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## Proximity to high streets, social isolation and social support in British adolescents: A longitudinal analysis of sociospatial influences on social connectedness using geospatial data

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### ABSTRACT

High streets have been shown to be central to socio-economic activity, given their diverse residential, leisure, and commercial activities. This study explores the link between adolescent social isolation and proximity to, and land use mix in, high streets. Hypothesising that greater distance from high streets might increase social isolation, measured via social activities, friend contact frequency, and social support, we used multilevel modelling with data from the Millennium Cohort Study. We did not observe a relationship between proximity to high streets and these social isolation indicators, suggesting that high streets may either not significantly influence adolescent social engagement or that young people are willing to travel greater distances.

### 1. Introduction

Social relationships are intrinsic to wellbeing and important for the maintenance of health (Holt-Lunstad et al., 2010). Social isolation is a recognised determinant of poor mental health with bi-directional associations between loneliness and poor mental health (Kirkbride et al., 2024). Social isolation in young people is associated with negative mental health outcomes such as depression (Matthews et al., 2016), long-term mental illness (Christiansen et al., 2021), emotional and psychological problems (Copeland, 2018; Högnäs et al., 2020) and suicidal thoughts (Armstrong and Manion, 2006). In older adults, pathways have been described from social isolation to loneliness and subsequent depression and anxiety symptoms (Santini et al., 2020), but more work is needed to understand these pathways in young people. This is important because adolescence represents a sensitive phase in life, marked by significant changes in social bonds and the peak period of onset for mental health (Solmi et al., 2022). Tackling social isolation in adolescence is therefore an obvious target for intervention to protect

mental health, yet we lack an understanding of the determinants of social isolation in young people.

Defining social isolation in young people is challenging. Social isolation is generally considered as an objective measure based on the quantity of social connections and number of meaningful ties (Wang et al., 2017). In adults this is typically assessed as the size of social networks, or number and frequency of social interactions (Holt-Lunstad and Steptoe, 2022) or most crudely as living alone, providing a proxy for limited social interactions with others. Such objective indicators show clear associations with poor mental health in older adults (Cornwell and Waite, 2009; Fakoya et al., 2020). However, for children and adolescents, who typically live with carers, indicators such as cohabitation status mean very little. In this age group, such indicators fail to capture differences in opportunities to interact with others and the developmental opportunities that arise from peer relationships and friendships. During early childhood the company of a friend is important, whilst in adolescence the need to feel accepted by peer groups becomes more valuable, including the feeling of belongingness, followed by a shift

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towards a desire for more intimate relationships into adulthood (Qualter et al., 2015). These changes in social needs and priorities during childhood and adolescence take place alongside transitions through education and puberty. Social isolation can also occur due to peer victimisation or rejection (Bowker et al., 2021). In this study, we utilise the frequency of social activities and social contact as indicators of social isolation in adolescence.

Estimates of the prevalence of social isolation in children and young people have used a range of indicators, such as number of close friends or degree of social support. Such work demonstrates that 5% of 11–15 year olds in Scotland have fewer than three close friends and 43% do not perceive high levels of peer support (Teuton, 2018). US survey data show that in-person social interaction time among young people (whether at home or in the community) declined significantly over the period 2006–2017 (Twenge et al., 2019). Comparing social isolation patterns across age groups and across adolescent populations is complicated by such differing definitions of social isolation. Nevertheless, a study using harmonised indicators in the UK revealed that younger age groups are less likely than older age groups to be members of clubs or organisations (Mansfield et al., 2023).

Social isolation is distinct from loneliness, which is defined as the distressing mismatch between a person's desired and perceived quantity and/or quality of social relationships (De Jong Gierveld, 1998) or as the subjective feeling of being alone and unsupported (Hämmig, 2019). The two are moderately correlated in adolescents (Matthews et al., 2016) and it is possible to feel lonely but not experience social isolation and vice versa (Holt-Lunstad et al., 2015). Both loneliness and social isolation are also distinct from social support, which can be described as the subjective availability of care and assistance (Scardera et al., 2020). Higher perceived social support has been linked with better health outcomes in adults, through lower loneliness (Segrin and Domschke, 2011). Among adolescents, perceived social support is associated with fewer depressive symptoms, with specifically family, friend and teacher support important (Rueger et al., 2016). A longitudinal study from Denmark concluded that perceived social support from friends at age 14/15 years was positively associated with indicators of mental health, including wellbeing, at age 20/21 years (Jakobsen et al., 2022). There is a specific evidence gap in relation to understanding the impacts of social isolation in adolescence on mental health (Qualter et al., 2022) in order to consider appropriate interventions.

Opportunities for young people to connect with others and nurture friendships must be considered in their wider (built) environmental contexts, including local areas where they might congregate with peers. High streets, traditionally the heart of urban communities, offer unique settings for social engagement and community integration (Joseph Rowntree Foundation, 2007). Social wellbeing is a key dimension of high streets as they can foster social interactions and a sense of community by acting as an accessible social space (Daly and Allen, 2018). Young people have less control over their home or school environment, so depend on socialising in outdoor and public spaces (Pearson et al., 2008). Investigating the relationship between these places of social interaction and social isolation and support can provide vital insights into how urban environments can influence adolescent well-being. With increasing concerns about social isolation in younger populations, particularly in the context of rapid urbanisation and digitalisation, understanding the impact of physical social spaces like high streets on adolescent social health becomes critical.

