



Social isolation, socioeconomic status, and development of functional impairments in Chinese older adults aged 70 years and over: a cohort study

Eric Tsz Chun Lai¹ · Suzanne C. Ho² · Jean Woo^{1,2} 

Received: 6 July 2022 / Accepted: 14 September 2022 / Published online: 22 October 2022
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2022

Abstract

Background Social isolation in older people has been increasingly regarded as a public health issue in the face of rapid population ageing. It is not clear whether social isolation mediates the relationship between socioeconomic status and functional impairment.

Methods We used data from a cohort of Chinese older people aged 70 or older living in community ($n = 1590$). Socioeconomic status (SES) was operationalised as highest education attainment, monthly income at baseline and longest held occupation in lifetime. Functional abilities were measured using Barthel's Index for activities of daily living (ADL) measured at 18 and 36 months of follow-up, from which impairment was defined as score ≤ 19 . Social isolation was measured by six attributes, such as marital status, living alone, and social contact with others. A score of ≥ 3 was defined as being in social isolation. Causal mediation analysis using natural effect models was used to assess mediation by social isolation.

Results We found that lower monthly income at baseline was related to higher risk of social isolation [relative risk comparing lowest to highest income (RR) = 1.52, 95% confidence interval (95% CI) 1.01–2.28]. Social gradient of ADL impairment was not clearly present. The evidence for the mediating role of social isolation was not clear.

Conclusions Older people with low SES, particularly those with lower income, were at greater risk of social isolation. Policymakers should strive to improve the current community services and pension scheme to mitigate the situation of social isolation in older people in Hong Kong.

Keywords Social isolation · Health inequalities · Hong Kong · Functional impairment

Introduction

Social isolation and loneliness in the older people have been increasingly regarded as a public health issue [1]. Following the loss of significant persons in their social network, deteriorating health conditions, being childless and living alone, social relationships of older people tend to wear thin with time, and they are at increasingly higher risk of loneliness and social isolation towards older age. Relationships with

one's own children and grandchildren are among the closest social relationship for older people, so frequent contact with them could represent the quality of social support that the older people are experiencing, which could be one of the keys to their quality of life and well-being [2]. Moreover, circle of friends and acquaintances and social participation also play important roles in their social network. However, social isolation and loneliness have been made more prominent especially amidst the recent COVID-19 pandemic [3]. Notwithstanding, the two closely related concepts carry slightly different meanings—social isolation is an objective state in which the older people have very infrequent or no social contact with other people, whereas loneliness is a subjective negative feeling which could be felt even they have social contact with others [4]; it arises when one's social relationships with other people could not meet their needs for belongingness and security [5]. By some estimates, around 20–30% of the older people in Europe, America, and

✉ Jean Woo
jeanwoowong@cuhk.edu.hk

¹ Institute of Health Equity, The Chinese University of Hong Kong, Suite 602, 6/F, Yasumoto International Academic Park, Shatin, New Territories, Hong Kong

² School of Public Health and Primary Care, The Chinese University of Hong Kong, Shatin, Hong Kong

Latin America and around 28% in China reported that they experienced loneliness, whereas the scale of social isolation was not clearly documented [3]. In Hong Kong, although no previous studies have formally assessed the scale of loneliness and social isolation in older people, recent census data showed that the number of older people aged over 65 living alone has risen 54% from 98,829 in 2006 to 152,536 in 2016 [6]; and in 2020, Hong Kong recorded 438 suicides by people aged 60 or above, the highest numbers since records began in 1973 [7].

Previous literature has shown that social isolation or loneliness was related to adverse health outcomes in older people. A previous systematic review suggested that weak or diminished social relationships were related to higher risks of coronary heart disease and stroke [8]. Notably, poor or insufficient social relationships were shown to have comparable effect of some well-established risk factors of morbidity and mortality, such as cigarette smoking, obesity, and physical inactivity [9]. One of the proposed mechanisms regarding how social relationships affect health is that it provides buffers from (or it exacerbates) external pressure, especially for those who are socioeconomically disadvantaged and often experience monetary or material deprivation [10]. As such, social participation has been regarded as one of the eight domains of the World Health Organisation (WHO) Age-friendly Cities guidelines as it enables older people to exercise their competence and foster their self-esteem [11]. The WHO is also promoting 2020–2030 as the Decade of Healthy Ageing, which posited that the ability to maintain optimum activities of daily living and an environment conducive to better social connection are both important components of healthy ageing [12]. While the ageing process itself contributes to decline in functional abilities with time, social determinants would likely influence the speed of decline, as with many other health outcomes. A previous study in Hong Kong showed that older people who were socially disadvantaged tended to have faster decline in functional abilities, as well as higher mortality risk [13].

