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Loneliness, Social Isolation, and Behavioral and Biological Health Indicators in Older Adults

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Objective: A number of mechanisms have been proposed through which social isolation and loneliness may affect health, including health-related behavioral and biological factors. However, it is unclear to what extent isolation and loneliness are independently associated with these pathways. The objective of the present analysis was to determine the impact of social isolation and loneliness, individually as well as simultaneously, on health-related behavioral and biological factors using data from the English Longitudinal Study of Ageing (ELSA). ***Method:*** Data on health behaviors (smoking and physical activity) were analyzed from 8,688 participants and data on blood pressure, cholesterol, and inflammatory markers were analyzed from over 5,000 of these participants who were eligible for a nurse visit and blood sampling. Loneliness was measured using the short form of the Revised UCLA scale and an index of social isolation was computed incorporating marital status; frequency of contact with friends, family, and children; and participation in social activities. ***Results:*** Fewer than 2% of participants reported being lonely all the time, while nearly 7% had the highest possible scores on social isolation. Both social isolation and loneliness were associated with a greater risk of being inactive, smoking, as well as reporting multiple health-risk behaviors. Social isolation was also positively associated with blood pressure, C-reactive protein, and fibrinogen levels. ***Conclusions***: Loneliness and social isolation may affect health independently through their effects on health behaviors. In addition, social isolation may also affect health through biological processes associated with the development of cardiovascular disease.

Keywords: older adults, social isolation, loneliness, health behaviors, inflammation

Individuals who live alone, have few friends or family, and have limited contact with people are viewed as being socially isolated. Loneliness or perceived social isolation is believed to be its psychological counterpart. While social isolation is an objective, quantitative measure of network size and diversity, and frequency of contact, loneliness is a qualitative, subjective evaluation related to individuals' expectations of and satisfaction with the frequency and closeness of contacts (de Jong Gierveld & Havens, 2004). Both loneliness and social isolation have been associated with an increased risk of developing health problems (Rutledge et al., 2008; Thurston & Kubzansky, 2009), hospitalization (Hastings et al., 2008; Jordan et al., 2008; Löfvenmark, Mattiasson, Billing, & Edner, 2009), poor cognitive function (Cacioppo & Hawkley, 2009; Luanaigh & Lawlor, 2008; Sampson, Bulpitt, & Fletcher, 2010), and mortality (Berkman et al., 2004; Holt-Lunstad, Smith, & Layton, 2010; Patterson & Veenstra, 2010; Shiovitz-Ezra & Ayalon, 2010).

Older adults are at greater risk of being socially isolated (Iliffe et al., 2007), and feelings of loneliness are also quite common among this group (Theeke, 2009; Victor, Scambler, Bowling, & Bond, 2005). As might be expected, feelings of loneliness are related to social isolation, although studies typically find the association to be weak to moderate (Cornwell & Waite, 2009b). A number of mechanisms have been suggested through which social isolation and loneliness might affect health, including health behaviors and biological pathways (Berkman, Glass, Brissette, & Seeman, 2000; Cacioppo et al., 2002). However, most studies in the area focus either solely on social isolation or on loneliness, and it is unclear to what extent each variable independently affects health (Cornwell & Waite, 2009a). This paper explores the impact of social isolation and loneliness, individually as well as simultaneously, on health-related behavioral and biological factors using data from a large, nationally representative sample of older adults in England.

Social isolation and loneliness are believed to affect health behaviors through their impact on social support or social cues for behavior choices (Cacioppo & Hawkley, 2003; House, 2001). Findings regarding the relationship between loneliness and health-risk behaviors remain equivocal with some studies finding no

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significant differences in health behavior profiles among lonely and nonlonely subjects (Cacioppo et al., 2002; Hawkley & Cacioppo, 2003; Hawkley, Burleson, Berntson, & Cacioppo, 2003; Steptoe, Owen, Kunz-Ebrecht, & Brydon, 2004), while others report that lonely individuals are less active (Hawkley, Thisted, & Cacioppo, 2009) and more likely to smoke (Lauder, Mummery, Jones, & Caperchione, 2006). Studies on the relationship between social isolation and health behaviors report more consistent findings. Individuals with smaller social networks report less healthy diets (Locher et al., 2005), heavy drinking, and less physical activity (Kharicha et al., 2007). The Alameda county study found that individuals who were less socially integrated were more likely to report multiple health-risk behaviors (Berkman & Glass, 2000). Christakis and colleagues in studies on the Framingham offspring cohort showed that social networks were associated with positive health behaviors such as smoking cessation (Christakis & Fowler, 2008) and alcohol abstinence (Rosenquist, Murabito, Fowler, & Christakis, 2010) as well as risk factors such as obesity (Christakis & Fowler, 2007) and heavy drinking (Rosenquist et al., 2010). As these studies were longitudinal, it was possible to see that changes in the individual predicted changes in others in the network with effects seen among friends, siblings, and spouses.