The role of the high street is varied: it brings people together for many different reasons including socialising, healthcare and travelling through to work (Vaughan, 2022). On the other hand, the distance of key facilities, such as shops, healthcare or leisure facilities, can prevent people from participating in the social life of the community (Church et al., 2000). High streets offer an array of functions, with users more likely to use those with a mix of products, stores and social experiences alongside practical features such as efficient transport (Hill and Cheshire, 2023). Accessibility to the high street can provide adolescents with

freedom of mobility without depending on parents or others for transport. Lacking their own spaces, young people often visit public spaces in groups to 'hang out' and gather without adult supervision (Pyry and Tani, 2015). These public spaces are opportunities for young people to make spaces of their own and develop a sense of identity and belongingness (Pickering et al., 2012).

Previous research has suggested a link between spatial factors that provide opportunities for social interactions, including local amenities and public spaces, and social isolation and loneliness (MacIntyre and Hewings, 2022). Research from older adults in the US concluded that those who lived closer to a city centre were less likely to report social isolation (Finlay and Kobayashi, 2018) whilst UK research has highlighted that high streets are important for social participation in older adults (Phillips et al., 2021). However, to our knowledge, no previous study has explored the association between high street proximity and diversity and social isolation outcomes in UK adolescents.

This study aimed to investigate the relationship between proximity to high streets at age 14 years, as a proxy for social opportunities, and social isolation and perceived social support in adolescents at age 17. We also aimed to investigate whether the diversity of high streets is associated with social isolation and social support. We hypothesised that greater distance from high street size may increase the likelihood of individuals being more socially isolated. We also hypothesised that high streets with greater diversity may potentially increase the number and variety of social venues available, therefore impacting social interactions.

## 2. Methods

This study was pre-registered on Open Science Framework (<https://doi.org/10.17605/OSF.IO/RZNYH>).

### 2.1. Participants

We analysed data from the publicly available Millennium Cohort Study (MCS); a nationally representative longitudinal birth cohort of 18,818 children born across the UK between September 2000 and January 2002 who were eligible to receive child benefits (Connelly and Platt, 2014). MCS used a stratified, clustered random sample design with oversampling of ethnic minority groups and disadvantaged areas. Data were collected at ages 9 months, 3 years (at which a further 1389 new families were included), 5, 7, 11, 14 and 17 years. At age 17, a total of 10,625 cohort members participated in the survey, including the face-to-face interview. At age 17, 6828 participants from England, Wales, Scotland and Northern Ireland completed an online self-completion questionnaire, which included responses to questions about social isolation. Participants from Northern Ireland were excluded due to a lack of high street data. The analytical sample ( $n = 5582$ ) was comprised of participants with available postcode data, successfully linked to a high street, and with any outcome measure at age 17.

### 2.2. Proximity to high streets

We measured proximity to the nearest high street as the shortest path through the street network between the participants' postcode centroid (i.e. the geographically central address of a postcode unit) at age 14 years and the nearest start, end, or intersection of a high street.

We used precise, vector-based geospatial data from Ordnance Survey (OS) i.e., OS Highways Roads and Path (Ordnance Survey, 2023) and OS Retail Geographies – High Streets (Kingston, 2019). These datasets offer a detailed, current snapshot of the urban road network for England, Wales, and Scotland (excluding Northern Ireland), including alleys and paths, the spatial extent of high streets, and their land uses.

OS defines high streets through a stepwise selection process (Office for National Statistics and Ordnance Survey, 2019). Initially, retail activity clusters are identified, each necessitating at least 15 retail

addresses within a 150-m radius. Subsequently, non-high street retail clusters (such as retail, business, or industrial parks) are filtered out by categorising address types and street names, enforcing building-to-address ratio limits, and the absence of residential land uses. We sought to offer a surrogate indicator for sites potentially hosting social activities, and locations where young people were likely to mingle with other people living or working in their neighbourhoods.

Distance between cohort members' postcodes to their closest high street was initially calculated in metres and re-scaled to kilometres for analysis.

### 2.2.1. Distance decay

In addition to the proximity to high streets, we also examined an exponential distance decay function (Vale and Pereira, 2017). This function allows for the effect of decreasing likelihood of interaction between an individual and their surrounding environment - whether making a purchase in a shop or visiting a leisure centre or park - namely the decreasing importance of an urban feature (in this case high streets) to a person with an increasing distance from it (Krenz et al., 2023). This yields a demonstrably better estimate of actual exposure than using circular buffers or aggregate estimates by census unit (Sadler and Lafreniere, 2017, p. 194) Distance decay functions continuously decrease values until converging to zero (when rounded), rather than an abrupt cut-off at pre-set distances, as is common inbuilt environment health studies (Ortegon-Sanchez et al., 2021). We applied a distance decay function at varying parameters equating to approximately 2000m, 1400m and 800m from each cohort member's postcode (Fig. 1a–b), based on precedent (Ortegon-Sanchez et al., 2021).

### 2.3. Diversity of high streets

We captured differences in high street character by measuring land use diversity using Shannon's Diversity Index (Shannon, 1948). The diversity index is an indicator of the number of different land uses present; high streets with a greater mix of land uses are considered to feature a higher potential for social interaction. We used the number of unique addresses classified into one of five land use classes (i.e., residential, leisure, office, retail and community) for each high street. Higher diversity values indicate higher diversity. Diversity was measured on a scale that takes account of the theoretical presence of all five land uses along any single high street, namely  $0-1.609^1$  (Shannon, 1948).