However, there are a few gaps in the literature regarding social isolation and functional abilities. First, previous studies investigating the association between social relationships and functional abilities in older people yielded mixed findings. Perissinotto and colleagues found that higher level of loneliness was related to more difficulties in activities of daily living (ADL), such as climbing stairs, bathing, and dress oneself [14]. On the other hand, using data from the Jerusalem Longitudinal Cohort Study with 7 years of follow-up, Stessman and colleagues reported that loneliness was not related to deterioration of functional abilities [15]. Buchman and colleagues investigated in a US cohort of community-dwelling older people and showed that loneliness was related to faster rate of decline in global motor function, but the size of social network was not related to motor function or

decline rate [16]. Some other previous studies also reported limited or no significant relationships between social relationships and functional abilities in older people [17, 18]. Second, prospective studies relating social support and participation are few and are mainly reported in Western settings [19–21]. Social engagement appears to be a stronger protective factor against dementia in Asian communities [22]. Third, there has been few previous studies assessing whether social isolation mediates the relationship between socioeconomic status (SES) and functional abilities. Gallo and colleagues proposed the reserve capacity model, which suggested that resilient psychological and social resources, i.e., reserve capacity, are important for those in the low SES to manage frequent challenges in daily lives [23]. Hence, those with higher reserve capacity are more capable to mitigate the adverse health impact brought by low SES [24]. Finally, it is not clear if the effect of SES on functional abilities or social isolation and the indirect effect by social isolation on functional abilities would vary across time [25] and different sexes [26] in the Hong Kong context. For instance, Guralnik et al. [27] reported that, using longitudinal data from the 1946 British Birth Cohort Study, men who were never married and those who were married and remained childless had poorer physical function when compared to married men with children, whereas these associations were generally absent in women. Longitudinal data from the German Ageing Surveys from 1996 to 2017 showed that as the risk of being socially isolated or lonely increased with age, men were at a particularly higher risk of isolation than women up to the age of 75, although women's advantage in older ages might have been outweighed by suffering more functional impairments than men and more likely being widowers towards older age [28]. Given these limitations in the previous literature, using a prospective cohort study of older people in Hong Kong, we aimed to assess the interrelationships between SES, social isolation, and functional abilities, and whether such relationships differ across age and sex.

Materials and methods

Data

Data were derived from a cohort of 1590 adults aged 70 years and over living in the community, recruited by stratified disproportional random sampling from 1991 to 1992. The sampling frame was from all recipients of old age allowance which covers more than 90% of the total population as well as those receiving disability allowances. Follow-up was carried out at 18, 36, 54, and 96 months from baseline. Details are provided elsewhere [29]. The survey was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong.

Table 1 Baseline characteristics of cohort participants

	Overall
<i>N</i> (%) for categorical variables	1590
Mean (SD) for continuous variables	
Not married	771 (48.5)
Live alone	143 (9.0)
Without contact with children at least monthly	302 (19.0)
Without contact with relatives at least monthly	222 (14.1)
Without contact with friends at least monthly	1060 (66.7)
Not participated in any social clubs	1135 (71.4)
Social isolation	608 (38.5)
Education level attained	
Tertiary or above	84 (5.3)
Secondary	254 (16.0)
Primary	697 (43.9)
No schooling	553 (34.8)
Monthly income at baseline (\$HKD)	
2000 or above	480 (30.5)
1500–1999	273 (17.4)
1000–1499	408 (26.0)
500–999	286 (18.2)
Less than 500	125 (8.0)
Longest held occupation in lifetime	
Managers, professionals, and associate professionals	223 (14.0)
Clerks and service workers	527 (33.1)
Semi-skilled and unskilled occupations	550 (34.6)
Economically inactive/unemployed persons	290 (18.2)
ADL impairment	264 (16.6)
Age	78.10 (6.47)
Male	865 (54.4)

Exposure

The main exposure of this study is the SES measured at baseline—the highest education attained, the monthly income at baseline, and the longest held occupation in lifetime. Education was categorized as tertiary or above, secondary, primary or no schooling. Income was categorized as less than HKD\$500, \$500 to \$999, \$1000 to \$1499, \$1500 to \$1999, \$2000 or above. Longest held occupation in lifetime was categorized as managers, professionals and associate professionals, clerks and service workers, semi-skilled and unskilled occupations, and economically inactive/unemployed persons. The three indicators of SES were then converted to form a relative index of inequality (RII) [30], which quantifies the odds ratio from the top to the bottom of the social gradient.

Mediator

We assessed the mediating role by social isolation, using an index of social isolation as per Steptoe [19] and Smith [21]. There are six attributes of social isolation, for each of which one point would be assigned should that attribute be present: unmarried, living alone, not contacted children at least for a month, not contacted a family member at least for a month, not contacted a friend at least for a month, and not participated in any social club or religious group. A score from 0 to 6 was computed from the above attributes, and social isolation was defined as having three or more of the six attributes [19].

