

Social isolation and physical activity mediate associations between free bus travel and wellbeing among older adults in England

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Word count: 3500

Abstract

Background: Aims of this study were: (i) to examine relationships between free bus travel and wellbeing, and (ii) to assess the extent to which these associations can be explained by two key potential mediators: social isolation and physical activity.

Methods: Data were from the English Longitudinal Study of Ageing ($n=5,861$). Linear regression models tested associations between (i) concessionary bus pass (CBP) ownership and (ii) frequency of CBP use and three measures of wellbeing (quality of life, life satisfaction, depressive symptoms), adjusting for age, sex, marital status, socioeconomic status and limiting long-standing illness. Mediation analyses tested the role of (i) social isolation and (ii) physical activity in each association between CBP ownership/use and wellbeing.

Results: Ownership and use of a CBP was significantly associated with better quality of life (both $p<0.001$), higher life satisfaction (both $p<0.01$) and fewer depressive symptoms (both $p<0.01$). Mediation models revealed significant indirect associations of CBP ownership (all $p<0.001$) and use (all $p<0.05$) via social isolation on wellbeing. There were also significant indirect associations of CBP ownership (all $p<0.01$) and use (all $p<0.001$) via physical activity on wellbeing. Social isolation explained 7.7-20.1% of the total association between free bus travel and wellbeing, and physical activity explained 9.0-17.4%.

Conclusions: Ownership and use of a CBP are associated with better quality of life, higher life satisfaction, and fewer depressive symptoms in older adults in England. Associations between free bus travel and wellbeing are partly explained by an increase in physical activity and a reduction in social isolation.

Key words: bus travel; public transport; older adults; wellbeing; social isolation; physical activity; depression; quality of life; public health

1. Introduction

Population ageing is a global phenomenon, and ageing well is important both for personal wellbeing and fiscal sustainability of health budgets [1]. With evidence demonstrating substantial benefits of wellbeing for morbidity and mortality [2], promoting wellbeing in later life has been identified as an important strategy for enhancing public health in government and organisational policies [1,3]. One policy the English government has implemented in an effort to maintain wellbeing among older adults is entitlement to a concessionary bus pass when a man or a woman reaches the female State Pension age (62 years at the time of data collection for the present study). No adult residing in England of female state pension age is excluded from the scheme. The concessionary bus pass enables them to travel anywhere in their country of residence (England) free of charge during off-peak hours [4]. The scheme was introduced in three stages between 2000 and 2008, but there has been little investigation into its potential impact on wellbeing at any stage during or after the implementation process [5]. This study examines relationships between free bus travel and wellbeing, and assesses the extent to which these associations can be explained by two potential mediators: social isolation and physical activity.

The existing evidence on associations between free bus travel and wellbeing among older adults is limited and relies on small surveys of concessionary bus pass holders. Findings are suggestive of benefits of free bus travel. In a survey of 144 disabled and older people in Scotland, almost 60% indicated that free bus travel had improved their quality of life either a lot or a little [6]. Similarly, in an on-board survey of 487 pass holders, 74% agreed that having a concessionary bus pass had improved their quality of life to some extent [7]. To the best of our knowledge, there has been no exploration of the impact of free bus travel on other aspects of wellbeing, such as positive affect (e.g. satisfaction with life) or negative affect (e.g. depressive symptoms). There is a need to objectively evaluate differences in a range of measures of wellbeing between older adults who do and do not hold concessionary bus passes in a larger, representative sample.

Two key mechanisms through which free bus travel might contribute to the maintenance of wellbeing in old age are by (i) reducing social isolation and (ii) increasing physical activity. Indeed, the importance of maintaining social relationships, being part of a community and staying active were highlighted in the 2010 White Paper 'Healthy Lives, Healthy People' as fundamental influences on health and wellbeing in later life [8].