### 2.4. Social isolation

#### 2.4.1. Social activities

At age 17, as part of the online self-completion questionnaire, participants were asked about the frequency of their social activities in the community. The questions captured how often they.

- Go to a party, dance, house party or nightclub
- Go to the theatre (for example to see a play, pantomime or opera)
- Go to watch live sport (for example at a stadium)
- Sing in a choir or play in a band or orchestra
- Go to a live music concert or gig
- Go to youth clubs, explorer scouts, senior guides or other organised activities
- Go to a library
- Go to museums or galleries, visit a historic place or stately home
- Do voluntary or community work
- Go to a political meeting, march, rally or demonstration
- Attend a religious service.

<sup>1</sup> This value is effectively  $\ln(\text{max number of classes})$ , or  $\ln(5)$  in our case; the value differs depending on the number of land uses (or species) measured.

The response options were: Most days, At least once a week, At least once a month, Several times a year, Once a year or less, Never or almost never. We combined and coded into three categories, whereby the lowest category reflected minimal social activity (responded Never, Once a year or less, or Several times a year to all activities), the middle category corresponded engaging in any activity At least once a month and the highest corresponded to high social activity with a frequency of At least once a week or Most days to any activity.

#### 2.4.2. Contact with friends

Participants were also asked about the frequency of contact with friends outside of school or work. Response options were: Most days, At least once a week, At least once a month, Several times a year, Once a year or less, Never or almost never. We combined this in categories where the lowest category reflected the lowest frequency of contact.

### 2.5. Social support

The Social Provisions Scale (SPS) was used to measure perceived social support. At age 17, three items were included from the 10-item Social Provisions Scale in the online self-completion questionnaire. Young people were asked to choose responses to the following.

- I have family and friends who help me feel safe, secure and happy
- There is someone I trust whom I would turn to for advice if I were having problems
- There is no one I feel close to.

Response options were: very true, partly true, or not at all true. The three variables were averaged together to create one continuous variable with a mean value and higher scores indicating higher social support.

### 2.6. Covariates

We included demographic and socioeconomic variables as covariates. We included sex at birth. Ethnicity was self-reported according to 6 categories: White, Mixed, Indian, Pakistani and Bangladeshi, Black or Black British, Other Ethnic Group (incl. Chinese, other, as defined by MCS). Parental education was measured as the overall highest level of educational attainment recorded up to the most recent survey sweep, namely age 17 years.

Highest parent occupational status was measured using the UK National Statistics Socio-economic Classification's (NS-SEC) 5 categories: managerial, administrative, and professional occupations; intermediate occupations; small employers and own account workers; lower supervisory and technical occupations; semi-routine and routine occupations; with an additional category for unemployed.

Household income was measured using parental self-reports of net household income.

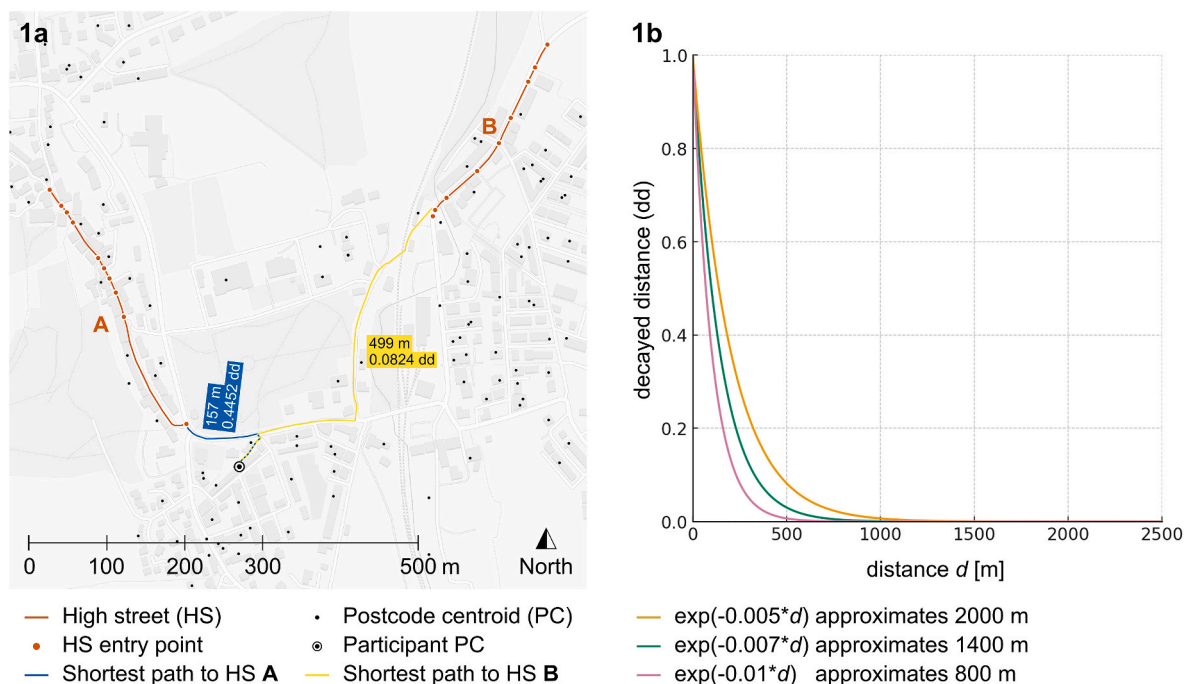
Mean financial wealth (investment and asset amount minus debts owed) and housing wealth (outstanding mortgage and house value) were also included.