Outcome

The outcome of this study is functional abilities, which was characterised by ADL and was measured by the modified Barthel Index at 18 and 36 months of follow-up [31]. The Barthel Index ranges from 0 to 20, with lower score indicating increased disability, while 20 indicating a fully independent state. There has not been a consensus on how the Barthel's ADL score could be categorized [32, 33]. However, a fully independent state was considered as functionally distinct from presence of any impairments [34]. We therefore dichotomised ADL impairments with a cut-off of Barthel Index ≤ 19 .

Covariates

Covariates were chosen on the basis that they are the common causal antecedents of the exposure, mediator and outcome, or factors potentially on the confounding pathways [35]. In assessing the association between education attainment and ADL impairment mediated by social isolation, age and sex were adjusted. In assessing the association between monthly incomes at baseline, longest occupation held in lifetime and ADL impairment mediated by social isolation, age, sex, and education attainment were adjusted.

Statistical analysis

The associations between SES and social isolation were assessed using multivariable logistic regression adjusted for the aforementioned covariates. We also assessed the association between social isolation and ADL impairment at 18 and 36 month follow-up using multivariable logistic regression adjusted for the above covariates and the three measures of SES. Effect modification by age and sex was assessed by its interaction term with SES—in the case when the interaction term was statistically significant (p for interaction < 0.05), stratified results were presented. We performed a causal mediation analysis with a

counterfactual framework to partition the total effect (TE) of SES on ADL impairment into natural indirect effect (NIE) via social isolation and natural direct effect (NDE), i.e., all mechanistic pathways from SES to ADL impairment that bypass the putative mediator. The counterfactual framework, in comparison to traditional mediation approach, has more formal definitions of the effect estimates, could handle exposure–mediator interaction and non-linear models [36]. Under this framework, the NIE could be defined as the expected difference in the risk of ADL impairment had all cohort participants were counterfactually set to low SES, but their mediator value had changed from the level of social isolation that would have naturally seen in those in high SES to the level of social isolation that would have naturally seen in low SES. NDE could be defined as the expected difference in risk of ADL impairment between high and low SES, and had the level of social isolation counterfactually set at the value that would be naturally observed at high SES. The mediating role of social isolation for the relationship between SES and ADL impairment at 18 and 36 months of follow-up was assessed by fitting multivariable logistic regression and linear probability model into the framework of natural effects model, which, respectively, gave the effect estimates on the relative and absolute risk scale [37]. The presence of exposure–mediator interaction and whether the indirect effects were different by age and sex were assessed by the respective interaction terms. More details on the theoretical basis [38, 39] of natural effect models were given elsewhere. Furthermore, among this cohort of community-dwelling older people ($n = 1590$), 1011 of

them were traceable by the 24 March 2002, which was the latest date we traced with the Death Registry. Among the traceable cohort participants, 757 (75%) of them died by that date. Cohort participants who were frailer are more likely to die and are more often in more social disadvantage than others. Such selection by mortality was corrected using inverse probability weighting method, with the model given by a gradient boosted model using a machine learning approach [40]. We then assessed whether the weighted respondents match the original sample in terms of baseline characteristics. Sensitivity analysis was performed by rerunning the causal mediation analysis using unweighted estimates. All statistical analysis were performed using R v.4.0.3.

Results

Baseline characteristics

Among the 1590 participants at baseline, 1340 of them were followed up at 18 months and 957 of them were followed up at 36 months (Fig. 1). At baseline, the average age of the participants was 78.1 years (Table 1). Among the cohort participants, 38.5% of them were considered to be in social isolation ($n = 608$). There were 78.7% of them either having received no schooling or only primary education ($n = 1250$), 8% of them earned HKD\$500 or less a month ($n = 125$), and 18.2% of them have been economically inactive or unemployed for most of their lifetime

