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Social isolation, loneliness, socioeconomic status, and health-risk behaviour in deprived neighbourhoods in Denmark: A cross-sectional study

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ABSTRACT

The importance of social isolation and loneliness on our health is widely recognised in previous research. This study compares loneliness in deprived neighbourhood with that in the general population. It further examines whether social isolation and loneliness are associated with health-risk behaviours (including low intake of fruit or vegetables, daily smoking, high-risk alcohol intake, and physical inactivity and their co-occurrence) in deprived neighbourhoods, and whether social isolation and loneliness modify the associations between socio-economic status and health-risk behaviours. Cross-sectional data from 5113 residents of 12 deprived neighbourhoods in Denmark were analysed using multiple logistic regression. Data on 14,686 individuals from the nationally representative Danish Health and Morbidity Survey 2010 were used as a comparison group with regard to loneliness. Cohabitation status, frequency of meeting with family and friends, participation in voluntary work were used as an indicator to measure social isolation. A question on feeling often unwillingly alone was used as an indicator to measure loneliness. Compared with the general population, residents of deprived neighbourhoods had higher odds of loneliness. Both social isolation and loneliness were significantly associated with higher odds of health-risk behaviour. When social isolation and loneliness were combined with low socioeconomic status, strong associations with health-risk behaviours were found. Social isolation and loneliness did not significantly modify the associations between socioeconomic status and health-risk behaviour. The findings in this study have important implications for the future planning of health promotion intervention programmes aimed to reduce health-risk behaviour in deprived neighbourhoods.

Introduction

Social relationships are widely recognised as important social determinants of health (Berkman & Glass, 2014). It is well documented that both social isolation and loneliness are associated with an increased risk of mortality (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015). Living alone and having infrequent social contacts with family and friends are some of the markers of social isolation (Perissinotto & Covinsky, 2014; Shankar, McMunn, Banks, & Steptoe, 2011). Whereas social isolation is an objective, quantifiable measure (Holt-Lunstad et al., 2015), loneliness is the subjective experience of being lonely, related to dissatisfaction with the discrepancy between desired and actual frequency of social contact (de Jong Gierveld & Havens, 2004; Peplau & Perlman, 1982). A number of mechanisms have been identified through

which social isolation and loneliness may affect mortality risk, including health behaviour (Berkman & Glass, 2014; Berkman, Glass, Brissette, & Seeman, 2000; Cacioppo et al., 2002; Hawkley & Cacioppo, 2010). Social relationships may affect health behaviour in many ways, for example through the diffusion of knowledge about health behaviour and the maintenance of healthy behavioural norms through informal social control (Berkman & Glass, 2014). Conversely, it is also argued that social relationships may be an important factor in the dissemination of health-risk behaviour, such as smoking (Christakis & Fowler, 2008).

Previous studies have found that social isolation is associated with health-risk behaviours, such as unhealthy diet, smoking, high alcohol intake, physical inactivity, and multiple health-risk behaviours (Kaplan, Lazarus, Cohen, & Leu, 1991; Locher et al., 2005; Shankar et al., 2011; Weyers et al., 2010a). Results concerning the association between

loneliness and health-risk behaviours are ambiguous, with some studies finding no significant difference in health-risk behaviour between lonely and non-lonely individuals (Cacioppo et al., 2002; Hawkley & Cacioppo, 2003), while others have found that lonely individuals are more likely to smoke (Lauder, Mummery, Jones, & Caperchione, 2006) and be less physically active (Hawkley, Thisted, & Cacioppo, 2009).

Most studies of health-risk behaviour have focused on either social isolation or loneliness and only few studies have examined both simultaneously (Holt-Lunstad et al., 2015; Shankar et al., 2011). Loneliness has been found to have a weak correlation with social isolation (Cornwell & Waite, 2009; Coyle & Dugan, 2012) and social isolation and loneliness may therefore be distinct concepts that can occur without one another. For instance, some persons may feel lonely despite having frequent social contact, whereas others with infrequent contact do not feel lonely. Due to the conceptual difference between social isolation and loneliness, the investigation of their relative importance on health-risk behaviour may provide important knowledge for the planning of interventions to reduce health-risk behaviour.

Particularly in deprived neighbourhoods, it may be relevant to examine the role of social isolation and loneliness on health-risk behaviour (Mackereth & Appleton, 2008), since health-risk behaviour has been found to be much more prevalent among residents of deprived neighbourhoods than among residents in non-deprived neighbourhoods (Algren, Bak, Berg-Beckhoff, & Andersen, 2015; Algren et al., 2017). Additionally, previous studies have found high prevalence of loneliness in deprived neighbourhoods (Kearns, Whitley, Tannahill, & Ellaway, 2015; Scharf, Phillipson, & Smith, 2005). A better understanding of the respective influence of social isolation and loneliness on health-risk behaviour would help identify groups at risk and thus improve interventions to reduce health-risk behaviour in deprived neighbourhoods. Furthermore, large socioeconomic differences in health-risk behaviour among residents of deprived neighbourhoods have been found (Algren et al., 2017) and it seems that social relationships have the potential to reduce these differences. However, it remains uncertain whether social isolation and loneliness have a negative effect on the associations between socioeconomic status (SES) and health-risk behaviours in deprived neighbourhood.

Although an association between social relationships and health-risk behaviour has been documented, research on this association in deprived neighbourhoods is scarce (Yu, Renton, Schmidt, et al., 2011; Yu, Renton, Wall, et al., 2011). Yu et al. (2011) found an association between weak social network and low physical activity in six deprived neighbourhoods in London (Yu, Renton, Wall, et al., 2011). In another study, they showed that higher levels of social contacts with friends and neighbours contributed to increased leisure time physical activity among residents of 40 deprived neighbourhoods in London (Yu, Renton, Schmidt, et al., 2011).