### 2.7. Statistical analysis

Statistical analyses were conducted using Stata 18.

We presented descriptive statistics as frequencies and means with standard deviations. Distributions of sex, ethnicity, parental education and income of the sample that completed the face-to-face interview compared with the analytical sample at age 17 can be found in the supplementary information (Supplementary Table S1.1).

Proximity to and diversity of high streets was captured for the built environment characteristics at age 14 and three outcomes of social isolation were measured at age 17, to measure prolonged exposure and capture prospective associations. The three-year interval between



**Fig. 1.** a) Visualisation of a hypothetical participant's postcode and two shortest paths to the nearest high street entry points (showing distance in meters and decayed distance value  $dd$ ). Contains data from © Ordnance Survey, 2023 and CartoDB; b) Visualisation of three distance decay functions. Each line corresponds to a decay model, illustrating the variation in decayed distance (0–1) as a function of the initial distance (in meters).

capturing the exposures at age 14 and the subsequent data collection at age 17 is deliberately chosen to provide sufficient time for a high street environment to influence adolescent social behaviour and potential social isolation. To take into account the potential for estimates to be biased due to some subjects having moved house over that period, we included in our supplementary material a post hoc sensitivity analysis excluding all those adolescents who moved house, to compare estimates to those from our main analysis. 9% ( $n = 512$ ) of participants in the analytic sample changed address between ages 14 and 17.

A random intercept multilevel regression was used to assess associations between proximity to high streets and the three social isolation outcome variables considered separately (social activities, frequency of contact with friends and social support). Multilevel modelling can account for neighbourhood clustering i.e. individuals nested within the same geographical areas are likely to have correlated observations. This was important as the MCS is geographically clustered by electoral wards.

Linear multilevel models were used to estimate associations between distance to closest high street and the continuous social support outcome variable, while the logistic multilevel model was used to estimate associations with the frequency of contact with friends and social activities outcome variables (reference group of lowest categories coded as 0).

We first estimated the proportion of variance in social isolation outcomes accounted for by neighbourhood clusters as a baseline reference. The Variance Partition Coefficient (VPC) measures how much variation in the independent variable (social isolation or social support) is accounted for by clustering.

In separate models we examined associations with 1) distance to the closest high street and 2) diversity of land use. We first ran each model unadjusted, then adjusted for sex, ethnicity, parental education, occupational status, overall wealth and income. We stratified adjusted models by sex; results are presented stratified.

## 2.7.1. Sensitivity analysis

**2.7.1.1. Non-linearity.** We tested for potential non-linearity in the relationship between distance to the closest high street and all three

outcomes by first including a quadratic term in the adjusted models (i.e., a squared term for proximity to a high street). We used visual plots, ROC curves and AIC/BIC to investigate the fit between the models with and without the quadratic term.

We additionally used a second approach to account for potential non-linearity, applying a decay function to spatial distances (Fig. 1a and b). We conducted an analysis exploring associations between decayed distance at varying parameters of approximately 2000m, 1400m and 800m and indicators of social support and social isolation.

**2.7.1.2. Average diversity of high streets.** We also explored associations between the average diversity of high streets within distance decayed radii of 2000m, 1400m and 800m and the social isolation and social support outcomes.

**2.7.1.3. High street size.** We hypothesised that high street size may potentially affect the number and variety of social venues available, therefore impacting social interactions. We included a measure of the size of the closest high street into models examining associations between distance to the closest high street and the three outcomes to test for potential confounding.

We additionally included the size of high streets within the radii of 2000m, 1400m and 800m and included these into the respective 2000m, 1400m and 800m distance decay models.

**2.7.1.4. House movers.** Sensitivity analysis was additionally conducted between the full sample (including those that changed address) and without those that moved house between the sweeps.

**2.7.1.5. Overall social isolation measure.** In addition, as a post hoc analysis we examined overall social isolation by combining measures of frequency of social activities and contact with friends. This overall measure was coded into three categories, whereby the lowest category reflected minimal social activity (responses: *Never*, *Once a year or less*, or *Several times a year* – to all activities that included contact with friends), the middle category corresponded to: engaging in any activity *At least*

once a month and the highest corresponded to high social activity with a frequency of *At least once a week* or *Most days* to any activity that included contact with friends.

### 2.7.2. Missing data

For missing information within the analytic sample, multiple imputation with chained equations was used with 10 imputations. To account for non-response and adjust for attrition and survey design, combined survey and non-response weights were used (Fitzsimons et al., 2020).