Susceptibility and reactivity to stress are other mechanisms through which loneliness and social isolation are believed to affect health and, indeed, prolonged isolation or loneliness may in themselves act as stressors (Cacioppo & Hawkley, 2003; House, 2001). Several studies have examined the impact of these variables on aspects of cardiovascular functioning such as blood pressure and to a lesser extent, cholesterol. In experimental studies using acute stressful challenges such as color-word interference and mirror tracing tasks, Steptoe and colleagues found that socially isolated participants had poorer recovery of systolic blood pressure (Grant, Hamer, & Steptoe, 2009; Steptoe et al., 2003) and greater increases in total:HDL cholesterol ratio (Grant et al., 2009). In observational studies, more isolated individuals were found to have less blood pressure dipping at night (Troxel et al., 2010), and children who were not well integrated with their peer group were found to have increased cholesterol levels in adulthood (Danese et al., 2009). Hawkley and colleagues also found that older adults who were lonely showed greater age-related increases in systolic blood pressure (Hawkley, Masi, Berry, & Cacioppo, 2006; Hawkley, Thisted, Masi, & Cacioppo, 2010).

Lately there has been interest in the role of inflammation in relation to social network variables. A recent genome-wide study indicated that genes associated with the anti-inflammatory glucocorticoid receptor pathway were underexpressed, while the proinflammatory NF-κB/Rel transcription pathway was overexpressed among lonely when compared with nonlonely participants (Cole et al., 2007). Steptoe and colleagues found lonely participants to have an increased fibrinogen and natural killer cell response to a stress task, when compared with nonlonely participants (Steptoe et al., 2004). Increased levels of fibrinogen are found among socially isolated individuals (Loucks, Berkman, Gruenewald, & Seeman, 2005; Steptoe et al., 2003; Wamala et al., 1999). Danese et al. (2009) in their study of adolescents also reported increased levels of C-reactive protein (CRP) at adulthood among those who were less integrated in adolescence.

In this analysis we examine the impact of social isolation and loneliness on two health-risk behaviors: smoking and low physical activity. Being physically active and nonsmoking are both associated with improved health, cognitive function, and reduced mortality in older adults (Etgen et al., 2010; Haveman-Nies et al., 2002; Khaw et al., 2008; Lee et al., 2010). We also examine the association between social isolation, loneliness and blood pressure, cholesterol and inflammatory markers (CRP and fibrinogen). It is important to consider the impact of depression as a possible confounding variable in examining the relationship between social isolation, loneliness, and the behavioral and biological factors mentioned above. Previous research indicates that both social isolation and loneliness are associated with depression (Cacioppo, Hawkley, & Thisted, 2010; Golden et al., 2009; Heritage, Wilkinson, Grimaud, & Pickett, 2008; Russell, 1996). Depression is considered a possibly pathway through which loneliness and isolation affect health. Indeed, depressed individuals are more likely to report poorer health-related behaviors (Allgower, Wardle, & Steptoe, 2001), be at a greater risk for cardiovascular disease (van der Kooy et al., 2007) and also have higher levels of inflammatory markers (Kop et al., 2010). In order to determine if loneliness or isolation were associated with these behavioral and biological variables independently of depression, all analyses were adjusted for depression.

As noted earlier, the relationship between social isolation and loneliness is weak to moderate. Cornwell and Waite (2009a) suggest that this may be particularly true for older adults, where the relationship is further "decoupled" due to expectations of, and hence greater preparation for, changes to their social network as people grow older. As a result smaller networks may not necessarily mean greater loneliness for this group (Cornwell & Waite, 2009a). Hence, we hypothesize that these variables might exert independent effects on the outcomes under consideration. We expected that frequency of contacts rather than perceived isolation would be more relevant for the social cues that are likely to affect behavior choices and hence, that social isolation would be more strongly related to health-risk behaviors than loneliness. As previous research in the area is limited, we did not formulate any hypotheses regarding the strength of the relationships between social isolation, loneliness, and biological measures.