Social isolation and loneliness have been shown to have a substantial impact upon wellbeing in older adults, accounting for around 70% of depression in this population [9]. Travel is a necessary requirement for the majority of social interactions, so the logic of offering concessionary bus passes is that by reducing the cost, older adults are more able to engage in social activities and maintain healthy social relationships. In qualitative studies, concessionary bus pass holders often comment that free bus travel enables them to visit family and friends and attend community activities [10], with some reporting that they use the bus specifically to meet new people and lessen feelings of boredom and loneliness [7]. These findings are supported by a recent evaluation using data from the English Longitudinal Study of Ageing (ELSA). This large scale evaluation on the impact of free bus travel on social isolation and loneliness among English older adults ($n=4,726$) found that people who had concessionary bus passes were around a third less likely to be socially isolated or lonely, both cross-sectionally and over four-year follow-up [11]. Such a reduction in social isolation is likely to be accompanied by an improvement in wellbeing.

Physical activity is also an established predictor of wellbeing among older adults [12]. A meta-analysis of physical activity interventions in older adults observed a mean change in wellbeing for treatment groups that was almost three times the mean for control groups, with strong benefits observed for aerobic training and moderate intensity activity [13]. Using public transport can contribute significantly to overall levels of free-living physical activity: by walking to and from transport access points, taking a simple journey each day can accumulate the full 150 weekly minutes of moderate intensity aerobic activity currently recommended for adults over the age of 65 [14]. A clear association between owning a concessionary bus pass and increased physical activity was demonstrated in a recent study of 4,650 older adults in England using data from ELSA, with bus pass holders 43% more likely to be physically active than those without a bus pass [15]. Such an increase in physical activity is likely to be accompanied by an improvement in wellbeing.

To our knowledge, no previous study has quantitatively examined differences in wellbeing between older adults who do and do not hold concessionary bus passes, nor have mediating effects of social isolation or physical activity on these relationships been tested. The present study analysed data from a large sample of older adults taking part in the English Longitudinal Study of Ageing (ELSA), to address the following research questions:

1. Among older adults in England, is holding a concessionary bus pass associated with better status on three markers of wellbeing: quality of life, life satisfaction, and depressive symptoms?

2. Among older adults in England who hold a concessionary bus pass, is more frequent use associated with better wellbeing?
3. To what extent can the above associations be explained by social isolation and level of physical activity?

2. Method

2.1 Study population

Data were from Wave 6 (2012/13) of ELSA. ELSA is a cohort study of adults aged ≥ 50 years living in England, drawn from a random stratified sample of households who participated in the Health Survey for England. Data are collected via computer-assisted personal interviews conducted in the home, and self-completion questionnaires. We restricted our sample to participants aged ≥ 62 years (in order to ensure eligibility for the bus pass at the time of survey [15]) who had complete data on bus pass ownership, all covariates and at least one measure of wellbeing ($n=5,861$, 88.0% of age-eligible participants interviewed). The study was approved by the London Multicentre Research Ethics Committee and all participants gave full informed consent.

2.2 Measures

2.2.1 Exposure: free bus travel

Bus pass ownership was assessed with the question “*Do you have a concessionary travel bus pass issued by your local authority? (yes/no)*”. Those who responded yes were asked about the frequency of bus pass use in the last month: “*In the last month, how many times have you used your concessionary travel bus pass when boarding a bus? (0/1-5/6-10/11-20/21 or more)*” We analysed frequency of use in three categories: 0, 1-5 and ≥ 6 , as has been done previously in ELSA [15].

2.2.2 Outcomes: wellbeing

We analysed associations with three measures of psychological wellbeing: quality of life, life satisfaction, and depressive symptoms. Our rationale for examining these separate constructs was to have one global measure of wellbeing, one of positive affect, and one of negative affect.

Quality of life was assessed with the CASP-19 [16], a scale designed to measure quality of life in older people. Items cover four domains of quality of life; control (e.g. *“I feel that what happens to me is out of my control”*), autonomy (e.g. *“My health stops me from doing things I want to do”*), self-realisation (e.g. *“I feel that life is full of opportunities”*), and pleasure (e.g. *“I enjoy being in the company of others”*). Respondents are asked how often each statement applies to them (often=0, sometimes=1, not often=2, never=3). Positively-worded items are reverse scored so that a higher total score indicates higher quality of life (range: 0–57).