The overall aim of the present study was first to compare loneliness among residents in deprived neighbourhoods with that in the general population, second to investigate whether social isolation and loneliness were associated with health-risk behaviours (including their co-occurrence) among residents of deprived neighbourhoods, and third to examine whether social isolation and loneliness modified the associations between SES and health-risk behaviours.

Materials and methods

Data material

Deprived Neighbourhood Health Profile Survey

Data on the residents of deprived neighbourhoods were derived from the cross-sectional *Deprived Neighbourhood Health Profile Survey* (DNHPS). Data were collected January–March 2011 in 12 deprived neighbourhoods in Denmark. "Deprived neighbourhood" is defined here as a geographically bounded area with a high proportion of adults with low SES characterised by indicators such as unemployment, low income,

low educational level, and low-paying jobs (Bak, Tanggaard Andersen, Bacher, & Draghiciu Bancila, 2012; Rasmussen, Poulsen, Rytter, Kristiansen, & Bak, 2016). The survey was based on a stratified random sample of 8835 households. Only persons aged 18 years or older were invited to participate. A total of 5113 interviews were carried out (response rate: 63%). A detailed description of the survey is provided elsewhere (Algren et al., 2017).

General population: Danish Health and Morbidity Survey 2010

We compared the prevalence of loneliness in the deprived neighbourhoods with that of the general population of Denmark, based on data extracted from the *Danish Health and Morbidity Survey 2010* (DHMS) (Christensen et al., 2012). It was not possible to compare the prevalence of social isolation in the deprived neighbourhoods with the corresponding prevalence in the general Danish population since social isolation was assessed differently in the two surveys. DHMS was based on data from 25,000 randomly sampled Danes aged 16 years or above, selected from the Danish Civil Registration System. The survey was conducted by the National Institute of Public Health at the University of Southern Denmark in February–April 2010. A total of 15,165 individuals completed the questionnaire (response rate: 61%) (Christensen et al., 2012). Only persons aged 18 years or above (n = 14,686) were included in the comparison group, reflecting the age distribution of the residents of the deprived neighbourhoods. The survey is described in further detail elsewhere (Christensen et al., 2012).

Variables

Social isolation

The assessment of social isolation was based on a measure of the individual's social network. As an indicator of social network, we used a modified version of the Berkman-Syme Social Network Index (SNI), which assesses the degree of social integration (Berkman & Syme, 1979). The following question was used to assess cohabitation status: "Who do you live with in your family?" The response categories were: *You live alone, with no children*; *You live alone, with one or more children*; *You live with your spouse/cohabitant, with no children*; *You live with your spouse/-cohabitant, with one or more children*; *You live with your parents*, and *Other*. Responses were dichotomized into (a) Cohabitating and (b) Living alone (the two first response categories). The following questions were used to assess contact frequency with family and friends: "How often do you meet with your family, you do not live with?" and "How often do you meet with your friends and acquaintances?" For both questions, the response categories were: *Daily; Several times a week; Several times a month; Less often than once a month;* and *Never*. Responses were dichotomized into (a) *Daily or rather daily/Once or twice a week/Once or twice a month* and (b) *Rarely/Never*, with (b) indicating the most isolated status. To assess membership of voluntary organisations, the following question was used: "Are you a member of an association or network where you do volunteer work?". The response categories were: *Yes, I am a member of one or more associations; I have previously done volunteer work in an association or network, but do not do so currently*; and *No, I do not do voluntary work in an association or a network*. Responses were dichotomized, with the third response indicating the most isolated status.

Ranging between 0 and 4, the social network index scores were categorized according to the standard described by Berkman and Syme (Berkman & Syme, 1979), into either 0–1 (most isolated), 2 (moderately isolated), 3 (moderately integrated), and 4 (most integrated). Social isolation was dichotomized into "Socially isolated" (most/moderately isolated) and "Non-socially isolated" (moderately/most integrated).

Loneliness

Loneliness was assessed by the question: "Are you ever alone, although you would prefer to be together with other people?", with the response options "Yes" and "No". An affirmative response led to further possible specification as to whether the respondent felt unwillingly

lonely (*Often*, *Occasionally* or *Rarely*). In the DHMS, loneliness was measured by an identically worded single question, but offering the following response categories: *Yes, often*; *Yes, occasionally*; *Yes, rarely* and *No*. For both surveys, loneliness was dichotomized into "Lonely" and "Non-lonely", with the "Often" response leading to categorization as "Lonely".

Health-risk behaviour

The following four indicators were used to assess health-risk behaviour: low fruit or vegetable intake, daily smoking, high-risk alcohol intake, and physical inactivity. Low fruit or vegetable intake was assessed by questions about the frequency of consumption. Respondents who ate neither fruit nor vegetables during a week were categorized as "Low intake of fruit or vegetables". Daily smoking was measured by asking whether the respondent was currently a daily smoker. Alcohol intake was assessed by obtaining information on the number of standard alcohol drinks consumed during a typical week. The Danish Health Authority's definition of high-risk alcohol intake was used (>14 standard drinks per week for women; >21 standard drinks per week for men) (Gronbaek et al., 1997). A slightly modified version of the Saltin-Grimby Physical Activity Level Scale was used to assess physical inactivity (Grimby et al., 2015). This was defined according to the response to a question about the typical level of leisure time physical activity during the past 12 months with the four predefined categories: *Heavy exercise and competitive sports regularly and several times a week*; *Exercise or heavy gardening at least 4 h a week*; *Walking, biking or other light exercise at least 4 h a week (include Sunday excursions, light gardening and cycling or walking to work)*; and *Reading, watching TV or other sedentary activity*. The latter category was used to define physical inactivity.