Method

Participants

The English Longitudinal Study of Ageing (ELSA) is a panel study of people living in England, aged 50 years or over. ELSA participants were selected from respondents who participated in the Health Survey for England (HSE, an annual, nationally representative, cross-sectional household survey) in 1998, 1999, or 2001 who were born on or before 29th February 1952 (i.e., who would be aged 50 or over at the start of fieldwork for ELSA wave 1). Further details regarding the sample design and measures are provided elsewhere (Marmot, Banks, Blundell, Lessof, & Nazroo, 2003). Participants are followed up every 2 years, with nurse visits including blood sample analysis carried out in alternate waves. Ethics approval for ELSA was provided by the London Multicenter Research Ethics Committee. Participants provided consent separately for the interview, nurse visit, and blood sampling.

Wave 2 of ELSA (2004) was the first wave that included a nurse visit and blood sample analysis. Hence, the present analysis fo-

cused on data collected in wave 2. Analysis of health behaviors was carried out on all 8,688 participants who completed an interview in person. Only participants with an interview in person were eligible for a nurse visit and 7,666 participants (88%) had the nurse visit. Blood pressure measurement and blood sampling were carried out during this visit. Blood samples were not collected from participants with a clotting or bleeding disorder, those on anticoagulants, and those who had ever had a fit. Over 80% of those eligible provided a blood sample. Participants who dropped out following ELSA wave 1 were of a lower socioeconomic status, less educated, in poorer health, and more likely to be non-White. Responders to the nurse visit and those who agreed to blood sampling were younger, of a higher social class, in better health and more physically active than nonresponders (Scholes, Taylor, Cheshire, Cox, & Lessof, 2008). Individuals who dropped out following wave 1 were also less socially connected.

Measures

Psychosocial Variables

Social isolation. A social isolation index was computed with respondents given a point if they were not married/not cohabiting with a partner, had less than monthly contact (including face-to-face, telephone or written/e-mail contact) with children, other immediate family and friends (each scored as 1) and if they did not participate in any organizations, religious groups, or committees (scored as 1). Membership of a gym or sports club was not considered, as this was directly related to one of the outcomes (physical activity). Scores ranged from 0 to 5, with higher scores indicating greater social isolation.

Loneliness. The mean of the three-item, short form of the Revised UCLA loneliness scale (Hughes, Waite, Hawkley, & Cacioppo, 2004) was used to measure loneliness. An example of an item used would be *How often do you feel you lack companionship?*, with response options *hardly ever or never, some of the time* and *often.* The scale showed acceptable internal reliability ($\alpha = .84$). Scores on the scale were summed to provide a loneliness score ranging from 3 to 9, with a higher score indicating greater loneliness.

Outcomes

Smoking. Participants were asked if they had ever smoked. Individuals who responded in the affirmative were asked whether or not they smoked at present. Participants who responded "yes" to both questions were classified as current smokers. This measure has been validated against saliva cotinine levels in the Health Survey for England (Erens & Primatesta, 2001).

Physical activity. ELSA includes measures of leisure-time and occupational physical activity. The measure is adapted from the Whitehall II study and has been found to predict cardiovascular mortality and future physical and cognitive function in older age groups (Batty, Shipley, Marmot, & Smith, 2003; Lang, Guralnik, & Melzer, 2007; Singh-Manoux, Hillsdon, Brunner, & Marmot, 2005). The leisure-time physical activity measure asked participants about the frequency with which they took part in vigorous, moderate, or mild physical activity. Individuals who were currently employed were asked whether their job was mainly *sedentary, standing, physical work* or *heavy manual work*. Participants who reported moderate or vigorous leisure-time physical activity only once a week or less and if currently employed, were in a primarily sedentary occupation were classified as not meeting physical activity criteria. Participants reporting high levels of occupational physical activity and no leisure time physical activity were classified as being physically active.

Blood pressure. During the nurse visit, participants were seated and three readings of blood pressure were taken at 1-min intervals in the right arm using the OMRON HEM 907 blood pressure monitor. Participants were asked not to smoke, consume alcohol, or exercise at least 30 minutes prior to taking the blood pressure reading and room temperature was adjusted to between 15 °C and 25 °C. The mean of the last two readings was used for analysis. As participants with diagnosed hypertension who are on medication may show blood pressure within the normal range, we adjusted the analysis for whether or not participants were taking antihypertensive medication. The number of participants included in the analysis for blood pressure was 6,639.