Life satisfaction was assessed with the Satisfaction With Life Scale [17], which asks respondents to rate the extent to which they agree with five statements about their life (e.g. *“In most ways my life is close to my ideal”*) on a scale from 0 (strongly disagree) to 6 (strongly agree). Item scores are summed to produce a total score of 0-30, with higher scores indicating greater life satisfaction.

Depressive symptoms were assessed with an eight-item version of the Center for Epidemiologic Studies Depression Scale, a scale highly validated for use in older adults [18]. The scale asks participants about their feelings over the last week (e.g. *“Over the last week have you felt lonely”*), with binary response options (1=yes/0=no). We reverse scored positively-worded items and summed item scores to create a total score of 0-8. Higher scores indicated a greater number of depressive symptoms.

We calculated standardised scores (z-scores) for each of the three scales for ease of comparison.

2.2.3 Mediators: social isolation and physical activity

Social isolation was assessed with an index that takes into account living status, frequency of contact with friends and relatives, and membership of social organisations. Participants scored one point if they lived alone, one point if they had less than monthly contact (including face-to-face, telephone, or written/e-mail contact) with each of friends, children, and other family members, and one point if they did not belong to any social clubs or organisations, for a total score of 0-5. As has been done in other investigations, we dichotomised this variable to distinguish between low (score <2) and high (score ≥2) levels of social isolation [19].

Physical activity was assessed with three items that asked participants how often they took part in vigorous, moderate and low-intensity activities (more than once a week, once a week, 1-3 times a month, hardly ever/never). We further categorised data into three groups, as previously described [20]: inactive (no

moderate/vigorous activity on a weekly basis); moderate activity at least once a week; and vigorous activity at least once a week.

2.2.4 Covariates

All covariates were selected *a priori*. We included information on age, sex, marital status (married vs. unmarried), household non-pension wealth (a sensitive indicator of socioeconomic status in this age group) and self-reported limiting long-standing illness. Wealth data were analysed as quintiles calculated across all Wave 6 ELSA participants. Limiting long-standing illness was defined as the presence of any long-standing illness, disability or infirmity that limited the participants' activities in any way.

2.3 Statistical analysis

Simple associations between bus pass ownership and frequency of use and age, sex and wealth were analysed using one-way independent analysis of variance for continuous variables and chi-square tests for categorical variables. We used linear regression to analyse associations between (i) bus pass ownership and (ii) frequency of use and quality of life, life satisfaction and depressive symptoms, adjusting for age, sex, marital status, wealth and limiting long-standing illness.

Where there was evidence of a non-random relationship between bus pass ownership or frequency of bus pass use and wellbeing, we ran additional analyses testing for mediation by (i) social isolation and (ii) level of physical activity (Figure 1). Establishing mediation requires the mediator to be correlated with the exposure (path *a*) and the outcome (path *b*), so for both social isolation and physical activity, we first tested associations with bus pass ownership, frequency of bus pass use and wellbeing outcomes using linear regression (continuous variables) and logistic regression (categorical variables), adjusting for covariates. Where these associations were found, we calculated the total (path *c*), direct (path *c'*), and indirect (path *a* × *b*) effects (using *sgmediation* in STATA), and tested the significance of the indirect effect (using the Sobel test). We used bootstrapping with 5,000 sampling replications to estimate the 95% confidence interval. We also calculated effect ratios, which reflect the proportion of the total effect of the independent variable on the dependent variable that is explained by the mediator. As was done in the primary analyses, we adjusted mediation models for age, sex, marital status, wealth and limiting long-standing illness at baseline.

All analyses were performed using IBM SPSS v.25, with the exception of the mediation models which were run in STATA v.13.

3. Results

Of the 5,861 older (≥ 62 years) men and women in our sample, 4,973 (84.8%) reported owning a concessionary bus pass. Among those who held a bus pass, 1,986 participants (39.9%) reported not having used it at all in the past month, 1,389 (27.9%) had used it between 1 and 5 times, and 1,598 (32.1%) had used it 6 or more times. Table 1 summarises sample characteristics in relation to bus pass ownership and use. Ownership of a concessionary bus pass was significantly associated with older age, female sex, mid to low levels of wealth and absence of limiting long-standing illness, but was not significantly associated with marital status. More frequent bus pass use was significantly associated with female sex, being unmarried, having low levels of wealth, and the absence of limiting long-standing illness. There was a curvilinear association with age, whereby the mean age was higher among participants using their bus pass ≥ 6 times a month or not at all than in those using it 1-5 times per month.