The co-occurrence of health-risk behaviours

To determine the co-occurrence of health-risk behaviours, a risk factor score was calculated as the sum of the respondent's health-risk behaviours (Algren et al., 2018; Algren et al., 2017). The following four health-risk behaviours were chosen for this calculation: *low intake of fruit or vegetables*; *daily smoking*; *high-risk alcohol intake; physical inactivity*. A value of 1 was given for each health-risk behaviour; hence, a score of 4 indicates that the respondent has a low intake of fruit or vegetables, is a daily smoker, exceeds the high-risk drinking limit, and is physically inactive. In contrast, a risk score of 0 indicates that the respondent eats fruit or vegetables each week, is a non-smoker, does not exceed the high-risk drinking limits, and is not physically inactive. We assessed co-occurrence by two separate indicators: (1) Having two or more health-risk behaviours; and (2) Having three and more health-risk behaviours.

Sociodemographic and socioeconomic characteristics

The measurement of sociodemographic and socioeconomic characteristics included sex, age, ethnic background, educational level, employment status, and cohabitation status. All sociodemographic and socioeconomic characteristics were self-reported in the DNHPS. For the DHMS, information on sex, age and ethnic background was extracted from the Danish Civil Registration System (Pedersen, 2011). We classified ethnic background into three groups: Danish background, other Western background (from the 28 European Union member states and Andorra, Iceland, Liechtenstein, Monaco, Norway, San Marino, Switzerland, Vatican City, Canada, the USA, Australia, and New Zealand) or Non-Western background (all other countries). Cohabitation status, the highest level of education completed, and employment status were based on self-reported data. Education was classified in accordance with Statistics Denmark's definition of the highest completed education (Kurita, Sjogren, Juel, Hojsted, & Ekholm, 2012). An SES index was constructed from highest educational level and employment status and was dichotomized into (a) Low and (b) Medium/high SES, where low included respondents who had not studied beyond primary school and not were employed.

Statistical analysis

The constructed index for social network was evaluated by confirmatory factor analysis (CFA). The root mean square error of approximation (RMSEA) was 0.0768. Ideally, the value of the RMSEA should be 0.05 or less to indicate a good model fit, but a value of approximately 0.08 or less is also acceptable (Browne & Cudeck, 1993). The standardized root mean square residual was 0.0312; a value of 0.08 or less indicates an acceptable model (Hu & Bentler, 1999). The Bentler Comparative Fit Index was 0.8228, where a value of 0.90 or greater is considered as acceptable (Hu & Bentler, 1999). Overall, the values of the CFA for the constructed social network index are considered as having an acceptable model fit.

Multiple logistic regression analyses were used to examine the difference in loneliness and social isolation, respectively, between residents of the deprived neighbourhood and the general population. The regression model was adjusted for sex, age, ethnic background, cohabitation status, educational level, and employment status, since these have been found to constitute important determinants of health behaviour (Christensen et al., 2012). The adjustment strategy was applied for all regression models in the present study (since cohabitation status was used to define social isolation, the analyses on social isolation were not adjusted for cohabitation status). When the model was adjusted for differences in educational level, the analyses were restricted to individuals aged 25 years or older, as these were assumed to have completed their education. Furthermore, when the model was adjusted for differences in employment status, the analyses were restricted to respondents aged 25–64 years and to employed, unemployed, disability pensioners, and other non-employed individuals (including home-makers, people on long-term sick leave or in rehabilitation, benefit claimants, and the group of non-classifiable individuals). These restrictions were applied for all regression models, including adjustment for educational level and employment status. Multiple logistic regression analyses were also applied for investigation of associations between social isolation and loneliness, respectively, and various health-risk behaviour outcomes among the residents of the deprived neighbourhoods. To examine whether sex modified the associations between health-risk behaviour and social isolation and loneliness, respectively, interaction terms between these variables were included in the models. In sensitivity analyses, the primary analyses on social isolation were repeated where those who did not feel lonely were excluded and the primary analyses on loneliness were repeated where those who did not feel social isolated were excluded.

Furthermore, for examination of a modifying influence of social isolation and loneliness on the association between SES and health-risk behaviour, we included interaction terms in the models between these variables. We also examined the joint effect of SES and social isolation and loneliness, respectively, on health-risk behaviour. Multiple logistic regression analyses were also used in the analyses of joint effect. The results of the multiple logistic regression analyses are presented as odds ratios (OR) with 95% confidence intervals (95% CI).

The DNHPS questionnaire offered a "Do not know" category, which was treated as missing in the analyses. To reduce non-response bias in the Danish Health and Morbidity Survey 2010, we used computed calibrated weights from Statistics Denmark. Register information on sex, age, ethnic background, educational level, and income, etc., for all persons invited to participate in the DHMS was obtained to calculate the weights (Christensen et al., 2012).

SAS version 9.3 was used for the data analyses.

Results

The prevalence of social isolation and loneliness among residents of deprived neighbourhoods in Denmark were 17.8% and 8.4%, respectively (Table 1). The prevalence of social isolation was highest among residents aged 65 years or older, while the prevalence of loneliness was

lowest in the oldest age group. For both social isolation and loneliness, the highest prevalence was observed among residents of western ethnic background. A high prevalence of both outcomes was found among the unemployed and disability pensioners. Low-SES residents had a higher prevalence of social isolation and loneliness than did residents with medium/high SES. APPENDIX A shows the prevalence of the items used

Table 1
Sociodemographic and socioeconomic characteristics and their associations with social isolation and loneliness among residents in deprived neighbourhoods. N = 5113.