Fig. 1 Flowchart of the current study

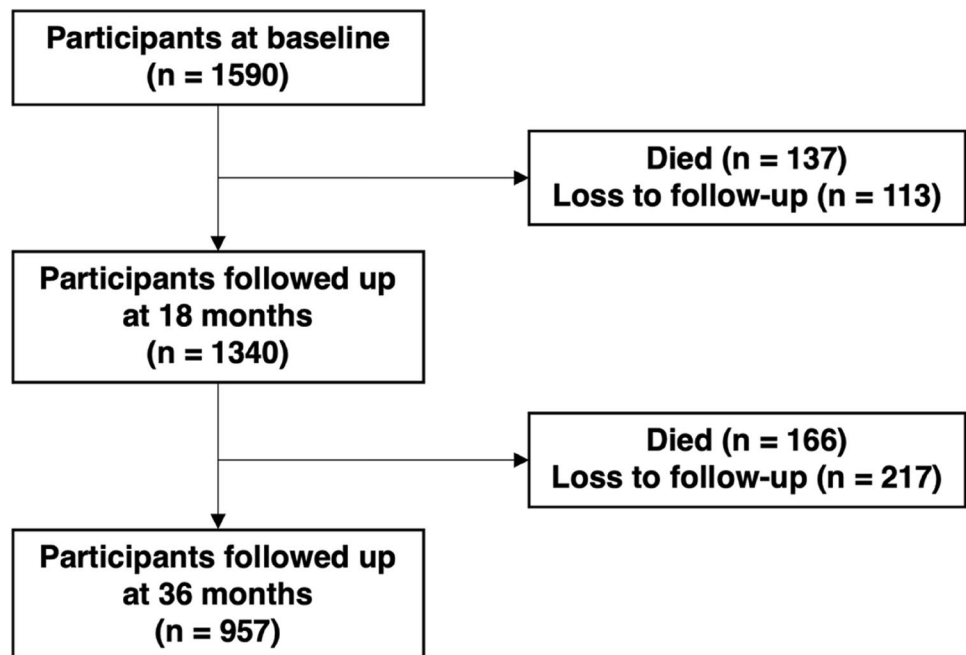
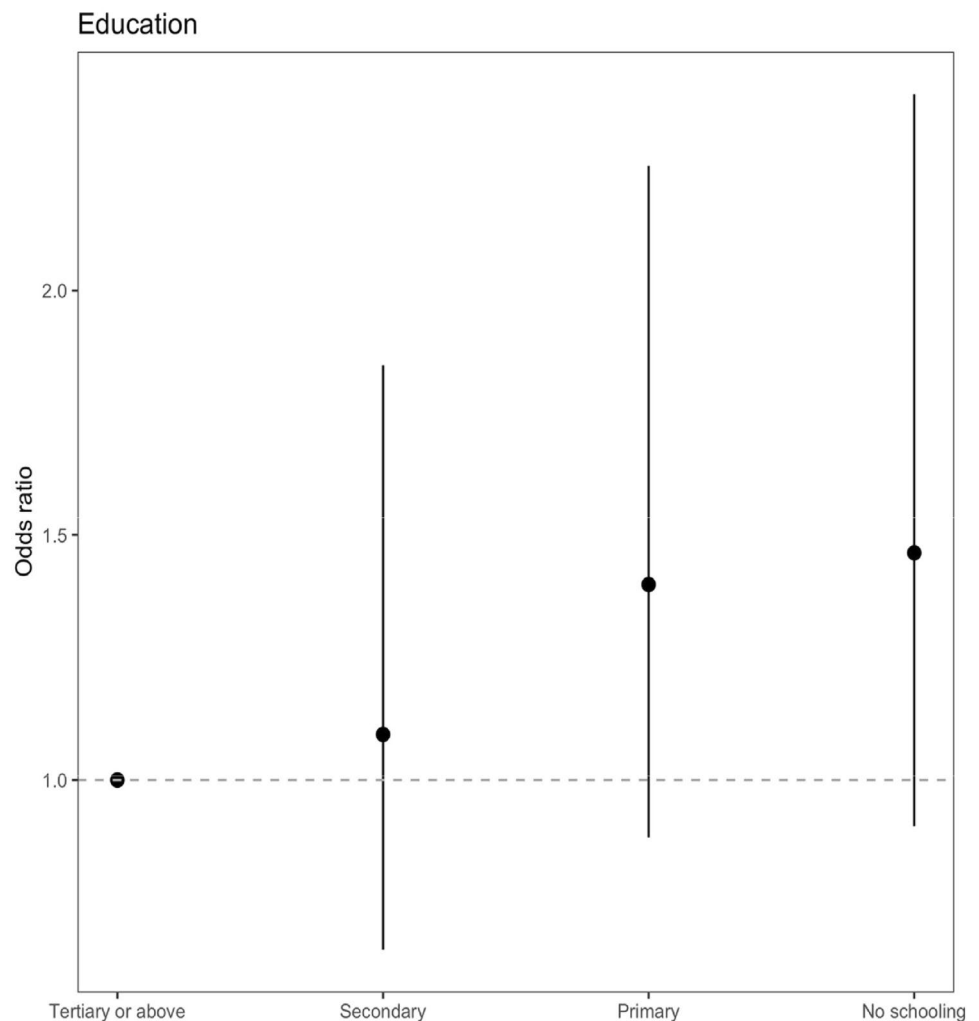


Fig. 2 Adjusted association between education attainment and social isolation



($n = 286$). There were 16.6% of the cohort participants who were recorded to have ADL impairment at baseline ($n = 264$).