Bus pass ownership was significantly related to wellbeing, after adjustment for age, sex, marital status, wealth and limiting long-standing illness (Figure 2). Participants who held a concessionary bus pass reported better quality of life ($B=0.160$, 95% CI 0.090 to 0.231, $p<0.001$), higher life satisfaction ($B=0.112$, 95% CI 0.039 to 0.185, $p=0.003$) and fewer depressive symptoms ($B=-0.097$, 95% CI -0.164 to -0.030, $p=0.005$) than those who did not (Figure 2). Furthermore, among those who held a bus pass, frequency of use was significantly associated with better wellbeing (Figure 2). Participants who used their bus pass more frequently reported significantly better quality of life ($B=0.061$, 95% CI 0.029 to 0.093, $p<0.001$), higher life satisfaction ($B=0.035$, 95% CI 0.001 to 0.069, $p=0.041$) and fewer depressive symptoms ($B=-0.060$, 95% CI -0.091 to -0.029, $p<0.001$).

Social isolation and physical activity were significantly related to bus pass ownership and frequency of bus pass use (Table 3; path *a* in Figure 1) and to wellbeing (Table 4; path *b* in Figure 1), after adjustment for covariates. Participants who held a concessionary bus pass had significantly lower odds of social isolation (OR=0.68, 95% CI 0.56 to 0.82) and significantly higher odds of engaging in a higher level of physical activity (OR=1.37, 95% CI 1.19 to 1.58) than those who did not. Among those who held a bus pass, participants who used their bus pass frequently (≥ 6 times in the past month) were significantly less likely to be socially isolated (OR=0.77, 95% CI 0.65 to 0.92) and significantly more likely to be physically active (OR=1.44, 95% CI 1.26 to 1.64) than those who had not used it at all. Participants with high levels of social isolation reported lower quality of life, lower life satisfaction and more depressive symptoms than those with low levels of isolation ($p<0.001$ for all comparisons; Table 4). In contrast, participants with higher levels of physical

activity reported better quality of life, higher life satisfaction and fewer depressive symptoms than those who were less active ($p < 0.001$ for all comparisons). These relationships were also evident in the raw data itself, with bus pass ownership being related to reduced social isolation (Figure 3) and increased physical activity (Figure 4) and an increase in all wellbeing measures (Figure 3; Figure 4)

The results of the mediation analyses (path c , path c' , and indirect effects in Figure 1) are shown in Table 5. After adjustment for covariates, we observed significant indirect effects of bus pass ownership via social isolation on all three measures of wellbeing (quality of life $B = 0.018$, 95% CI 0.009 to 0.030, life satisfaction $B = 0.020$, 95% CI 0.010 to 0.032, depressive symptoms $B = -0.012$, 95% CI -0.021 to -0.006). Among participants who held a concessionary bus pass, there were also significant indirect effects of frequency of bus pass use via social isolation on all three measures of wellbeing (quality of life $B = 0.006$, 95% CI 0.001 to 0.011, life satisfaction $B = 0.006$, 95% CI 0.002 to 0.011, depressive symptoms $B = -0.004$, 95% CI -0.007 to -0.001). Effect ratios indicated that social isolation explained 12.6-17.8% of the association between bus pass ownership and wellbeing, and 7.7-20.1% of the association between frequency of bus pass use and wellbeing. We also observed significant indirect effects of bus pass ownership via physical activity on wellbeing (quality of life $B = 0.019$, 95% CI 0.008 to 0.031, life satisfaction $B = 0.010$, 95% CI 0.004 to 0.018, depressive symptoms $B = -0.016$, 95% CI -0.025 to -0.008), and significant indirect effects of frequency of bus pass use via physical activity on wellbeing among participants who held a bus pass (quality of life $B = 0.011$, 95% CI 0.005 to 0.016, life satisfaction $B = 0.006$, 95% CI 0.003 to 0.010, depressive symptoms $B = -0.009$, 95% CI -0.014 to -0.005). Effect ratios indicated that physical activity explained 9.0-17.0% of the association between bus pass ownership and wellbeing, and 15.6-17.4% of the association between frequency of bus pass use and wellbeing.