	Study population		Socially isolated	P	Lonely	P
	%	n	%		%	
Total		5113	17.8		8.4	
Sex				0.81		0.75
Men	45.8	2342	17.7		8.2	
Women	54.2	2771	17.9		8.5	
Age (years)				<0.01**		0.01**
18–24	9.0	460	10.0		8.2	
25-44	33.9	1734	14.9		9.3	
45–64	35.0	1791	19.6		9.0	
≥65	22.0	1126	22.6		5.9	
Ethnic background				<0.01**		0.03*
Danish	82.8	4235	16.9		7.9	
Western	2.1	106	32.1		13.2	
Non-Western	15.1	772	21.0		10.0	
Cohabitation status						<0.01**
Cohabiting	44.7	2287	—[d]		4.0	
Living alone	55.3	2826	—		11.9	
Highest educational level				<0.01**		0.06
No education/ Basic school	32.6	1664	21.9		10.1	
Upper secondary or vocational school	36.0	1837	15.4		7.4	
Short-cycle higher education	10.0	508	15.2		7.3	
Medium-cycle higher education	11.0	610	15.1		7.1	
Long-cycle higher education	3.5	179	26.8		9.1	
Other education[a]	6.0	307	15.3		8.3	
Employment status				<0.01**		<0.01**
Employed	41.3	2108	11.7		5.1	
Unemployed	14.7	752	21.8		15.0	
Disability pensioner	9.9	504	29.6		16.5	
Other non-employed[b]	34.1	1743	20.1		7.0	
Socioeconomic status[c]				<0.01**		<0.01**
Low socioeconomic status	23.3	1191	25.4		11.7	
Medium/high socioeconomic status	76.7	3920	15.5		7.4	

* indicates a significance level p < 0.05, and ** indicates a significance level p < 0.01.
[a] Including "Still attending school".
[b] Others (E.g. student, early retirement/age pensioners).
[c] Based on highest educational level and employment status.
[d] No prevalence shown since cohabitation status is a part of the social isolation index used to define social isolation.

to construct the social network index, the distribution of response categories in the social network index, and the item used to measure loneliness.

The social network index and the item used to assess loneliness correlated; though, the strength of the correlation was weak to moderate (r = 0.24). Residents who were socially isolated had a higher prevalence of loneliness (18.6%) than did residents who were non-socially isolated (6.1%). However, it should be noted that while some non-socially isolated residents in fact felt lonely, others who were socially isolated did not feel lonely (81.4%).

The prevalence of loneliness was 8.4% and 5.4% for residents in deprived neighbourhoods and the general population, respectively (see APPENDIX B). After adjustment for differences in sex, age, and ethnic background, residents of deprived neighbourhoods had 1.51 times higher odds (95% CI: 1.33–1.72) of being lonely when compared to the general population. The results remained significant when the analyses were further adjusted for differences in educational level and employment status.

Table 2 shows the associations between social isolation and health-risk behaviours. Social isolation was significantly associated with higher odds of health-risk behaviour, including low fruit or vegetable intake, daily smoking, physical inactivity, and the co-occurrence of health-risk behaviours, even after adjustment for sociodemographic and socioeconomic characteristics. The association between social isolation and high-risk alcohol intake was only significant when the analysis was adjusted for sex, age, ethnic background, and educational level. A significant interaction was found between sex and social isolation in relation to daily smoking (p-value = 0.004). After adjustment for differences in sociodemographic and socioeconomic characteristics, socially isolated men had 1.37 times higher odds (95% CI: 1.03–1.83) of being daily smokers compared to men who were non-socially isolated. No difference was found among women with regard to social isolation and daily smoking (data not shown). Furthermore, in a sensitivity analysis no markedly differences in health-risk behaviour were observed, when those who did not feel lonely where excluded from the analyses on social isolation (data not shown).

Table 3 shows associations between loneliness and health-risk behaviours. Loneliness was significantly associated with higher odds of all the health-risk behaviours (except high-risk alcohol intake) and the co-occurrence of health-risk behaviours. However, daily smoking was no longer significant when the analysis was adjusted for employment status as well. Interaction analyses showed no significant association between sex and loneliness with regard to health-risk behaviour (all p-values > 0.05; data not shown). In addition, a sensitivity analysis showed nearly similar estimates, when the socially isolated residents were excluded from the analyses (data not shown).

Table 4 shows associations between the combination of SES and social isolation in regard to health-risk behaviours. The combined variable included four possible combinations of SES and social isolation: Low SES and socially isolated (n = 138), low SES and non-socially isolated (n = 390), medium/high SES and socially isolated (n = 393), and medium/high SES and non-socially isolated (n = 2195). Socially isolated residents with low SES had higher odds of health-risk behaviour (except for high-risk alcohol intake) and co-occurrence of health-risk behaviour compared with non-socially isolated residents with higher SES. Socially isolated residents with medium/high SES had higher odds of high-risk alcohol intake (OR: 1.77; 95% CI: 1.16–2.70) than did non-socially isolated residents with medium/high SES. There were no statistically significant interactions between SES and social isolation with respect to health-risk behaviour (all p-values > 0.05). Furthermore, the analysis showed no significant interactions between sex and the combination of SES and social isolation with regard to health-risk behaviours (all p-values > 0.05; data not shown).

In Table 5 the associations between the combination of SES and loneliness regarding health-risk behaviours are shown. The combined variable included four possible combinations of SES and loneliness: Low

Table 2

Associations between social isolation and health-risk behaviours among residents in deprived neighbourhoods. ORs with 95% CI for health-risk behaviours. N = 5113.