Cholesterol. The analysis included total cholesterol and the total cholesterol:HDL cholesterol ratio. We did not analyze LDL here as fasting samples were available for just over 60% of the present sample and the Friedewald equation used to compute LDL is not recommended for nonfasting samples (Grant et al., 2009). Total cholesterol was analyzed using the cholesterol oxidase assay method and HDL cholesterol was analyzed using a direct method (no precipitation) on an Olympus 640 analyzer (Craig, Deverill, & Pickering, 2006). As levels of total cholesterol and HDL may be affected if participants were on medication, we adjusted the analysis for whether participants were taking any action to control their cholesterol levels. The lipids analysis included 5,899 participants.

Inflammatory markers. C-reactive protein (CRP) and fibrinogen were the measures of inflammation. CRP was measured using the *N* Latex CRP mono immunoassay on the Behring Nephelometer II analyzer. Fibrinogen was analyzed using a modification of the Clauss thrombin clotting method on the Organon Teknika MDA 180 analyzer (Craig et al., 2006). Participants with CRP values greater than 10 mmol/L were excluded as such high CRP values may be indicative of an acute inflammatory response (Shine, de Beer, & Pepys, 1981). Participants who reported having any respiratory infection over the past 3 weeks were also excluded from CRP analysis. The final number of participants in the CRP analysis was 5,009 while the fibrinogen analysis included 5,866 participants.

All blood analyses were carried out at the Royal Victoria Infirmary in Newcastle-upon-Tyne, using methods identical to those used in the Health Survey for England. Further details on these methods are available elsewhere (Craig et al., 2006).

Covariates

Data were available on participants' age and gender. ELSA includes detailed information on social position and the present analysis included quintiles of total (nonpension) wealth adjusted for marital status, as a covariate. Wealth was calculated net of debt and includes the value of any home and other property (less mortgage), financial assets covering all types of savings available in England, the value of any business assets and physical wealth such as artwork and jewelry. Participants were also asked if they

suffered from one or more long-standing illness, and if the illness limited their daily activities. The two questions were combined to form a dichotomous variable, classifying participants as suffering from a limiting long-standing illness or not (McMunn, Hyde, Janevic, & Kumari, 2003). Depression was measured using the 8-item version of Centre for Epidemiologic Studies Depression Scale (CES-D). Participants reporting three or more symptoms were classified as being depressed. The scale has been found to have acceptable internal reliability and validity (Steffick, 2000). The CES-D scale includes a question on loneliness and for the present analysis, this item was not included in computing the total scale score (Cornwell & Waite, 2009a). We used the dichotomous measure for our analyses, but the pattern of results remained identical when using the continuous CESD measure.

Statistical Analysis

Analyses were weighted for nonresponse at wave 2, with separate weights used to account for the bias in the nurse visit and blood sample analyses. For each outcome, three models were run, each adjusted for covariates age, gender, depression, limiting long-standing illness, and marital status-adjusted wealth; Model A with loneliness as the predictor, Model B using social isolation, and Model C with both social isolation and loneliness. For the analysis of health behaviors, we classified participants into four groups, namely those reporting no health-risk behaviors, those who smoked but met the physical activity criterion, those who did not smoke but failed to meet the physical activity criterion, and participants who were both smokers and physically inactive. A multinomial logistic regression model was run using absence of any risk behavior as the reference group. Linear regression analysis was carried out for continuous outcomes (blood pressure, total cholesterol, total cholesterol:HDL cholesterol, CRP, and fibrinogen). As the distribution of CRP values was positively skewed, the analyses were carried out using log-transformed values. Missing data (for variables imputed median percentage missing = 0.9%, M = 3.5%, maximum = 12%) were imputed using the multiple imputation procedure in SAS (PROC MI). Five complete datasets were created and analyzed. Estimates from these analyses were combined using the MIANALYZE procedure. As results for the analyses carried out on a sample where values were not imputed do not differ substantively from the analyses for the imputed dataset, results of the analysis using the complete (imputed) dataset are reported here. All analyses were carried out using SAS v9.1 (SAS Institute, Cary, NC).