Multivariable analysis

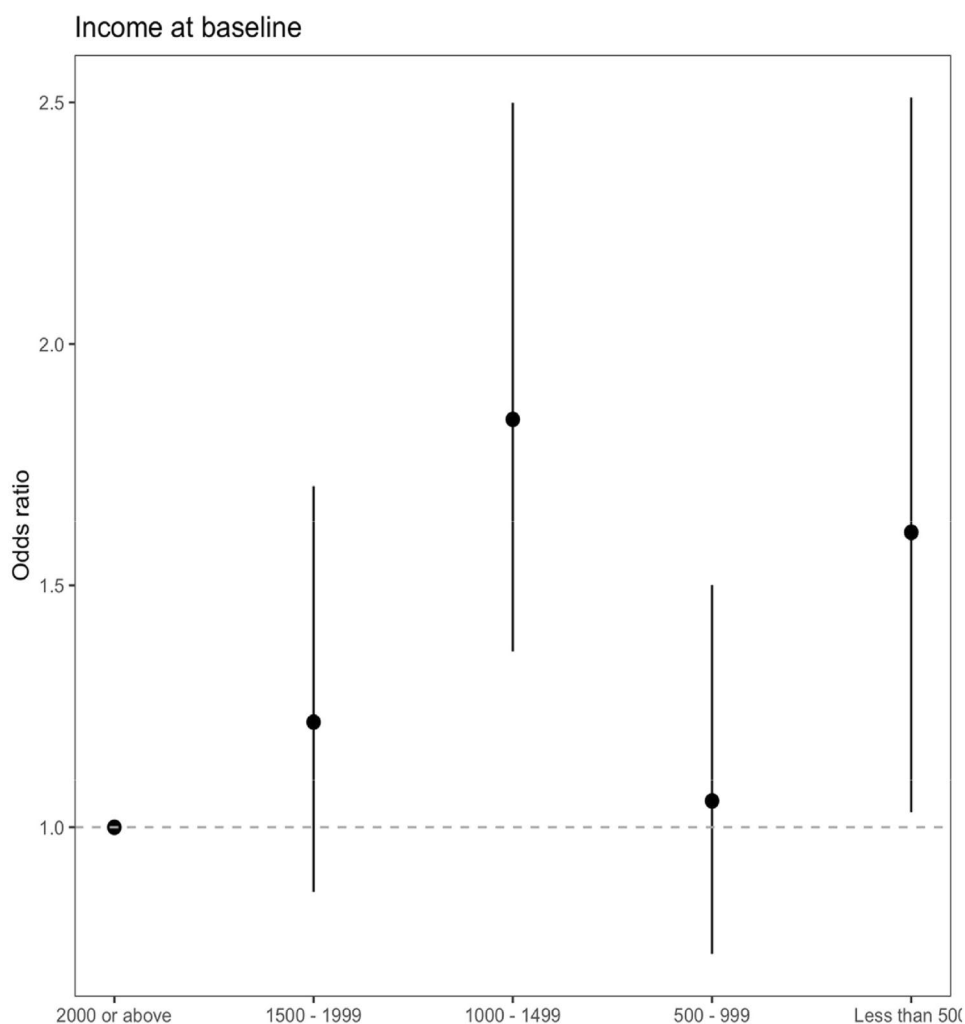
Our multivariable logistic regression analysis showed that education attainment [Odds ratio (OR) 1.29; 95% confidence interval (95% CI) 0.81–2.04] was not clearly related to social isolation in this cohort of older people (Fig. 2). However, lower monthly income at baseline was related to higher risk of social isolation (OR 1.52, 95% CI 1.01–2.28, Fig. 3). While these two relationships did not vary by age and sex, the relationship between longest held occupation in lifetime and social isolation differed by sex. In men, lower rank job as the longest held occupation in lifetime tended to relate to high risk of social isolation (OR 1.88, 95% CI 0.95–3.72, Fig. 4). However, for women, lower rank job was related to lower risk of social isolation (OR

0.37, 95% CI 0.20–0.66). Moreover, social isolation was related to ADL impairment at 18 months of follow-up (OR 1.31; 95% CI 1.01–1.70), but not ADL impairment at 36 months of follow-up (OR 1.02, 95% CI 0.74–1.39).

Causal mediation analysis

The effects of SES on ADL impairment were represented by the TE estimates, which showed that all three SES measures were not clearly related to ADL impairment (Table 2). The natural effects for education seemed to vary by age group at baseline—the NIE and NDE were not clearly evident at 18 months of follow-up; however, the NDE at 36 months of follow-up showed that lower education attainment was related to lower risk of ADL impairment on an absolute risk scale for those who were aged 80 or older at baseline [risk difference (RD)_{NDE} = -0.29; 95% CI -0.56 to -0.02]. The mediation by social isolation was not evident at both time points of follow-up. The natural effects did not vary by sex.

Fig. 3 Adjusted association between income at baseline and social isolation



Sensitivity analysis showed that the reweighted sample of respondents was of similar characteristics as the overall cohort (Supplementary Table 1). Analysis using unweighted sample yielded similar estimates as the weighted ones (Supplementary Tables 2 and 3).