	Socially isolated	Non-socially isolated	Unadjusted		Adjusted					
	%		OR	(95% CI)	OR[a]	(95% CI)	OR[b]	(95% CI)	OR[c]	(95% CI)
Fruit and vegetables										
Low intake of fruit or vegetables	13.3	6.4	**2.25**	**(1.79–2.82)**	**2.70**	**(2.13–3.43)**	**2.83**	**(2.20–3.65)**	**2.30**	**(1.67–3.16)**
Smoking										
Daily smoking	44.8	36.6	**1.40**	**(1.21–1.62)**	**1.52**	**(1.31–1.76)**	**1.48**	**(1.27–1.73)**	**1.29**	**(1.06–1.57)**
Alcohol										
High-risk alcohol intake	6.7	5.3	1.29	(0.96–1.73)	1.29	(0.96–1.74)	**1.37**	**(1.01–1.86)**	1.42	(0.96–2.08)
Physical activity										
Physical inactivity	29.7	16.8	**2.10**	**(1.78–2.47)**	**2.01**	**(1.70–2.37)**	**1.94**	**(1.63–2.30)**	**1.48**	**(1.18–1.85)**
Co-occurrence of health-risk behaviours										
Having 2 or more health-risk behaviours	24.6	13.1	**2.17**	**(1.82–2.59)**	**2.33**	**(1.94–2.79)**	**2.39**	**(1.98–2.89)**	**1.99**	**(1.57–2.52)**
Having 3 or more health-risk behaviours	5.9	2.7	**2.25**	**(1.61–3.14)**	**2.42**	**(1.72–3.42)**	**2.51**	**(1.75–3.61)**	**1.96**	**(1.26–3.07)**

Bold values indicate significant OR.

[a] Adjusted for sex, age and ethnic background.

[b] Adjusted for sex, age, ethnic background and educational level. Analysis restricted to respondents aged 25 years or older.

[c] Adjusted for sex, age, ethnic background, educational level and employment status. Analysis restricted to respondents aged 25–64 years and employed, unemployed, disability pensioners and other non-employed.

Table 3

Associations between loneliness and health-risk behaviours among residents in deprived neighbourhoods. ORs with 95% CI for health-risk behaviours. N = 5113.

	Lonely	Non-lonely	Unadjusted		Adjusted					
	%		OR	(95% CI)	OR[a]	(95% CI)	OR[b]	(95% CI)	OR[c]	(95% CI)
Fruit and vegetables										
Low intake of fruit or vegetables	15.8	6.9	**2.52**	**(1.89–3.36)**	**2.72**	**(2.02–3.65)**	**1.84**	**(1.31–2.58)**	**1.83**	**(1.25–2.67)**
Smoking										
Daily smoking	48.6	37.2	**1.60**	**(1.31–1.95)**	**1.58**	**(1.29–1.93)**	**1.32**	**(1.06–1.65)**	1.18	(0.90–1.53)
Alcohol										
High-risk alcohol intake	7.2	5.4	1.36	(0.92–2.01)	1.45	(0.98–2.17)	1.27	(0.83–1.95)	1.15	(0.70–1.90)
Physical activity										
Physical inactivity	34.0	17.7	**2.40**	**(1.93–2.98)**	**2.44**	**(1.96–3.04)**	**2.26**	**(1.79–2.85)**	**1.82**	**(1.37–2.42)**
Co-occurrence of health-risk behaviours										
Having 2 or more health-risk behaviours	28.3	13.9	**2.44**	**(1.94–3.07)**	**2.49**	**(1.97–3.15)**	**2.08**	**(1.62–2.69)**	**1.77**	**(1.31–2.39)**
Having 3 or more health-risk behaviours	9.2	2.8	**3.53**	**(2.42–5.14)**	**3.81**	**(2.59–5.61)**	**2.14**	**(1.44–3.48)**	**2.04**	**(1.23–.3.37)**

Bold values indicate significant OR.

[a] Adjusted for sex, age and ethnic background.

[b] Adjusted for sex, age, ethnic background, educational level and cohabitation status. Analysis restricted to respondents aged 25 years or older.

[c] Adjusted for sex, age, ethnic background, educational level, cohabitation status and employment status. Analysis restricted to respondents aged 25–64 years and employed, unemployed, disability pensioners and other non-employed.

Table 4

Adjusted ORs with 95% CI of health-risk behaviours by combinations of socioeconomic status and social isolation among residents in deprived neighbourhoods. N = 3116.

Combined indicator of SES and social isolation	OR[a] (95% CI)					
	Low intake of fruit or vegetables	Daily smoker	High-risk alcohol intake	Physical inactivity	Having 2 or more health-risk behaviours	Having 3 or more health-risk behaviours
	p = 0.20	p = 0.64	p = 0.28	p = 0.67	p = 0.81	p = 0.27
Low socioeconomic status and socially isolated	**5.28 (3.26–8.54)**	**2.80 (1.95–4.01)**	1.46 (0.71–3.00)	**2.64 (1.81–3.84)**	**4.85 (3.33–7.07)**	**2.91 (1.38–6.13)**
Low socioeconomic status and non-socially isolated	**2.86 (1.97–4.15)**	**1.84 (1.47–2.29)**	1.37 (0.84–2.22)	**1.76 (1.36–2.84)**	**2.10 (1.58–2.78)**	**1.80 (1.00–3.26)**
Medium/high socioeconomic status and socially isolated	**2.82 (1.96–4.07)**	**1.37 (1.10–1.70)**	**1.77 (1.16–2.70)**	**1.67 (1.28–2.16)**	**2.17 (1.65–2.85)**	**2.82 (1.73–4.62)**
Medium/high socioeconomic status and non-socially isolated	1.00	1.00	1.00	1.00	1.00	1.00

Bold values indicate significant OR.

[a] Adjusted for sex, age and ethnic background. Analysis restricted to respondents aged 25–64 years and employed, unemployed, disability pensioners and other non-employed.

SES and lonely (n = 77), low SES and non-lonely (n = 437), medium/high SES and lonely (n = 199), and medium/high SES and non-lonely (n = 2366). Lonely residents with low SES had higher odds of health-risk behaviour (except for high-risk alcohol intake) and of having two or more health-risk behaviours than did non-lonely residents with higher SES. Lonely residents with medium/high SES had higher odds of having

Table 5
Adjusted ORs with 95% CI of health-risk behaviours by combinations of socioeconomic status and loneliness among residents in deprived neighbourhoods. N = 3079.