Results

Table 1 shows the characteristics of the participants in the study. More than half the participants were female. The mean age was close to 67 years and nearly 70% were married or lived with a partner. Over a third reported suffering from a limiting long-standing illness. Scores on loneliness and social isolation show a positive skew, with mean scores being close to the lower end of the scales. Only 2% of participants reported feeling lonely all the time, while 7% reported maximum possible scores on the isolation index. While nearly 16% of participants smoked and about a third were inactive, only 6% reported both health-risk behaviors. The mean score on CRP was 2.5 mmol/L and mean fibrinogen was 3.2 g/L. Thirty percent of participants had a CRP result greater than or equal to 3 mmol/L and nearly 8% of participants had fibrinogen levels of over 4 g/L, which have been associated with increased risk of cardiovascular disease. Mean systolic blood pressure was 135.4 mmHg and mean diastolic blood pressure was 74.9 mmHg. Mean total cholesterol was 5.9 mmol/L and mean total:HDL cholesterol ratio was 4.0. Over a third of participants included in the analysis of blood pressure were on antihypertensive medication and fewer than 3% of participants included in the lipids analysis were taking any action to control their cholesterol levels. Nearly a quarter of participants were depressed.

Table 1
Characteristics of Participants at Wave 2 (N = 8,688)

Characteristics	Analytic sample
Male (%)	46.1
Age in years—Mean (*SD*)	66.9 (10.4)
Limiting long-standing illness (%)	36.0
Married/Cohabiting (%)	67.9
Loneliness—Mean (*SD*)	4.2 (1.4)
Social isolation—Mean (*SD*)	1.6 (1.4)
Health-risk behaviors	
No health-risk behaviors (%)	57.8
Current smokers (%)	15.9
Physically inactive (%)	32.3
Smokers and physically inactive (%)	6.0
Depressed (%)	22.3
Blood pressure (N = 6,639)	
Systolic blood pressure (mmHg)—Mean (*SD*)	135.4 (19.1)
Diastolic blood pressure (mmHg)—Mean (*SD*)	74.9 (11.3)
On antihypertensive medication (%)	33.4
Cholesterol (N = 5,899)	
Total cholesterol (mmol/L)—Mean (*SD*)	5.9 (1.2)
Total cholesterol:HDL ratio—Mean (*SD*)	4.0 (0.98)
Taking steps to reduce cholesterol (%)	2.4
CRP (N = 5,009)	
Mean (*SD*) (mmol/L)	2.5 (2.1)
$\geq$ 3 mmol/L (%)	30.3
Fibrinogen (N = 5,866)	
Mean (*SD*) (g/L)	3.2 (0.7)
$>$ 4 g/L (%)	7.7

Increased age was associated with greater social isolation (β = 0.028, 95% CI: 0.026 to 0.032, $p < .0001$) and loneliness (β = 0.013, 95% CI: 0.010 to 0.017, $p < .0001$). There were no significant gender differences in social isolation (β = 0.03, 95% CI: −0.03 to 0.09, $p = .40$) but women reported higher scores on loneliness (β = 0.27, 95% CI: 0.21 to 0.34, $p < .0001$). Individuals who did not suffer from a limiting long-standing illness reported less social isolation (β = −0.37, 95% CI: −0.44 to −0.31, $p < .0001$) and loneliness (β = −0.60, 95% CI: −0.67 to −0.54, $p < .0001$). Depression was positively associated with both loneliness (β = 1.21, 95% CI: 1.14 to 1.28, $p < .0001$) and social isolation (β = 0.63, 95% CI: 0.56 to 0.71, $p < .0001$). Both variables showed a significant wealth gradient, with increasing wealth being associated with decreasing levels of social isolation and loneliness (p for quintile 5 vs. quintile 1 < 0.0001). All further analyses were adjusted for age, gender, marital status-adjusted wealth quintile, depression, and limiting long-standing illness.

Relationship Between Loneliness and Social Isolation

In unadjusted analyses, social isolation was positively associated with loneliness ($\beta = 0.19$, 95% CI: 0.17 to 0.22, $p < .0001$). Adjusting for age, gender, depression, limiting long-standing illness, and wealth attenuated this relationship, although social isolation was still a significant predictor of loneliness ($\beta = 0.12$, 95% CI: 0.09 to 0.15, $p < .0001$).

We compared participants who reported feeling lonely at least some of the time with those who reported never feeling lonely, using a grouped measure of social isolation (scores of 0, 1 and greater than 1) and adjusting for all covariates. Compared with participants who were most integrated (i.e., had a score of 0 on the social isolation index), those with a score of 1 were 60% more likely to report feeling lonely at least some of the time (OR: 1.60, 95% CI: 1.42 to 1.82, $p < .0001$) and those with a score greater than 1 were nearly three times as likely to report feeling lonely at least some of the time (OR: 2.80, 95% CI: 2.46 to 3.16, $p < .0001$).