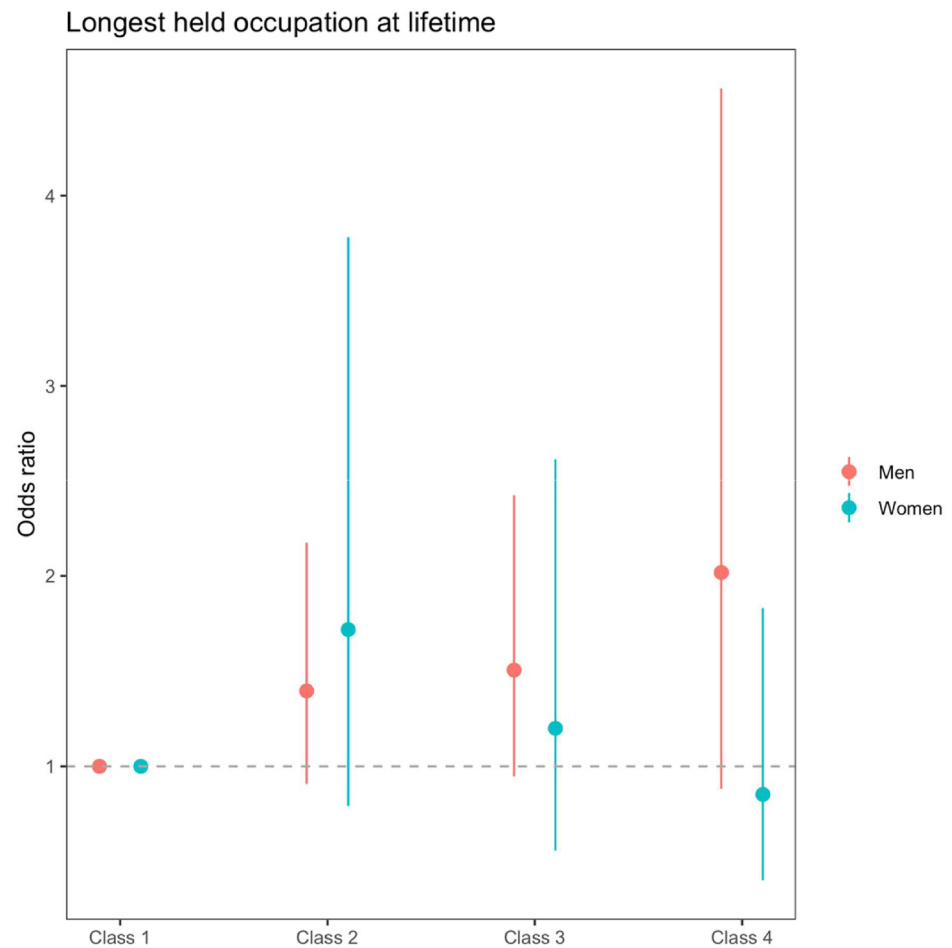
Discussion

In a cohort of community-living Chinese older people in Hong Kong who were followed up longitudinally, our analysis showed that social isolation was related to SES; and that social isolation was related to longest held occupation in lifetime with the results being different by sex. Moreover, social gradient of ADL impairment was not clearly present; and such gradient might be specific to a particular age group. We also showed that social isolation did not clearly mediate the relationship between SES and ADL impairment.

Comparison with previous studies

Our study corroborated the previous studies in the Western settings that there was a social gradient of social isolation, i.e., lower SES was related to higher risk of social isolation [41–44]. Studies about social network suggested that older people with low SES usually have smaller social networks, within which kin relationships constituted a relatively large proportion, when compared to those with higher SES, thus making them more vulnerable to social isolation [42, 45]. Particularly, we have shown in the results that lower incomes in this cohort of older adults were related to higher risk of social isolation. In one of our previous local qualitative study, we interviewed 37 older people living in community in Hong Kong and assessed the main sources of social alienation. One of the common themes that emerged, particularly for those who were in low SES, was the lack of income security for the older people—and the support they obtained from the government pension scheme could hardly make ends meet [46]. The older people felt that they

Fig. 4 Adjusted association between longest held occupation at lifetime and social isolation



Class 1 denotes managers, professionals and associate professionals, **Class 2** clerks and service workers, **Class 3** semi-skilled and unskilled occupations, and **Class 4** economically inactive/unemployed persons respectively

are always on the receiving end of financial support, and hence increasingly adopted a passive and isolated lifestyle. We found that income group 1000–1499 apparently had higher risks of social isolation than other income groups. However, there is no immediate explanation to understand why this is so. We found that this group of participants (28% in this group, see Supplementary Table 4) were more likely to receive public assistance as their major source of income. Public assistance schemes such as the Comprehensive Social Security Assistance (CSSA) often linked with the image of being lazy or unproductive [47], which might link to a higher risk of social isolation. In this cohort, those who reported to rely more on public assistance as the major source of income were more likely to be in social isolation (Supplementary Table 5). However, we could not ascertain why this group was more likely to rely more heavily on public assistance schemes than other groups.

Our findings that lower rank longest held occupation in lifetime is related to higher risk of social isolation in men, whereas it is the opposite for women was in line with the

literature, which has argued that men usually have smaller social network as they often vent their social and emotional needs to their spouses, while women usually rely on multiple sources [48].

