al. had previously established, social determinants of health consist of multiple strata of action (Berkman et al., 2000), which are interconnected yet have independent health effects (Shin et al., 2017). Our results suggest that although the strata of deprivation are closely related, they are independently associated with suicidal behaviors, similar to other health outcomes.

Interestingly, our study also uncovered that community-level deprivation can exacerbate the effects of individual deprivation on suicidal behaviors. This previously undetected non-linear but positive interaction between individual and area deprivation unveils a potential novel facet to be considered in the study of suicide risk. Consequently, this study suggests a need for dual-targeted interventions that tackle not just individual-level risk factors, but also the broader socioeconomic milieu in which individuals live. Research suggests that suicide can have a 'contagious' effect, where the occurrence of suicide within a community can increase the risk among others in the same community (Haw et al., 2013). Socioeconomically deprived areas often have higher suicide rates, potentially increasing this contagion risk. Furthermore, communities under greater socioeconomic deprivation may have fewer resources to implement public health initiatives or interventions, such as suicide prevention programs (Zalsman et al., 2016).

Several limitations of our study should be acknowledged. First, since the study design was cross-sectional, it was not possible to establish the direction of causality. Second, the findings may not be generalizable to other populations given that the study was conducted using the UK Biobank, which mainly consists of middle-aged and older adults (Fry et al., 2017). Although previous studies have suggested that the generalizability evidence from the UK Biobank, if investigated under correct

(A) Model-predicted probabilities
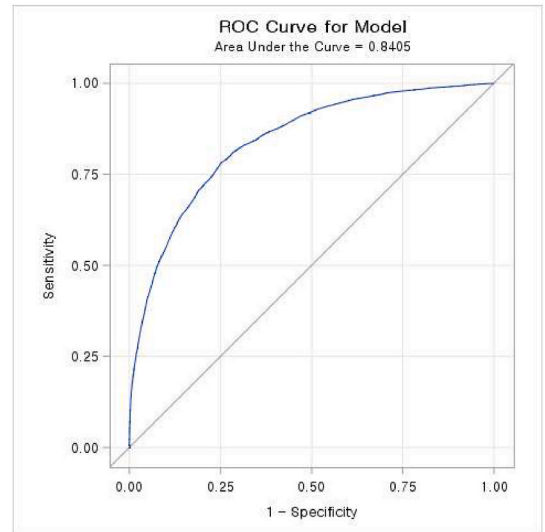
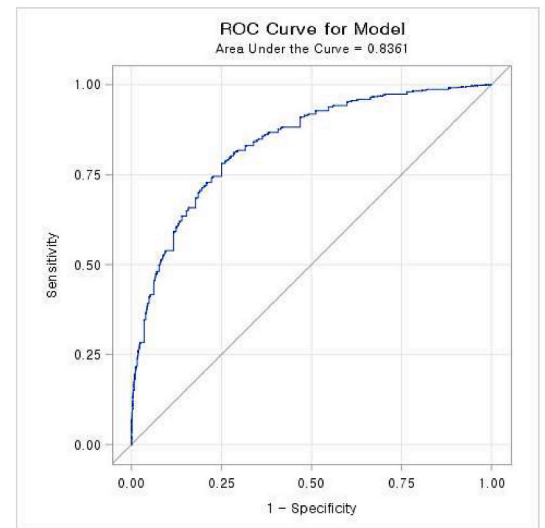**(B) Cross-validated probabilities**

Fig. 1. Receiver operating curve for prediction of objective poverty. (A) Model-predicted probabilities; (B) Cross-validated probabilities.

methods, could be widely generalized due to its large size and heterogeneity of exposure measures (Batty et al., 2020; Ebrahim & Davey Smith, 2013; Fry et al., 2017), selection bias might drift the effect size away from the 'real-world estimand'. It should be also considered that since this study was based on the UK population, the results should not be generalized within other nations. Missing data was also a probable source of errors, although the sensitivity analysis showed that the effect of missing data on the estimand is likely to be insignificant. Whilst the individual-level deprivation was developed within the population of UK Biobank and showed good prediction of individuals' objective poverty, individual's household income was only provided as a categorical form; therefore, we could not capture the continuum aspect of that in constructing the indicator. Another challenge we have encountered is that as the UK Biobank restricted access to location data since November 2022, we were unable to run multilevel analysis, which would provide better understanding on the hierarchies of deprivation than single-level regression analysis. Furthermore, some important factors, such as mental health status, were self-reported, which could lead to reporting bias.

Table 4

Logistic regression coefficients between objective poverty and sociodemographic factors.