Health Behaviors

Increasing loneliness was associated with a greater likelihood of being physically inactive, being a smoker, and reporting both health-risk behaviors (see Table 2). Effects of social isolation were stronger, with greater social isolation associated with higher odds of being a smoker, being less active and reporting both health-risk behaviors. In a model including social isolation and loneliness, both variables continued to be independently associated with a greater likelihood of reporting low physical activity and both risk behaviors. However, loneliness was no longer significantly predictive of increased risk of being a smoker.

We repeated the analysis using standardized scores for loneliness and social isolation to facilitate comparison, given the scaling differences in the measures. A standard deviation increase on the loneliness score was associated with a 13% increase in odds of being inactive (OR: 1.13, 95% CI: 1.06 to 1.20), a 10% increase in odds of being a smoker (OR: 1.10, 95% CI: 1.08 to 1.19) and a 16% increase in the odds of being both inactive and a smoker (OR: 1.16, 95% CI: 1.06 to 1.27). For social isolation, a standard deviation increase was associated with a 23% increase in odds of being inactive (OR: 1.23, 95% CI: 1.16 to 1.29), a 32% increase in odds of being a smoker (OR: 1.32%, 95% CI: 1.23 to 1.43) and a 56% increase in odds of reporting both risk behaviors (OR: 1.56, 95% CI: 1.43 to 1.71).

Blood Pressure

Loneliness was not significantly associated with either systolic or diastolic blood pressure. However, increases in social isolation were associated with small, significant increases in both systolic and diastolic blood pressure. Estimates for both variables remained similar in the combined model (see Table 2).

Cholesterol

Neither loneliness nor social isolation was associated with total cholesterol levels or the total cholesterol:HDL ratio (see Table 3).

Inflammatory Markers

Scores on loneliness were not related with CRP or fibrinogen levels (see Table 3). However, social isolation showed small positive associations with both CRP ($\beta = 0.05$, 95% CI: 0.01 to 0.09, $p < .05$) and fibrinogen ($\beta = 0.02$, 95% CI: 0.01 to 0.04, $p < .001$). Estimates for both variables remained similar in the combined model.

Given the known relationship between marital status and many of the outcomes considered in this analysis, we repeated all analysis with a social isolation index excluding the marital status dimension. The pattern of results remained identical for health behaviors and cholesterol. In the case of blood pressure, CRP and fibrinogen, results were no longer significant when marital status was excluded from the index, suggesting that these effects are substantially driven by marital status.

We also repeated all analysis for participants who had at least one blood result, since this number ($N = 5{,}961$) was somewhat smaller than the total cohort on which other analyses were carried out. The pattern of results remained identical for inflammatory markers, blood pressure, cholesterol, and the relationship between social isolation and health behaviors. Loneliness was no longer significantly associated with physical activity or smoking individ-

Table 2
Results of Regression Analysis for Health Behaviors and Blood Pressure

	Health-risk behavior (reference category: no risky behaviors)[a]				
	Inactive only OR (95% CI)	Smoker only OR (95% CI)	Both inactive and smoker OR (95% CI)	Systolic blood pressure[b] β (95% CI)	Diastolic blood pressure[b] β (95% CI)
Model A					
Loneliness	1.08 (1.04 to 1.13)†	1.07 (1.01 to 1.13)*	1.12 (1.04 to 1.19)†	−0.17 (−0.53 to 0.18)	0.02 (−0.18 to 0.22)
Model B					
Social isolation	1.15 (1.11 to 1.19)†	1.21 (1.15 to 1.28)†	1.36 (1.28 to 1.45)†	0.40 (0.07 to 0.74)*	0.31 (0.11 to 0.51)**
Model C					
Loneliness	1.06 (1.02 to 1.11)**	1.04 (0.98 to 1.09)	1.08 (1.02 to 1.15)*	−0.23 (−0.58 to 0.13)	−0.02 (−0.22 to 0.18)
Social isolation	1.15 (1.11 to 1.20)†	1.21 (1.15 to 1.27)†	1.35 (1.27 to 1.45)†	0.43 (0.09 to 0.77)*	0.31 (0.11 to 0.51)**

Note: [a] N = 8,688. Analyses were adjusted for age, gender, limiting long-standing illness, depression, and marital status-adjusted wealth. [b] N = 6,639. Analyses were adjusted for age, gender, limiting long-standing illness, depression, marital status-adjusted wealth, and antihypertensive medication.
* $p < .05$. ** $p < .01$. † $p < .001$.