The finding that social isolation did not mediate the relationship between SES and ADL impairment perhaps contrasted with the existing literature. However, the literature on whether social isolation, or a closely related construct in social epidemiology—social capital, mediates health inequalities has not been conclusive [49]. A recent study using data from the English Longitudinal Study of Ageing found that loneliness is related to higher risk of functional impairment, with the association stronger in those with lower SES [50]. Another study using path analysis and longitudinal data from a small cohort of older people on Portugal found that SES is related to quality of life and that perceived social support mediated this relationship [51], hence corroborating the stress-buffering model [10]. Conversely, previous studies reported a lack of mediating effect by social capital for the social gradients of health outcomes which were mainly

Table 2 Causal mediation analysis of the association of SES and ADL impairment mediated by social isolation at 18 and 36 months of follow-up

Socioeconomic status	Effect	OR ^a	95% CI	RD ^a	95% CI	Age group ^b
18 months of follow-up						
Education	Natural direct effect	1.05	0.35–3.11	0.01	– 0.16 to 0.18	70+
Education	Natural indirect effect	1.00	0.96–1.04	0.00	– 0.01 to 0.01	70+
Education	Total effect	1.05	0.35–3.14	0.01	– 0.17 to 0.18	70+
Education	Natural direct effect	2.87	0.97–8.45	0.24	0.00 to 0.48	80+
Education	Natural indirect effect	1.01	0.96–1.06	0.00	– 0.01 to 0.02	80+
Education	Total effect	2.90	0.98–8.59	0.25	0.00 to 0.49	80+
Income	Natural direct effect	1.51	0.73–3.11	0.07	– 0.07 to 0.21	All
Income	Natural indirect effect	1.00	0.95–1.05	0.00	– 0.01 to 0.01	All
Income	Total effect	1.50	0.74–3.06	0.07	– 0.07 to 0.20	All
Job ^c	Natural direct effect	1.14	0.56–2.33	0.03	– 0.10 to 0.15	All
Job	Natural indirect effect	1.00	0.97–1.03	0.00	0.00 to 0.00	All
Job	Total effect	1.14	0.56–2.33	0.03	– 0.10 to 0.15	All
36 months of follow-up						
Education	Natural direct effect	1.22	0.48–3.15	0.02	– 0.14 to 0.17	70+
Education	Natural indirect effect	0.99	0.94–1.03	0.00	– 0.01 to 0.01	70+
Education	Total effect	1.21	0.47–3.09	0.02	– 0.14 to 0.17	70+
Education	Natural direct effect	0.34	0.10–1.16	– 0.29	– 0.56 to 0.02	80+
Education	Natural indirect effect	0.99	0.95–1.04	0.00	– 0.01 to 0.01	80+
Education	Total effect	0.34	0.10–1.15	– 0.29	– 0.56 to –0.02	80+
Income	Natural direct effect	1.67	0.81–3.44	NA ^d	NA	All
Income	Natural indirect effect	0.94	0.86–1.02	NA	NA	All
Income	Total effect	1.56	0.75–3.25	NA	NA	All
Job	Natural direct effect	1.99	0.94–4.20	NA	NA	All
Job	Natural indirect effect	1.04	0.97–1.11	NA	NA	All
Job	Total effect	2.07	0.98–4.40	NA	NA	All

95% CI 95% confidence interval, RD risk difference, OR odds ratio

^aThe effect estimates of OR and RD could be interpreted as the effect from the top to the bottom of the social gradient

^bResults were stratified by age where the interaction term between SES and age was significant. Age at baseline were broken down into two groups—“70+” means aged 70–79 and “80+” means those who were aged 80 or above

^cJob refers to the longest held occupation in lifetime as in the main text

^dSome results for the natural effect model using linear probability model showed as “NA”, since the model did not converge

reported in Nordic countries, where they have generally higher and more homogenous distribution of social capital and less income inequalities [52, 53]. However, the formal role of social isolation being a mediator between SES and functional impairment in older people was not assessed in the literature, especially in the non-Western context. Urban features of Hong Kong might have buffered some of the adverse effect of social isolation in older people. Hong Kong is a highly urbanized small territory with an approximate size of 1110 square kilometres, and about 40% of the land comprises protected country parks; its population of 7.5 million is concentrated in merely about 25% of the land that was developed [54]. Therefore, the majority of the Hong Kong population live in high-rise buildings. Public facilities, such

as open markets, transport terminus, and outpatient clinics, are clustered around housing estates. Urban planning of housing estates is such that those in the lower SES would have high connectivity to essential networks for daily living. Furthermore, there is a widespread network of community centres all over Hong Kong run by various non-government organizations, predominantly situated close to public housing estates. The urban planning also encourages walking as the main mode of navigation around local networks, that are more accessible with public transport and walking. There are also pockets of green spaces within each district that provide social interactions as well as encouraging physical activities. Facilitating physical activities would predispose to maintenance of function. It could therefore be argued that

even though those in lower SES would have a higher risk of social isolation, the high connectivity in the urban environment in Hong Kong enables older people to seek help and support relatively easily should need be.