4. Discussion

In a large, representative sample of older adults in England, ownership and use of a concessionary bus pass was associated with significantly better wellbeing. Findings from the present study explain between 21.6% and 34.8% of the total association between bus pass ownership and wellbeing and 23.3% and 37.5% of the total association between frequency of bus pass use and wellbeing.

Taken together, these findings support and add to the existing evidence base. In line with smaller convenience surveys and qualitative studies [6,7], we found that holding a concessionary bus pass was positively associated with quality of life. For the first time to our knowledge, we have also demonstrated

that holding a bus pass, and using it frequently, is also associated with higher levels of positive affect (life satisfaction) and lower levels of negative affect (depressive symptoms). Identification and quantification of the mediating role of two key variables – social isolation and physical activity – in associations between concessionary bus pass ownership and use and wellbeing is an additional novel contribution to the literature.

The importance of tackling social exclusion in order to maintain wellbeing was highlighted in the 2006 Budget that announced the extension of the concessionary bus travel scheme England-wide (paragraph 5.50) [4], but whether the scheme was achieving this had not been tested. We have previously demonstrated that owning and using a concessionary bus pass reduces the odds of social isolation and loneliness among older adults in England [11]. Social isolation has been shown to reduce quality of life and positive affect and increase negative affect [21], likely resulting from lack of human interaction. Studies have shown strong associations between the size and quality of social networks and quality of life scores [22] as well as depression [23]. Our results suggest that the influence of the concessionary bus pass scheme on reducing social isolation may account for a substantial proportion of its influence on wellbeing; that is, in the present analyses up to a fifth of the association with better wellbeing was attributable to concessionary bus passes potentially facilitating older people to engage in social activities and relationships.

While targeting levels of physical activity among older adults is not a primary objective of the concessionary bus travel scheme, previous evidence has demonstrated that bus pass holders tend to be significantly more active than those without a bus pass [15]. Regular participation in physical activity has been shown to improve quality of life and life satisfaction, and reduce depressive symptoms [24,25]. There are several mechanisms that may explain how physical activity leads to an increase in wellbeing. Physical activity has favourable effects on a range of psychological (e.g. self-efficacy beliefs) and physical (e.g. functional ability, chronic disease) outcomes in older adults that are likely to be associated with an increase in, or maintenance of, wellbeing in later life [26]. Physiological effects of physical activity may also contribute to a reduction in depressive symptoms; for example, levels of the brain neurotransmitters monoamines and endorphins are elevated after participation in physical activity, and these have been shown to be related to positive feelings and thus fewer symptoms of depression [27]. Our results indicate that physical activity plays an important role in the relationship between concessionary bus travel and wellbeing; that is, up to a sixth of the association with better wellbeing is attributable to concessionary bus passes encouraging or facilitating older people to be more physically active.

In the present study we have explained between 21.6% and 34.8% of the total association between bus pass ownership and wellbeing and 23.3% and 37.5% of the total association between frequency of bus pass use and wellbeing. Thus, a large proportion of the relationship remains unexplained. Future research may wish to explore how much of the total association is explained by the amount and quality of social interaction individuals engage in, over and above a crude measure of social isolation. The quality of a person's social experience may feasibly be associated with bus pass ownership and use and has previously been shown to be associated with quality of life and depression [22,23]. Other potential mechanisms that could be implicated include access to medical care, which has previously been identified as a common reason for using the concessionary bus pass [5], or perception of self-worth [28].

Strengths of the present study include the large sample drawn from a nationally-representative cohort, assessment of several markers of wellbeing, and formal testing of mediation effects. However, there were several limitations. All measures were self-reported, and assessment of the frequency of bus pass use relied on recall of the past month, introducing scope for bias. Although the sample was representative of the English population, there was a significant amount of missing data which meant our sample was restricted to 88% of eligible participants. Comparison of the analysed sample with participants who were excluded indicated that our sample was on average wealthier and scored higher on measures of wellbeing. It is therefore possible that our results underestimate associations between free bus travel and wellbeing, and that stronger effects would be observed if more socioeconomically disadvantaged groups were better represented. Finally, from our analyses it is not possible to determine the direction of the observed associations. It is possible that those who are more physically active make greater use of the bus pass rather than owning a bus pass facilitating higher levels of physical activity. It is likely that the relationship is bidirectional. Moreover, those who are less socially isolated may be using the bus pass to engage in greater in-person contact compared to those who are more socially isolated. Further research of a longitudinal or experimental design is required.