## 3. Results

### 3.1. Descriptive characteristics

Table 1 shows the descriptive characteristics of the analytic sample

**Table 1**  
Study sample characteristics (n = 5582).

Sex	Frequency	Percent
Female	3123	55.95
Male	2459	44.05
Total	5582	100.00
<b>Highest Parental Education</b>		
NVQ level 1 (CSE below grade 1/GCSE or O Level below grade C, SCE Standard, Ordinary grades below grade 3 or Junior Certificate below grade C)	100	2.00
NVQ level 2 (O Level or GCSE grade A-C, SCE Standard, Ordinary grades 1–3 or Junior Certificate grade A-C)	722	14.46
NVQ level 3 (A/AS/S levels, SCE Higher, Scottish Certificate Sixth Year Studies, Leaving Certificate)	656	13.14
NVQ level 4 (first degree, diplomas in higher education, teaching qualifications for schools or further education)	2107	42.20
NVQ level 5 (higher degree, postgraduate qualification, certificate or diploma)	1178	23.59
Other academic qualifications (incl. overseas)	230	4.61
Total	4993	100.00
Missing	589	
<b>Ethnicity</b>		
White	4472	80.13
Mixed	249	4.46
Indian	168	3.01
Pakistani and Bangladeshi	379	6.79
Black or Black British	170	3.05
Other ethnic group (inc Chinese, other)	143	2.56
Total	5581	100.00
Missing	1	
<b>Income Quintile</b>		
First quintile	686	12.30
Second quintile	747	13.40
Third quintile	1037	18.60
Fourth quintile	1436	25.75
Highest quintile	1670	29.95
Total	5576	100.00
Missing	6	
<b>ONS Rural/Urban classification</b>		
Rural	1399	25.09
Urban	4177	74.91
Total	5576	100.00
Missing	6	
<b>Occupational status</b>		
Not in work	1339	24.18
Semi-routine and routine	904	16.32
Lower supervisory and technical	142	2.56
Small employers/self-employed	373	6.74
Intermediate	971	17.53
Higher managerial	1809	32.67
Total	5538	100.00
Missing	44	

(n = 5582). 56% of our sample were female and 44% were male. The sample was also mostly white (80%). There were no sociodemographic differences between our analytic sample and the full MCS age 17 sample that completed the face-to-face interview (Supplementary Table S1.1).

Tables 2 and 3 show the distribution of responses for the frequency of social contact, social activities and social support. At age 17, 55% and 69% of participants reported participating in social activity or contact with friends respectively at least once a week or every day. 63% reported the highest level of social support.

269 (5% of the analytic sample) participants were in the lowest category for both frequency of social activities and social contact (i.e. they reported never, once a year or less, or several times a year) meaning they scored the highest in both indicators for social isolation. Supplementary Table S1.2 shows the demographic characteristics of these 269 participants compared with the remaining analytic sample. The demographic and person characteristics of this group (lowest category for both frequency of social activities and contact) were similar to the analytic sample with the exception of parental occupational status. 41% of participant's main parental respondent (predominantly mothers) were not in work compared to 23% in the analytic sample.

Sensitivity analysis excluding the 9% of those who moved house produced estimates that were no different from those from the main analytic sample.

The mean distance to the closest high street was 2.23 km (min = 0.0002 km; max = 160.49 km); 2024 participants (36%) lived within 800m (around a 10-min walk) of their closest high street whilst 617 (11%) participants lived over 5 km away from a high street.

We found that 3.1% (95% CI 1.9, 4.9) of the variance in social contact with friends, 8% (95% CI 6.1, 10.8) of the variance in frequency of social activity and 1.2% (95% CI 0.4, 3.3) of the variance in social support was due to differences in neighbourhood clusters.

### 3.2. Distance to closest high street

#### 3.2.1. Frequency of social activities

There was no association of between distance (km) to closest high street and frequency of social activities in either males or females (Table 4). The VPC estimated that neighbourhood clusters account for 6.1% (95% CI 3.83, 9.76) of total residual variance in highest category of social activities frequency.

#### 3.2.2. Frequency of contact with friends

We found no associations between participant's distance (km) to closest high street at age 14 and frequency of contact with friends at age 17 in unadjusted or adjusted models in either males or females (Table 4). The VPC estimated that neighbourhood clusters account for 9.1% (95% CI 5.34, 15.19) of total residual variance in the highest category of social contact with friends.

#### 3.2.3. Social support

We found no associations between participant's distance (km) to closest high street at age 14 and social support at age 17, in either females or males (Table 4). The VPC estimated that neighbourhood clusters accounted for 0.9% (95% CI 0.25, 3.45) of total residual variance in social support.

### 3.3. Diversity index of land uses of the closest high street

We found no associations between the diversity of participants closest high street and frequency of social activities, contact with friends or social support, in either males or females in unadjusted or adjusted models (Table 5).

**Table 2**  
Distributions of indicators of social isolation at age 17 years.

	Frequency of contact with friends						Social activities					
	All (n = 5577)		Male (n = 2458)		Female (n = 3119)		All (n = 5577)		Male (n = 2455)		Female (n = 3122)	
Lowest category ( <i>never, once a year or less, or several times a year</i> )	605	10.85%	292	11.88%	313	10.04%	1259	22.57%	584	23.79%	675	21.62%
Middle category ( <i>at least once a month</i> )	1100	19.72%	424	17.25%	676	21.67%	1271	22.79%	547	22.28%	724	23.19%
Highest category ( <i>at least once a week or every day</i> )	3872	69.43%	1742	70.87%	2130	68.29%	3047	54.67%	1324	53.93%	1723	55.19%

Note: Participants were asked about the frequency of contact with friends outside of school or work and about the frequency of their social activities in the community.

**Table 3**  
Distributions of Social Provisions Scale (SPS) items used to capture social support, age 17 years.

I have family and friends who help me feel safe, secure and happy	Frequency	Percent
Not true at all	81	1.49
Partly true	1061	19.48
Very true	4306	79.04
Total	5448	100.00
Missing	134	
<b>There is someone I trust whom I would turn to for advice if I were having problems</b>		
Not true at all	191	3.51
Partly true	906	16.64
Very true	4349	79.86
Total	5446	100.00
Missing	136	
<b>There is no one I feel close to</b>		
Not true at all	4260	78.37
Partly true	966	17.77
Very true	210	3.86
Total	5436	100.00
Missing	146	

Note: for analysis variables were combined and averaged to create one continuous variable with lower scores indicating lower social support. Analytic sample (n = 5582).