	Fully adjusted model		Interaction model	
	OR	95% CI	OR	95% CI
A) Suicidal ideation (N=119,253)				
Individual deprivation index, per 1SD increase	**1.11**	**1.10–1.13**	**1.11**	**1.10–1.13**
Townsend deprivation index (TDI), per 1SD increase	**1.06**	**1.05–1.07**	**1.06**	**1.05–1.08**
Interaction term: (Individual deprivation index) × (TDI)			1.00	0.99–1.01
B) Self-harm (N=119,482)				
Individual deprivation index, per 1SD increase	**1.21**	**1.18–1.25**	**1.21**	**1.17–1.25**
Townsend deprivation index, per 1SD increase	**1.10**	**1.07–1.13**	**1.10**	**1.06–1.13**
Interaction term: (Individual deprivation index) × (TDI)			1.01	0.99–1.04
C) Suicide attempt (N=119,482)				
Individual deprivation index, per 1SD increase	**1.27**	**1.22–1.33**	**1.27**	**1.21–1.33**
Townsend deprivation index, per 1SD increase	**1.14**	**1.10–1.18**	**1.13**	**1.09–1.18**
Interaction term: (Individual deprivation index) × (TDI)			1.00	0.97–1.03

All models were adjusted for age, PHQ-9 score, GAD-7 score, current smoking status, current alcohol consumption frequency, and traumatic events.
OR, odds ratio; CI, confidence interval; SD, standard deviation; PHQ-9: Patient Health Questionnaire-9; GAD-7: Generalized Anxiety Disorder-7.

5. Conclusion

Our findings underscore the necessity of addressing socioeconomic deprivation at both individual and community levels to mitigate the burden of suicide. The design and implementation of multilevel interventions that tackle deprivation from a dual perspective may offer a promising approach in suicide prevention strategies. The development and application of the individual deprivation index in this study paves the way for its use in future research to assess and understand the role of socioeconomic deprivation in health outcomes. As socially deprived individuals are at higher risk of engaging with suicidal behaviors, active preventive measures should be provided for individuals with lower socioeconomic status. Future research should continue to explore the complex interplay between individual- and community-level factors in suicide risk, with a particular focus on elucidating potential mechanisms for these associations. Furthermore, longitudinal studies would provide valuable insights into the temporal relationship between deprivation and suicidal behaviors.

Ethical statement

UKB received approval from the National Information Governance Board for Health and Social Care and the National Health Service North West Centre for Research Ethics Committee (Ref: 11/NW/0382). The data access application submitted by the researchers of this article (application number 70227) had been reviewed by UK Biobank Ethics and Governance Council. The Institutional Review Board (IRB) of Yonsei University Health System had advised that no additional approval from the IRB is required since the research protocol had been approved by UK

(A) Linear interaction model
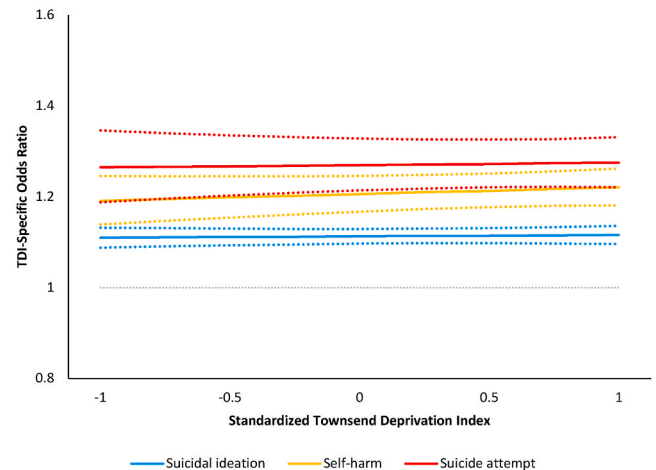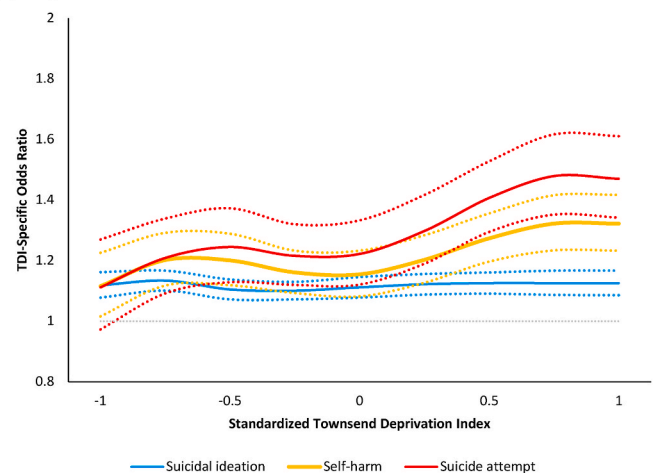
(B) Polynomial interaction model

Fig. 2. Interaction analysis: TDI-specific odds ratio of individual deprivation index on suicidal behaviors. (A) Linear interaction model; (B) Polynomial interaction model (color). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Biobank Ethics and Governance Council.

CRediT authorship contribution statement

Kwanghyun Kim: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Doo Woong Lee:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Sun Jae Jung:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

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 data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2024.101654.

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