5. Conclusions

Ownership and use of a concessionary bus pass is associated with better wellbeing in older adults in England, and this association is partly explained by an increase in physical activity and a reduction in social isolation. These findings have important implications for policy. The concessionary bus travel scheme has been criticised on the basis that it is not financially viable and offering free bus travel universally to older adults is a waste of resources [29]. In England alone, the concession costs approximately £1.17 billion per

annum, with an average annual cost of £120 per pass [29]. With our results indicating clear benefits of offering concessionary bus travel on maintaining wellbeing in old age – a key public health priority [3] – this study provides strong support for the worth of the scheme. Moreover, given that poor mental health and wellbeing in old age are associated with physical health outcomes (e.g. depression in later life is associated with disability, increased mortality, and poorer recovery from physical illness [30]), concessionary bus travel likely provides a cost-effective method of reducing the substantial financial burden of morbidity associated with an ageing population.

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Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the National Research Ethics Service and all participants gave full informed consent to participant.

Consent for publication

Participants consented to their information being analysed and published.

Availability of data and material

The raw data are available from the UK Data Service.

Competing interests

None.

Funding

SEJ's salary is funded by Cancer Research UK (C1417/A22962).

Authors' contributions

SEJ and LS conceived of the design of the current study. SEJ performed the data analysis and drafted the paper. JAF produced the figures. All authors provided critical revisions and approved the final version of the paper for submission.

Acknowledgements

None.

Tables

Table 1 Sample characteristics in relation to free bus travel

	Has a concessionary bus pass			How often has used concessionary bus pass ¹			
	No (n=888)	Yes (n=4973)	<i>p</i>	Never (n=1986)	1-5 times (n=1389)	≥6 times (n=1598)	<i>p</i>
Age (mean [SD] years)	70.88 (7.36)	71.83 (6.87)	<0.001	72.30 (7.18)	71.12 (6.55)	71.86 (6.70)	<0.001
Sex							
Men	53.6	43.0	<0.001	48.2	42.0	37.3	<0.001
Women	46.4	57.0	-	51.8	58.0	62.7	-
Marital status							
Married	62.2	64.3	0.220	68.6	69.8	54.2	<0.001
Unmarried	37.8	35.7	-	31.4	30.2	45.8	-
Wealth quintile							
1 (poorest)	16.3	15.2	<0.001	14.4	10.6	20.3	<0.001
2	14.4	19.1	-	16.5	18.3	23.0	-
3	17.7	23.0	-	23.5	22.2	23.3	-
4	21.4	22.1	-	21.3	27.4	18.5	-
5 (richest)	30.2	20.6	-	24.4	21.6	14.9	-
Limiting long-standing illness							
No	56.3	62.5	0.001	56.5	67.8	65.2	<0.001
Yes	43.7	37.5	-	43.5	32.2	34.8	-
Social isolation							
Low	62.6	71.2	<0.001	69.8	74.4	70.0	0.016
High	37.4	28.8	-	30.2	25.6	30.0	-
Physical activity							
Inactive	31.9	25.4	<0.001	31.0	21.1	22.3	<0.001
Moderate at least once a week	42.1	48.0	-	43.6	50.4	51.4	-
Vigorous at least once a week	26.0	26.5	-	25.4	28.5	26.3	-

¹ Usage in the past month among participants who had a concessionary bus pass.

Values are percentages unless otherwise stated.

SD = standard deviation.