**Table 4**  
Associations between distance (km) to closest high street and indicators of social isolation and social support.

Frequency of social activities OR (95% CI)	All (n = 5577)		Male (n = 2455)		Female (n = 3119)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Middle category (compared to lowest)						
Distance	1.01 (0.97, 1.05)	1.00 (0.98, 1.03)	1.06 (1.00, 1.11)	1.04 (0.99, 1.09)	1.00 (0.98, 1.03)	1.00 (0.98, 1.02)
VPC	10.0% (7.59, 1.53)	7.6% (4.49, 12.91)	13.3% (7.69, 2.22)	10.5% (5.26, 20.20)	13.4% (7.69, 22.24)	10.2% (5.12, 19.40)
Highest category (compared to lowest)						
Distance	1.01 (0.97, 1.04)	1.01 (0.98, 1.03)	1.04 (1.00, 1.09)	1.04 (1.00, 1.08)	1.00 (0.97, 1.02)	0.99 (0.97, 1.02)
VPC	9.5% (6.58, 1.36)	6.1% (3.83, 9.76)	11.2% (7.26, 16.9)	7.6% (3.83, 14.24)	12.7% (7.10, 21.76)	10.0% (5.93, 17.15)
<b>Frequency of social contact OR (95% CI)</b>						
Middle category (compared to lowest)						
Distance	1.01 (0.99, 1.03)	1.00 (0.99, 1.02)	0.99 (0.97, 1.02)	0.99 (0.97, 1.01)	1.03 (0.98, 1.08)	1.02 (0.99, 1.04)
VPC	10.2% (6.38, 15.88)	10.3% (6.45, 16.17)	18.8% (9.96, 32.59)	18.1% (9.41, 32.45)	20.4% (12.82, 30.85)	20.4% (11.76, 34.85)
Highest category (compared to lowest)						
Distance	0.99 (0.97, 1.01)	0.98 (0.96, 1.00)	0.98 (0.96, 1.00)	0.98 (0.95, 1.00)	1.01 (0.95, 1.08)	0.98 (0.93, 1.04)
VPC	9.44% (6.08, 14.37)	9.1% (5.34, 15.19)	12.9% (7.51, 21.33)	13.1% (7.57, 21.85)	16.3% (10.37, 24.64)	15.5% (8.72, 27.18)
<b>Social support coefficient (95% CI)</b>						
Middle category (compared to lowest)						
Distance	0.001 (-0.001, 0.003)	0.00 (-0.002, 0.002)	-0.001 (-0.004, 0.002)	-0.001 (-0.005, 0.002)	0.003 (-0.001, 0.01)	0.002 (0.00, 0.00)
VPC	1.2% (0.44, 3.42)	0.9% (0.25, 3.45)	2.8% (1.23, 6.41)	3.1% (1.41, 6.72)	2.4% (0.79, 6.83)	1.9% (0.52, 6.62)

Note: Logistic random intercept multilevel regression used to estimate relationships with frequency of social activities and social contact, OR (Odds ratio). Linear random intercept multilevel regression used to estimate association with social support. Model 1 unadjusted. Model 2 adjusted for overall wealth, occupational status, income, parental education, sex and ethnicity.

VPC = Variance Partition Coefficient. Lowest category = responded never, once a year or less, or several times a year to all activities. Middle category = responded at least once a month to any activity. Highest category = at least once a week or every day to any activity. Social support variable was comprised of 3 items from the Social Provisions Scale; higher scores indicate higher social support.

### 3.4. Sensitivity analyses

#### 3.4.1. Non-linearity

We explored non-linearity firstly with the inclusion of a quadratic term within all models. We did not find evidence that including a quadratic term improved model fit. We also modelled distance decayed at radii cutoffs of approximately 2000m, 1400m and 800m; which did not show evidence of better model fit. Full modelling results are presented in [Supplementary Information Tables S4–6](#).

#### 3.4.2. Average diversity of all high streets

We found no associations between the average diversity of all high streets within radii of 800m, 1400m and 2000m and the frequency of social activities, frequency of contact with friends or social support. Full modelling results can be found in [Supplementary Tables S8–10](#).

#### 3.4.3. High street size

We included the size of the closest high street as an additional covariate to the distance to the closest high street and social isolation and support models; this did not change the results. These results can be found in [Supplementary Tables S11–12](#).

#### 3.4.4. House movers

We found no associations between proximity to closest high street and closest high street diversity and indicators of social isolation and social support in the analytic sample excluding the 9% of house movers. Results can be found in [Supplementary Tables S13–14](#).

Table 5

Associations between diversity of land use of closest high street and indicators of social isolation and social support.