Combined indicator of SES and loneliness	OR[a] (95% CI)					
	Low intake of fruit or vegetables	Daily smoker	High-risk alcohol intake	Physical inactivity	Having 2 or more health-risk behaviours	Having 3 or more health-risk behaviours
	p = 0.07	p = 0.71	p = 0.80	p = 0.15	p = 0.07	p = 0.18
Low SES and lonely	**3.39 (1.85–6.21)**	**2.35 (1.46–3.79)**	1.59 (0.70–3.62)	**2.67 (1.63–4.39)**	**3.15 (1.90–5.22)**	2.24 (0.91–5.52)
Low SES and non-lonely	**2.63 (1.86–3.72)**	**1.88 (1.53–2.33)**	1.12 (0.70–1.78)	**1.80 (1.41–2.29)**	**2.29 (1.77–3.00)**	1.54 (0.89–2.68)
Medium/high SES and lonely	**2.65 (1.69–4.14)**	**1.40 (1.04–1.88)**	1.24 (0.68–2.23)	**2.35 (1.70–3.25)**	**2.49 (1.77–3.51)**	**3.13 (1.79–5.50)**
Medium/high SES and non-lonely	1.00	1.00	1.00	1.00	1.00	1.00

Bold values indicate significant OR.

[a] Adjusted for sex, age, ethnic background and cohabitation status. Analysis restricted to respondents aged 25–64 years and employed, unemployed, disability pensioners and other non-employed.

three or more health-risk behaviours (OR: 3.13; 95% CI: 1.79–5.50) compared to non-lonely residents with the same SES. There were no statistically significant interactions between SES and loneliness with regard to health-risk behaviour (all p-values > 0.05). The analysis showed no significant interactions between sex and the combination of SES and loneliness with respect to health-risk behaviours (all p-values > 0.05; data not shown).

Discussion

When comparing with the general population, we found significantly higher odds of loneliness among residents of deprived neighbourhoods. This underlines the importance of interventions focusing on tackling loneliness targeted at deprived neighbourhoods. The present study found that social isolation and loneliness in deprived neighbourhoods were associated with increased odds of low intake of fruit or vegetables, daily smoking, physical inactivity, and the co-occurrence of health-risk behaviours. The associations (except smoking) moreover persisted after adjusting for all sociodemographic and socioeconomic characteristics. The association between social isolation and high-risk alcohol intake was only significant when the analysis was adjusted for sex, age, ethnic background, and educational level. Loneliness was not associated with high-risk alcohol intake.

The findings of this study are supported by similar studies of associations between social isolation, loneliness, and health-risk behaviour in other populations (Berkman et al., 2000; Cacioppo et al., 2002; Hawkley et al., 2009; Kaplan et al., 1991; Kharicha et al., 2007; Lauder et al., 2006; Locher et al., 2005; Shankar et al., 2011; Trost, Owen, Bauman, Sallis, & Brown, 2002; Weyers et al., 2010a; Weyers, Dragano, Richter, & Bosma, 2010b). The association between social isolation and low fruit or vegetable intake has also been found in prior research (Weyers et al., 2010a). Furthermore, Locher et al. (2005) found that individuals with a relatively weak social network reported less healthy dieting (Locher et al., 2005). However, in relation to loneliness, Cacioppo et al. (2002) reported that lonely and non-lonely individuals did not differ significantly on diet quality (Cacioppo et al., 2002). As its population size was very small, the results of Cacioppo et al.'s study should be interpreted with caution.

Our result on smoking supports a study by Shankar et al. (2011), who also found an association between social isolation and smoking (Shankar et al., 2011). Mixed results have been found with regard to the association between loneliness and smoking; while Lauder et al. (2006) found that lonely people were more likely than non-lonely people to be smokers (Lauder et al., 2006), others found no association (Cacioppo et al., 2002).

The absence of an association between social isolation and high-risk alcohol intake has not been shown in any previous study. But a study by Kharicha et al. (2007) found that people living alone were more likely to

report hazardous alcohol use (Kharicha et al., 2007). Regarding loneliness and alcohol intake, Cacioppo et al. (2002) neither found any difference between lonely and non-lonely individuals (Cacioppo et al., 2002). In relation to alcohol intake, it should be stressed that residents in deprived neighbourhoods have lower odds of high-risk alcohol intake, compared with that of the general population in Denmark (Algren et al., 2017). This may indicate that alcohol intake is a special case in deprived neighbourhood (Algren et al., 2017). The finding on the association between social isolation, loneliness, and physical inactivity among residents of deprived neighbourhoods was not surprising since many studies have reported that social isolation and loneliness are associated with physical inactivity (Hawkley et al., 2009; Kaplan et al., 1991; Shankar et al., 2011; Trost et al., 2002; Weyers et al., 2010a). Nevertheless, one study found no association between loneliness and physical activity (Cacioppo et al., 2002). In the Alameda County Study, social isolation was found to predict declines in the level of physical activity over a nine-year period (Kaplan et al., 1991). Another study found that loneliness predicted a reduced probability of physical activity over a two-year period and that loneliness increased the likelihood of transitioning from physical activity to inactivity over a three-year period (Weyers et al., 2010b).

Our findings highlight that deprived neighbourhood residents who are socially isolated and lonely form a high-risk group for co-occurrence of health-risk behaviours. Our findings of an association between social isolation and the co-occurrence of health-risk behaviours are in line with the Alameda County Study, which also showed that individuals who were less socially integrated were more likely to report multiple health-risk behaviours (Berkman & Glass, 2000). Furthermore, Shankar et al. (2011) found that both social isolation and loneliness were associated with a greater risk of reporting multiple health-risk behaviours (Shankar et al., 2011).