Table 2 Associations of bus pass ownership and frequency of bus pass use with wellbeing

	Has a concessionary bus pass				Frequency of bus pass use			
	<i>n</i> ¹	Coeff.	95% CI	<i>p</i>	<i>n</i> ¹	Coeff.	95% CI	<i>p</i>
Quality of life	4937	0.160	0.090; 0.231	<0.001	4208	0.061	0.029; 0.093	<0.001
Life satisfaction	5137	0.112	0.039; 0.185	0.003	4378	0.035	0.001; 0.069	0.041
Depressive symptoms	5812	-0.097	-0.164; -0.030	0.005	4934	-0.060	-0.091; -0.029	<0.001

¹ Total analysed sample size.

Quality of life, life satisfaction and depressive symptoms were analysed as z-scores.

Values are adjusted for age, sex, marital status, wealth and limiting long-standing illness.

Coeff. = regression coefficient.

Table 3 Associations of bus pass ownership and frequency of bus pass use with social isolation and physical activity

	Social isolation			Physical activity		
	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>
Has a concessionary bus pass						
No	1.000	-	-	1.000	-	-
Yes	0.681	0.564; 0.822	<0.001	1.368	1.187; 1.577	<0.001
Frequency of bus pass use						
0	1.000	-	-	1.000	-	-
1-5	0.839	0.699; 1.007	0.060	1.187	1.036; 1.359	0.013
6 or more	0.773	0.648; 0.923	0.004	1.435	1.257; 1.638	<0.001

Values are adjusted for age, sex, marital status, wealth and limiting long-standing illness.

OR = odds ratio.

Table 4 Associations of social isolation and physical activity with wellbeing

	Social isolation				Physical activity			
	<i>n</i> ¹	Coeff.	95% CI	<i>p</i>	<i>n</i> ¹	Coeff.	95% CI	<i>p</i>
Quality of life	4443	-0.268	-0.329; -0.207	<0.001	4936	0.224	0.186; 0.262	<0.001
Life satisfaction	4610	-0.291	-0.356; -0.227	<0.001	5136	0.123	0.082; 0.163	<0.001
Depressive symptoms	4764	0.173	0.113; 0.234	<0.001	5811	-0.172	-0.209; -0.134	<0.001

¹ Total analysed sample size.

Quality of life, life satisfaction and depressive symptoms were analysed as z-scores.

Values are adjusted for age, sex, marital status, wealth and limiting long-standing illness.

Coeff. = regression coefficient.

Table 5 Models testing mediation of associations of bus pass ownership and use with wellbeing by social isolation and physical activity (see Figure 1)

	Social isolation (MV)					Physical activity (MV)				
	Coeff.	SE	<i>p</i> *	Bootstrap 95% CI	Effect ratio	Coeff.	SE	<i>p</i> *	Bootstrap 95% CI	Effect ratio
Bus pass ownership (IV)										
Quality of life (DV)										
Total effect (path <i>c</i>)	0.145	0.038	<0.001	-	-	0.160	0.036	<0.001	-	-
Direct effect (path <i>c'</i>)	0.127	0.038	<0.001	-	-	0.142	0.035	<0.001	-	-
Indirect effect (via mediator)	0.018	0.005	<0.001	0.009; 0.030	0.126	0.019	0.006	0.001	0.008; 0.031	0.118
Life satisfaction (DV)										
Total effect (path <i>c</i>)	0.113	0.040	0.005	-	-	0.111	0.037	0.003	-	-
Direct effect (path <i>c'</i>)	0.093	0.040	0.020	-	-	0.102	0.037	0.006	-	-
Indirect effect (via mediator)	0.020	0.006	<0.001	0.010; 0.032	0.178	0.010	0.003	0.004	0.004; 0.018	0.090
Depressive symptoms (DV)										
Total effect (path <i>c</i>)	-0.085	0.037	0.023	-	-	-0.097	0.034	0.005	-	-
Direct effect (path <i>c'</i>)	-0.073	0.037	0.053	-	-	-0.080	0.034	0.018	-	-
Indirect effect (via mediator)	-0.012	0.004	<0.001	-0.021; -0.006	0.146	-0.016	0.004	<0.001	-0.025; -0.008	0.170
Frequency of bus pass use (IV)										
Quality of life (DV)										
Total effect (path <i>c</i>)	0.060	0.017	<0.001	-	-	0.061	0.016	<0.001	-	-
Direct effect (path <i>c'</i>)	0.055	0.017	0.001	-	-	0.050	0.016	0.002	-	-
Indirect effect (via mediator)	0.006	0.002	0.012	0.001; 0.011	0.094	0.011	0.003	<0.001	0.005; 0.016	0.174
Life satisfaction (DV)										
Total effect (path <i>c</i>)	0.031	0.018	0.080	-	-	0.035	0.017	0.041	-	-
Direct effect (path <i>c'</i>)	0.025	0.018	0.160	-	-	0.029	0.017	0.089	-	-
Indirect effect (via mediator)	0.006	0.002	0.006	0.002; 0.011	0.201	0.006	0.002	<0.001	0.003; 0.010	0.171
Depressive symptoms (DV)										
Total effect (path <i>c</i>)	-0.048	0.017	0.004	-	-	-0.060	0.016	<0.001	-	-
Direct effect (path <i>c'</i>)	-0.045	0.017	0.008	-	-	-0.051	0.016	0.001	-	-
Indirect effect (via mediator)	-0.004	0.001	0.012	-0.007; -0.001	0.077	-0.009	0.002	<0.001	-0.014; -0.005	0.156