Frequency of social activities OR (95% CI)						
	All (n = 5577)		Male (n = 2455)		Female (n = 3119)	
Middle category (compared to lowest)						
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Diversity	1.82 (1.06, 3.14)	1.59 (0.92, 2.75)	2.50 (1.22, 5.10)	1.93 (0.95, 3.93)	1.58 (0.81, 3.10)	1.57 (0.79, 3.12)
VPC	9.3% (5.87, 14.39)	7.1% (4.09, 12.40)	12.3% (6.73, 21.40)	9.8% (4.72, 19.69)	11.9% (6.41, 21.05)	9.5% (4.59, 18.81)
Category 3 (compared to lowest)						
Diversity	1.49 (0.90, 2.47)	1.33 (0.79, 2.25)	1.69 (0.90, 3.17)	1.32 (0.71, 2.49)	1.47 (0.74, 2.91)	1.65 (0.80, 3.42)
VPC	9.3% (6.32, 13.37)	6.0% (3.66, 9.69)	10.9% (6.99, 16.72)	7.7% (3.83, 14.49)	12.9% (8.16, 20.04)	9.9% (5.80, 17.10)
<b>Frequency of social contact OR (95% CI)</b>						
Middle category (compared to lowest)						
	All (n = 5577)		Male (n = 2458)		Female (n = 3119)	
Diversity	1.27 (0.63, 2.54)	1.04 (0.52, 2.06)	2.18 (0.80, 5.92)	1.42 (0.53, 3.83)	0.77 (0.30, 1.96)	0.76 (0.28, 2.02)
VPC	10.1% (6.31, 15.70)	10.3% (6.43, 16)	0.19 (0.60, 1.26)	18.0% (9.26, 32.49)	0.20 (0.13, 0.30)	19.8% (11.26, 34.30)
Category 3 (compared to lowest)						
Diversity	0.97 (0.55, 1.71)	0.83 (0.47, 1.48)	1.25 (0.59, 2.62)	1.08 (0.50, 2.35)	0.68 (0.29, 1.60)	0.62 (0.25, 1.51)
VPC	9.5% (6.10, 14.41)	9.4% (5.5, 15.60)	0.13 (0.07, 0.21)	13.2% (7.69, 21.91)	0.17 (0.11, 0.25)	16.2% (9.04, 28.36)
<b>Social support coefficient (95% CI)</b>						
	All (n = 5450)		Male (n = 2397)		Female (n = 3053)	
Diversity	-0.003 (-0.07, 0.06)	-0.03 (-0.09, 0.04)	-0.003 (-0.10, 0.09)	-0.02 (-0.12, 0.08)	-0.01 (-0.10, 0.08)	-0.03 (-0.12, 0.06)
VPC	1.2% (0.44, 3.43)	1.0% (0.26, 3.43)	2.9% (1.23, 6.46)	3.1% (1.43, 6.82)	2.4% (0.80, 6.82)	1.9% (0.53, 6.54)

Note: Logistic random intercept multilevel regression used to estimate relationships with frequency of social activities and social contact, OR (Odds ratio). Linear random intercept multilevel regression. Model 1 unadjusted.

Model 2 adjusted for overall wealth, occupational status, income, parental education, sex and ethnicity. VPC = Variance Partition Coefficient. Lowest category = responded never, once a year or less, or several times a year to all activities. Middle category = responded at least once a month to any activity. Highest category = at least once a week or every day to any activity. Social support variable was comprised of 3 items from the Social Provisions Scale; higher scores indicate higher social support.

### 3.4.5. Overall social isolation

We additionally measured associations between proximity to closest high street and closest high street diversity and overall social isolation (combined measure of frequency of social activities and social contact). We found no associations; results are displayed in [Supplementary Table S15](#).

## 4. Discussion

### 4.1. Main findings

Contrary to expectations, our study revealed no associations between proximity to high streets or diversity of closest high streets with the frequency of various social activities, contact with friends or social support in adolescents. Our findings may indicate that proximity to and land use diversity of high streets are not significant for participation in social activities and social contact and perceived support in this age group in Britain.

Our study filled a recognised evidence gap (Qualter et al., 2022) in providing an estimate of the level of social isolation and perceived social support in adolescence and investigating place-based influences on adolescent connectedness. Previous research has reported that adolescent males experience greater social isolation than females (Umberson et al., 2022). However, our data revealed no differences between the frequency of social activities and social contact between males and females. 24% of males, compared to 22% of females, responded never, once a year or less, or several times to participating in any social activity. 12% of males reported never, once a year or less, or several times a year to see friends outside of school or work compared to 10% of females. However, our analytic sample was relatively smaller than this study (n = 14,056 and 22,156) (Umberson et al., 2022).

### 4.2. Findings in the context of other studies

We found that 8% (95% CI 6.1, 10.8) of the variance in social activity could be accounted for by neighbourhood clusters, in this case, electoral wards. This is similar to previous research that reported UK geographic regions accounted for 5–8% of the variation in loneliness in young

people (Marquez et al., 2023).

There is limited existing research examining proximity to high streets and social isolation indicators, making it difficult to compare our findings with other studies. The role of the high street in social participation appears to be important for older adults (Phillips et al., 2021) but our findings indicate that the distance to high streets may not be as important for social activities, social contact and social support for adolescents as we had hypothesised. It is possible that younger individuals can overcome these distances more easily due to higher mobility and better access to transport, as compared to older individuals and that the proxy of distance to the high street therefore becomes less relevant. Further, some of the social activities we investigated at age 17 included going to a club, theatre, stadium, museum or gig, for which young people might be willing to travel longer distances. Other social activities that we investigated, such as attending a religious service or explorer scouts might, in turn, be less related to distance to the high street (British Youth Council, 2012; Collings et al., 2023).