Some of the inconsistencies in the above results may in part be due to the theoretical conceptualization and operationalization of social isolation and loneliness used in the different studies, which makes comparison difficult. Additionally, the inconsistent results may be caused by cultural differences in the studied populations from different countries (Rico-Uribe et al., 2016).

In the present study, it was found that residents with low SES had a higher prevalence of social isolation and loneliness than did higher-SES residents. The potentially 'negative' impact of social isolation and loneliness may be even more pronounced among residents with lower SES, given their already limited access to health-promoting resources (Algren et al., 2017). Generally, we found that both socially isolated and lonely residents in deprived neighbourhoods with low SES have higher odds of health-risk behaviours. The results support a previous study showing that the combination of poor social relations and low socioeconomic position displays stronger associations with adverse health behaviours (Weyers et al., 2010a). These results may reflect a common

tendency towards increased vulnerability among low-SES residents, whose lives are frequently exposed to cumulative burdens in the form of several different and possibly interacting physical, social, and behavioural risk factors (Diderichsen et al., 2012; Weyers et al., 2010a).

Different conceptual models for social relationships and health have been suggested within social epidemiology (Berkman & Glass, 2014; Due, Holstein, Lund, Modvig, & Avlund, 1999). In general, the models describe social relationships by their structural and functional features. The structural aspects relate to the structure of the social network, such as the size of the social network and the frequency of contact between its members. The functional aspects relate to the function of the social network, such as a person's perception of the quality of the support provided (Kuiper et al., 2016). Our hypothesis about how social isolation and loneliness influence health-risk behaviour is based on the conceptual model developed by Berkman, where she links social relationships and health (Berkman & Glass, 2014). Researchers examining the importance of social relationships on health have suggested that social relations may influence health via the adoption and maintenance of healthy behavioural norms through social control over deviant health-related behaviour (Berkman & Glass, 2014). Previous studies have indicated that both descriptive and injunctive norms independently have important consequences for health behaviours (Shankar et al., 2011). Descriptive norms describe normality regarding how significant others actually behave, whereas injunctive norms describe the rules of moral approval or disapproval among significant others (Shankar et al., 2011; Tay, Tan, Diener, & Gonzalez, 2013). Social networks may furthermore provide opportunities for social support to resist risky behaviour and maintain healthier choices (Berkman & Glass, 2014; Stimpson, Ju, Raji, & Eschbach, 2007). The contagion hypothesis suggests that health behaviours are spread through social exchange (Stimpson et al., 2007). Christakis and Fowler, (2008 and 2010) studies on the Framingham Offspring Cohort found that social networks were associated with beneficial health behaviours, such as smoking cessation (Christakis & Fowler, 2008) and alcohol abstinence (Rosenquist, Murabito, Fowler, & Christakis, 2010) as well as with health-risk behaviours, e.g. heavy drinking (Rosenquist et al., 2010). Since these studies were longitudinal, it could be observed that changes in health behaviour in one person predicted changes among others in the social network. Researchers have argued that social networks are important also in the diffusion of health-risk behaviours (Christakis & Fowler 2007, 2008). A person's social relations may have both beneficial and harmful effects on health behaviour, depending on the social norms prescribed in the social network. For example, being together with family or friends who smoke represents the descriptive norm of smoking, whereas the injunctive norm of smoking among family or friends may encourage a person to smoke. Socially isolated persons are less likely to be influenced by others, and it has been suggested that the association between social isolation and health behaviours is stronger than the association between loneliness and health behaviours (Shankar et al., 2011). Social isolation has been found to predict decline in self-efficacy, while loneliness has been linked to lower self-esteem and limited use of active coping methods (Valtorta, Kanaan, Gilbody, Ronzi, & Hanratty, 2016).

Social relationships among neighbours in deprived neighbourhoods may also shape norms about health-related behaviour. The adoption or continuation of healthy behaviours or a sense of self-efficacy to pursue healthy behaviours may depend on social norms and social support from social contacts in the local neighbourhood (Stimpson et al., 2007). For example, smoking may be more socially acceptable or of lesser concern in deprived neighbourhoods than in non-deprived neighbourhoods, because of the higher prevalence of smoking in deprived neighbourhoods.

Implications for public health practice

Our results stress the need to diminish social isolation and loneliness in order to reduce health-risk behaviour in deprived neighbourhoods.

Thus, it appears to be meaningful to add social isolation and loneliness to the list of public health concerns in deprived neighbourhoods. This is further supported by evidence that social isolation and loneliness in general are increasing in society (Holt-Lunstad et al., 2015), as more people live alone and longer (Kearns et al., 2015). Strategies to decrease social isolation and loneliness therefore need to be integrated into existing health promotion interventions to address health-risk behaviour in deprived neighbourhoods. Interventions aiming to tackle social isolation and loneliness may especially be relevant for residents with low SES in deprived neighbourhoods.

Interventions aimed at tackling social isolation and loneliness have typically focused on enabling people to better maintain their existing social interactions, facilitating the creation of new social connections and using psychological therapies to help people to change the way they think about their social relations (Jopling & Aiden, 2017). The ability to form social connections seems to be limited by in deprived neighbourhoods factors such as low income, poor services, fear of crime, and transient population (Kearns et al., 2015). Thus, we recommend promoting social interactions in deprived neighbourhoods, which can support the residents in maintaining existing social relations and forming new relations, e.g. through social activities such as communal eating, cooking classes, or joint exercise classes provided in a community centre (NIRAS, 2015). By building and supporting new social networks and gathering places, it is possible to increase the social capital of the deprived neighbourhoods, which may offer psychological health benefits and further contribute to social cohesion (Kearns et al., 2015).

Social isolation may be impacted through interventions aimed to promote social relations, where the feelings of loneliness seem to be more complex to change (Coyle & Dugan, 2012). Yet, by reducing social isolation through the strengthening of social relationships in deprived neighbourhoods, we believe there is a greater chance to reduce loneliness as well for some residents. However, the weak correlation between social isolation and loneliness suggests that promoting social relationships may not necessarily reduce feelings of loneliness.