CI = confidence interval; Coeff. = coefficient; DV = dependent variable; IV = independent variable; MV = mediating variable; SE = standard error.

Models use z-scores for all psychological wellbeing variables.

All models are adjusted for age, sex, marital status, wealth and limiting long-standing illness.

**p* values shown for indirect effects are derived from the Sobel test for consistency with total and direct effects, however bootstrap 95% confidence intervals provide a more robust indication of significant mediation (see Method for more details).

In some instances, total effects differ from results presented in Table 2 due to a reduction in sample size resulting from missing data on social isolation or physical activity.

Figure legends

Figure 1. Mediation model of associations between bus pass ownership/frequency of bus pass use and wellbeing via social isolation and physical activity.

Figure 2. The relationship between bus pass ownership and wellbeing measures: (a) quality of life, (b) life satisfaction and (c) depressive symptoms.

The black points show the raw mean averages, and the size of the point is scaled according to sample size. The dotted lines around this point show the 95% range of the mean averages estimated from bootstrapping the sample (5,000 times). The solid black line shows the linear model fit estimating the effect of bus pass ownership when controlling for confounding factors (see methods), and the light grey polygon shows the confidence (se) around this fit.

Figure 3. Summary of the raw data in regard to the relationships between bus pass ownership, social isolation and wellbeing measures: (a) quality of life, (b) life satisfaction and (c) depressive symptoms.

The lower x axis shows social isolation category and the upper x axis shows bus pass ownership. The location of the pie chart on the y axis denotes the mean value for that social isolation/bus pass ownership category for that wellbeing measure, and the dotted grey lines around this point show the 95% range of the mean averages estimated from bootstrapping this category (5,000 times). The dark section of the pie chart shows the proportion of the total sample falling into that social isolation/bus pass ownership category for each wellbeing measure (with total sample sizes of 4443, 4610 and 4764 for a, b, and c respectively). As such, the raw data also illustrate primary findings from the models, that social isolation (lower x) is related to decreased wellbeing, bus pass ownership (upper x) is related to increased wellbeing, and bus pass ownership is generally associated with reduced social isolation (pie charts).

Figure 4. Summary of the raw data in regard to the relationships between bus pass ownership, physical activity and wellbeing measures: (a) quality of life, (b) life satisfaction and (c) depressive symptoms.

The lower x axis shows physical activity (1=inactive, 2=moderate, 3=vigorous - see methods) and the upper x axis shows bus pass ownership. The location of the pie chart on the y axis denotes the mean value for that physical activity/bus pass ownership category for that wellbeing measure, and the dotted grey lines around this point show the 95% range of the mean averages estimated from bootstrapping this category (5,000

times). The dark section of the pie chart shows the proportion of the total sample falling into that physical activity/bus pass ownership category for each wellbeing measure (with total sample sizes of 4936, 5136 and 5811 for a, b, and c respectively). As such, the raw data also illustrate primary findings from the models, that physical activity (lower x) and bus pass ownership (upper x) are related to increased wellbeing, and bus pass ownership is generally associated with increased physical activity (pie charts).