Alternatively, it might be possible that adolescents socialise in spaces other than around the high street, including online, and that distances to high streets are therefore less relevant for social connectedness. In the current study social contact was measured as how often the respondent sees friends outside of school or work, but we did not include communication via social media, gaming, or mobile phones. This approach overlooks the extent to which adolescents use social media to maintain social relationships. Indeed, some research has suggested that increased social media use leads to the displacement of face-to-face interactions among adolescents (Winstone et al., 2021). Furthermore, other spaces may be meaningful for adolescent social interaction, which may include green spaces as indicated in the existing literature (Hind et al., 2021; Lyons et al., 2022). Some research indicates that adolescents prefer indoor shopping centres and green spaces close to home and that these areas support social interaction behaviours (Clark and Uzzell, 2002). A case study of 48 participants from London reported that young people (16–24 year olds) felt most socially connected in parks, religious places and places where they could engage in activities (Moore et al., 2023).

In this study, we did not consider the quality and character of high streets. Although a greater mix of land uses, as captured through Shannon's diversity index, is indicative of a healthier high street (Daly

and Allen, 2018) it does not measure local crime, aesthetics, places to sit or other important features of high streets, which may impact their usage. For example, research has shown that crime, such as street robbery, can limit resident's social activities and negatively impact mental health (Jones et al., 1987; Dustmann and Fasani, 2016). Increased levels of litter, fly-tipping and graffiti also reduce the amount of time people spend visiting those areas (Daly and Allen, 2018). Moreover, high streets with carefully placed seating provide opportunities for people to gather and talk, which may be particularly important for adolescents who often rely on public spaces to socialise (Pearson et al., 2008; Department for Communities and Local Government, 2012).

In this current study, we did not consider neighbourhood perceptions. A study set in the UK reported that young people aged 16–24 years experienced less loneliness if they felt a greater sense of belonging to their neighbourhood and had higher perceived neighbourhood quality (Marquez et al., 2023). Similarly, a study set in London highlighted the important role of young people's views and experiences of their neighbourhood with regard to feelings of social connectedness Moore et al. (2023). Whilst high street proximity and diversity may be important, participant perceptions of their local area could be a salient factor in levels of social isolation that we did not consider.

#### 4.3. Strengths and limitations

Strengths of this study include a large sample size and the use of nationally representative, demographically diverse longitudinal data on a sample of adolescents. Another key strength is the use of diverse disciplinary perspectives in building our hypotheses, linking the datasets, and interpreting findings. Rather than conflating social isolation, social ties and loneliness (Valtorta et al., 2016) we conceptualised social isolation as an objective lack of social contact, operationalised by measuring the frequency of social activities and social contact. We used geographically detailed measures of high street proximity, taking into account both the closest and those within walking distance (including using distance decay measures) from the high street.

Limitations of this study included that our frequency of social activities variable included components such as frequency of attending a youth club, religious service, music gig or party. The aggregation of these social activities lacked specificity and may have obscured possible effects. However, it was not computationally possible to run each model with every individual component of the activity exposure. We measured perceived social support with three items from the 10-item Social Provisions Scale (Cutrona and Russell, 1987); a validated and widely used measure of social support. However, the inclusion of only three items in the MCS may have limited the scale's ability to represent social support. Such measures also failed to capture the digital connectivity of adolescents or acknowledge that social media and gaming are important modes of communication. Furthermore, a measure of sense of belonging, which may be particularly important during adolescence, was not available in MCS.

Our data did not allow us to assess the exact provisions and amenities in the local areas of cohort members. Although the land use diversity index would, to some extent, capture the availability of facilities such as parks, religious places or other places where they could engage in activities, we were limited by the diversity index to land use categories of residential, leisure, office, retail, and community and did not include green spaces. We therefore were not able to specify whether particular features of the high street were significant for social isolation in adolescents.

As address-level data were not available due to confidentiality, we utilised participant postcodes, which is not a precise measure of the home location. The administrative classifications of postcodes may lead to scaling issues, giving rise to the modifiable areal unit problem (MAUP) and ecological fallacy in particular (Sadler and Lafreniere, 2017).

Furthermore, we used a standard OS definition of a high street,

which only includes high streets with a minimum of 15 retail addresses. It is possible that the importance of smaller high streets, particularly in coastal and rural areas, was therefore overlooked.

#### 4.4. Research and policy implications

Our null findings in the cohort of adolescents suggest that proximity to high streets is not a key influence on adolescent social connectedness in Britain. Further qualitative work, including walking interviews and GPS-based tracking of participants, is needed to understand which spaces offer opportunities for young people to encounter and congregate with others, and which features of the sociospatial environment attract such encounters in rural and urban environments. It would also be important to understand if, and how, young people may be able to overcome greater distances to high streets. It would be important to conduct similar quantitative work to investigate our hypotheses in older cohorts and compare findings, as high street proximity may be important for other age groups.

### 5. Conclusions

This study sought to improve understanding of the effects of proximity to high streets on social isolation and or perceived social support in adolescents. We did not find evidence for associations between proximity or diversity of closest high streets and either social isolation or perceived social support in our British sample. Further research focusing on quality and perceptions of high streets is warranted, including in other age groups and settings.

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#### CRediT authorship contribution statement

**Charlotte Constable Fernandez:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Jane Maddock:** Writing – review & editing, Validation, Supervision, Methodology. **Praveetha Patalay:** Methodology, Conceptualization. **Anne-Kathrin Fett:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization, Methodology. **Alexandra Pitman:** Writing – review & editing, Conceptualization, Methodology. **Laura Vaughan:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Kimion Krenz:** Writing – review & editing, Visualization, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization.

#### Declaration of competing interest

None.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.healthplace.2024.103260>.

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