Promoting social interaction may result in improved social integration and social support, whereby self-efficacy and adaptive coping strategies can be strengthened (Klein, Vonneilich, Baumeister, Kohlmann, & von dem Knesebeck, 2012), which can lead to improved health behaviour. Social network interventions may be developed to promote knowledge of healthy behaviour and to influence social norms and attitudes to healthy behaviour through social diffusion mechanism, whereby health-risk behaviour can be changed (Latkin & Knowlton, 2015).

Very few interventions designed to reduce social isolation and loneliness have been shown to be effective (Shankar et al., 2011). In a review study, Cattan, White, Bond, and Learmouth (2005) found that group interventions such as educational and social activities targeted at specific groups are likely to be beneficial in preventing social isolation and loneliness (Cattan et al., 2005). Moreover, social support provided by family, friends, or people with similar health-risk behaviours (e.g. other smokers) has been found to be effective (Hogan, Linden, & Najarian, 2002).

We kindly refer to other previous studies, where further proposals for health promotion interventions in regard to reduce health-risk behaviour in deprived neighbourhood are discussed (Algren et al., 2015, 2017, 2018).

Implications for future studies

Besides their direct effects, social isolation and loneliness may have indirect effects on health-risk behaviour through stress. According to Cohen's (1985) stress buffering hypothesis, social relationships can buffer the negative effect of stress on health-related outcomes (Cohen & Wills, 1985), as has previously been shown (Holt-Lunstad, Smith, & Layton, 2010). In addition, social isolation and loneliness may themselves act as stressors, which produce negative affect, such as higher

levels of perceived stress (Kearns et al., 2015; Shankar et al., 2011). Cacioppo, Hawkley, and Berntson (2003) suggest that socially isolated and lonely individuals suffer from higher levels of stress, which may in turn influence their health (Cacioppo et al., 2003). Social buffering may be particularly important for residents living in deprived neighbourhoods, since it has been found that they have higher odds of perceived stress, compared to the general population, and that perceived stress is associated with a higher risk of health-risk behaviour among residents in deprived neighbourhoods (Algren et al., 2018). Further, it has been suggest by Kearns et al. (2015) that residents in deprived neighbourhoods are exposed to stressors such as poverty, unstable family circumstances, and crime, safety and antisocial behaviour issues in the neighbourhood (Kearns et al., 2015). Therefore, it would be highly relevant to investigate whether social relationships can act as a buffer in the association between perceived stress and health-risk behaviours in deprived neighbourhoods.

Longitudinal studies are also needed to investigate social isolation and loneliness with regard to health-risk behaviour to infer causality from the association found in the present study, and to identify possible mechanisms linking social isolation and loneliness to health-risk behaviour.

While social technology (mobile phone, email, Facebook, etc.) has gained widespread use for communication and social interaction in our society (Holt-Lunstad & Smith, 2016) and offers potential for preventing social isolation and loneliness, it may as well contribute to new problems in social interaction. Research is therefore needed to study the effects of social interaction via social technology, and whether its influence on health-risk behaviour is comparable to that of face-to-face social interactions. As a consequence of the new means of communication and social interaction, the rethinking of definitions and measurements of social relationships is also required. For example, future research should include questions on the frequency of contact to family, friends, and others via the different social technologies.

Finally, it could be interesting to investigate, whether social isolation and loneliness modify the associations between SES and health-risk behaviours in the general population, thus it is possible to compare the results with the results from the residents in the deprived neighbourhoods.

Strength and limitations

The key strength of the present study is the large sample of residents from deprived neighbourhoods with a response rate of 63%. Attaining such a high proportion is remarkable since residents of deprived neighbourhoods are known to be less likely to participate in health research (Kuipers et al., 2013; Rasmussen et al., 2016) and tend to be underrepresented in health profile surveys (Andersen, Bak, Vangsgaard, Dokkedal, & Larsen, 2011; Nielsen, Curtis, Kristensen, & Nielsen, 2008). There were three main limitations to this study. First, it was limited by its cross-sectional design due to which causality cannot be inferred. Secondly, we were unable to compare social isolation among residents in deprived neighbourhoods with that of the general Danish population, since the DHMS used different question formulations in regard to contact frequency with family and friends and did not include information on membership of voluntary organisations. Thirdly, examination of interactions was performed based on significance of the interaction terms. However, alternative methods such as the relative excess risk due to an interaction (RERI) could have been used.

Conclusion

The present study showed that residents in deprived neighbourhoods have higher odds of loneliness when compared to the Danish population in general. Furthermore, social isolation and loneliness are strongly associated with low fruit or vegetable intake, daily smoking, physical inactivity, and the co-occurrence of health-risk behaviours among residents of deprived neighbourhoods. Finally, social isolation and loneliness increased the odds of health-risk behaviour among residents with low SES. The findings have important implications for the planning of future health promotion intervention programmes. Further research is needed for a deeper understanding of the pathways by which social isolation and loneliness affect health-risk behaviour.

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Ethics approval

Ethical approval and written consent were not required for this type of study.

Declaration of competing interest

None.

CRediT authorship contribution statement

Maria Holst Algren: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Ola Ekholm:** Methodology, Software, Formal analysis, Writing - review & editing, Visualization, Supervision. **Line Nielsen:** Conceptualization, Writing - review & editing. **Annette Kjær Ersbøll:** Methodology, Software, Formal analysis, Writing - review & editing, Visualization. **Carsten Kronborg Bak:** Conceptualization, Investigation, Resources, Writing - review & editing, Supervision. **Pernille Tanggaard Andersen:** Conceptualization, Investigation, Resources, Writing - review & editing, Supervision, Funding acquisition.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100546.

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