Table 3
Results of Regression Analyses for Levels of Cholesterol, CRP and Fibrinogen

	Total cholesterol[a] β (95% CI)	Total cholesterol: HDL ratio[a] β (95% CI)	CRP level[b] β (95% CI)	Fibrinogen level[c] β (95% CI)
Model A				
Loneliness	−0.01 (−0.04 to 0.01)	−0.004 (−0.02 to 0.01)	0.02 (−0.03 to 0.06)	0.01 (−0.01 to 0.02)
Model B				
Social isolation	−0.01 (−0.03 to 0.01)	−0.003 (−0.02 to 0.02)	0.05 (0.01 to 0.09)*	0.02 (0.01 to 0.04)†
Model C				
Loneliness	−0.01 (−0.03 to 0.01)	−0.003 (−0.02 to 0.02)	0.01 (−0.03 to 0.06)	0.002 (−0.01 to 0.02)
Social isolation	−0.01 (0.03 to 0.02)	−0.003 (−0.02 to 0.02)	0.05 (0.003 to 0.09)*	0.02 (0.01 to 0.04)†

Note: [a] N = 5,899. Analyses were adjusted for age, gender, limiting long-standing illness, depression, marital status-adjusted wealth, and cholesterol management. [b] N = 5,009. Analyses were adjusted for age, gender, depression, limiting long-standing illness, and marital status-adjusted wealth. Log-transformed values were used, as the distribution of CRP values was positively skewed. [c] N = 5,866. Analyses were adjusted for age, gender, depression, limiting long-standing illness, and marital status-adjusted wealth.
* $p < .05$. ** $p < .01$. † $p < .001$.

ually but was associated with an increased risk of reporting multiple risk behaviors.

We also performed gender-specific analyses. For women, loneliness was no longer significantly associated with smoking and isolation was not significantly associated with blood pressure or CRP levels. It appears that effects of social isolation work through health behaviors for women.

Discussion

Older adults are at a greater risk of experiencing social isolation and loneliness. In addition, risk factors such as physical inactivity and smoking are common in this age group (Shankar, McMunn, & Steptoe, 2010), as are reduced immune function and increased cardiovascular reactivity in response to stress (Hawkley, Bosch, Engeland, Marucha, & Cacioppo, 2010; Keicolt-Glaser & Glaser, 2001; Uchino, Birmingham, & Berg, 2010). Hence it is important to study the relationship between these pathways, isolation and loneliness. In a combined model, both loneliness and social isolation were independently associated with physical activity levels and multiple risk behaviors. In addition, social isolation was related to smoking. Social isolation was also associated with increases in systolic and diastolic blood pressure and also showed small positive associations with CRP and fibrinogen which are markers of inflammation.

As noted earlier, evidence regarding the effects of loneliness on health behaviors is mixed. In this analysis, loneliness was significantly associated with physical activity such that individuals who were lonelier were more likely to report low physical activity and also more likely to report multiple health-risk behaviors. Increasing isolation was associated with an increased risk of smoking and low physical activity individually as well as a greater likelihood of reporting multiple health-risk behaviors. Most social–cognition models of health behavior recognize the importance of significant others in adopting and maintaining healthy behaviors and this may be in the form of support for healthier choices or by providing social cues for behavior (Conner & Norman, 2005). A distinction is also made between injunctive norms that stress the importance of what significant others say or want an individual to do and descriptive norms, which relate to how significant others actually behave. Studies indicate that both independently predict health behaviors (Conner & Sparks, 2005). Individuals who are isolated are less likely to have an opportunity to be influenced by either and hence, the relationship between social isolation and health behaviors is likely to be stronger than that between loneliness and health behaviors. Christakis and colleagues suggest that changes in perceived acceptability of behaviors or states may account for social network effects, with lessening acceptability of behaviors such as smoking leading to smokers becoming more peripheral in their networks (Christakis & Fowler, 2007; Christakis & Fowler, 2008).

We found no significant relationship between loneliness and blood pressure, although social isolation was associated with increases in systolic and diastolic blood pressure among men with substantial effects seen for the marital status component of the social isolation index. Previous studies have indicated the impact of both marital status and marital quality on blood pressure (Holt-Lunstad, Uchino, Smith, Olson-Cerny, & Nealey-Moore, 2003; Holt-Lunstad, Uchino, Smith, & Hicks, 2007), and effects of marital status on health are usually stronger for men (Blomgren, Martikainen, Grundy, & Koskinen, 2010). Marital transitions such as widowhood are more common among older adults and individuals experiencing such marital transitions would benefit from additional support to minimize negative health effects. Neither loneliness nor social isolation was associated with cholesterol levels in the present analysis.

We found no significant relationship between CRP levels and loneliness. Similar findings have been reported from the Chicago Health, Aging, and Social Relations Study (McDade, Hawkley, & Cacioppo, 2006). Social isolation was positively associated with both fibrinogen and CRP. Fibrinogen is known to play a role in hemostasis and high levels of fibrinogen are associated with increased risk of heart disease and stroke (Fibrinogen Studies Collaboration, 2005). Similarly, elevated levels of CRP have been associated with coronary events (Kaptoge et al., 2010), although the causal significance of the association is debatable (Danesh & Pepys, 2009). Studies of older adults, particularly older men, have shown positive associations between social isolation and CRP levels (Ford, Loucks, & Berkman, 2006; Loucks, Berkman, Gruenewald, & Seeman, 2006) and we report similar effects here. Depression is one of the pathways through which social isolation could lead to inflammation (Kiecolt-Glaser, Gouin, & Hantsoo,

2010), although the effect of isolation on CRP and fibrinogen remains significant in our analysis even after controlling for depression in our studies. Controlling for adiposity, medication, other clinical risk factors and health behaviors may further modify this association (Kiecolt-Glaser et al., 2010).

The results of the present study also support previous work indicating only a weak relationship between social isolation and loneliness. As noted earlier, the strength of the relationship between these variables may be attenuated in this age group. It has also been suggested that relative to not-so-close relationships, emotionally close relationships decline less in older age (Pinquart & Sorensen, 2001). Although we found no significant gender differences in social isolation, in our study women were more likely to report being lonely than men. Findings regarding gender differences in loneliness are mixed. Pinquart and Sorensen (2001) in their meta-analysis found that women were more likely report being lonely when compared to men; however, this may be affected by the measures used in some studies (Borys & Perlman, 1985).

Study Strengths and Limitations

One of the main strengths of our study is the use of data from a survey that is multidisciplinary nature, incorporating psychosocial, behavioral, economic, and biological variables for a large, nationally representative sample of older adults. This enables us to use a more detailed measure of social isolation. Studies have varied in their operationalization of this construct, making comparisons difficult. It has been suggested that the assessment of social isolation should include multiple measures (Cornwell & Waite, 2009b). Here, we use an index comprised of different aspects of the social network and thus incorporate not only network size but also frequency of contact. Taking into account that older adults may have limited face-to-face contact with children, family, and friends, we also considered frequency of e-mail and telephone contact. Holt-Lunstad et al. (2010) in their meta-analysis of studies examining the relationship between social relationships and mortality found that studies using complex measures of social integration found stronger associations between social integration and mortality and suggest that this may be because such measures incorporate the many pathways through which social networks affect health. In our analysis, all relationships were given equal importance and future work could consider weighting relationships as it is likely that certain relationships may be more important than others.

Our study is limited by its cross-sectional nature due to which we cannot infer causality. Indeed it is important to consider that some individuals may become more isolated because they feel ill or lack energy. The issue of selective attrition is common in such longitudinal studies and the sample analyzed here was generally healthier, wealthier, and more socially connected than those who either dropped out entirely from wave 2 or had refused the nurse visit or blood sampling. Although we have used weights to correct for this nonresponse, it is possible that the weighting does not correct for all variables of interest.

As data from more waves of ELSA become available, we will be better placed to study changes in isolation and loneliness, the differential impact of situational and chronic isolation and loneliness (e.g., Shiovitz-Ezra & Ayalon, 2010), and the impact of marital quality and social support. In addition to outcomes studied here, we can also examine the impact of these social network variables on cognitive function, hospitalization, and mortality.

Conclusions

In the present analysis, we found that both loneliness and social isolation may affect health independently through their effects on health behaviors. In addition, social isolation may also affect health through increases in blood pressure as well as through inflammatory processes associated with the development of cardiovascular disease. The results highlight the need to provide additional support to older adults who are isolated, particularly those who may be experiencing marital transitions. Only a small number of interventions aimed at reducing isolation or loneliness have been effective, and in their review, Cattan and colleagues note that group interventions targeted at specific groups and incorporating educational or social activities are likely to be beneficial (Cattan, White, Bond, & Learmouth, 2005).

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