We found that for the older cohort participants, lower education was related to lower risks of ADL impairment, compared to the younger cohort participants in which the relationship was not as clear. The explanation for this difference might not be immediately clear. It is possible that the older cohort participants who have survived to such old age might be a particularly resilient group who have different physical and social characteristics than those who were younger at baseline, buffering partially the adverse effect of lower education attainment. It is therefore also reasonable to see that monthly income at baseline and longest held occupation in lifetime, which are causal descendants from education attainment, were not related to ADL impairment. It has also been documented elsewhere that the effects of different measures of SES on health outcomes in older adults could change over time [55]. Nonetheless, the social gradient of functional impairment was not clearly present in this cohort of community-living Chinese older adults, suggesting that the mechanism of the aforementioned urban characteristics of Hong Kong might have mitigated some of the adverse effects of low SES.

Policy implications

First, our results showed that there is a social gradient of social isolation, and monthly income appeared to be an important determinant. Although Hong Kong performs well in terms of health indicators such as having the longest life expectancy in the world, and lower prevalence of obesity and high blood pressure when compared to other developed settings, Hong Kong's older people have a high rate of poverty and often experience income insecurity [56]. In 2019, there were 32% of people aged 65 or older in poverty, even after recurrent cash transfer interventions [57]. The current schemes of Old Age Allowance and Old Age Living Allowance only provide minimal social protection to the older people [47]. Future policies should consider more generous pension schemes as they could potentially mitigate social isolation of older people. Second, men tend to be at greater risk of social isolation than women. As men tend to maintain close relationships with few people, whereas women tend to have more varied social networks, interventions mitigating social isolation could employ different strategies for older men and women. For instance, emotional support from people with close relations with older men was shown to be related to better mental health in older men, whereas group activities appeared to be more helpful for older women [58]. Third, maintaining functional abilities should become an important priority for any policies targeting healthy ageing.

In particular, against the backdrop of the WHO Decade of Healthy Ageing in 2020–2030, policymakers should promote policies that monitor functional disabilities in the older adults and foster active and healthy ageing as a policy target [12].

Strengths and limitations

This is the first study that used causal mediation analysis to formally assess the mediating role of social isolation for the relationship between SES and functional impairment. We also used inverse probability weighting to account to selective attrition by mortality. However, there are limitations in this study. The data set consists of a group of people who were born between two world wars, and lived through the Sino Japan war, the China civil war, and the birth of the People's Republic of China. During this time, large-scale immigration from mainland China to Hong Kong occurred. With successive generations, there will be a change in cohort profile, with respect to SES, health outcomes, sense of community, and neighbourhood characteristics, that may alter the findings of this study. For example, age period cohort studies of older people in Hong Kong showed rising frailty and ADL impairment with time [59]. The changing impact of continuing urban redevelopment as well as the role of information technology with time may also affect the findings. It is also uncertain what would be a valid measure of SES in older adults, and whether there is indeed a suitable composite measure. Nevertheless, we may conclude that in a small compact urban environment, with good existing foundation for social support and a free healthcare system, the impact of social isolation on the influence of SES on ADL impairment is buffered to some extent. Finally, the causal mediation analysis relied on the assumption that no unmeasured confounding is present for the interrelationship between SES, social isolation, and ADL impairment.

Conclusion

We showed that there is a social gradient of social isolation in a cohort of Chinese older people living in the community. However, social isolation did not seem to mediate the relationship between SES and functional impairment, and that a social gradient of functional impairment is not clearly present. Our findings highlighted that importance that the socioeconomically disadvantaged older people are often at higher risks of social isolation. Policymakers and local service providers should adopt a more targeted approach to establish meaningful social connection to those underprivileged in the face of a rapidly ageing population.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40520-022-02259-w>.

Acknowledgements Eric Tsz Chun Lai is supported by the Institute of Health Equity, The Chinese University of Hong Kong, and The Vice Chancellor's Discretionary Fund.

Author contributions Study concept and design: ETCL and JW; acquisition of data: SCH and JW; analysis and interpretation of data: ETCL; drafting of the manuscript: ETCL and JW; critical revision of the manuscript for important intellectual content: ETCL, SCH, and JW. All authors have read and agreed to the published version of the manuscript.

Funding The study was supported by the Croucher Foundation and the Hong Kong Health Services Research Grant #411009. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval This study analyzed existing data from a cohort study and does not require approval from the Research Ethics Committee. The original cohort study was carried out according to the Declaration of Helsinki and approved by the Research Ethics Committee of the Chinese University of Hong Kong in 1990.

Informed consent Informed consent was obtained from all subjects involved in the study.

References

- Nicholson NR (2012) A review of social isolation: an important but underassessed condition in older adults. *J Prim Prev* 33:137–152
- Bachrach CA (1980) Childlessness and social isolation among the elderly. *J Marriage Fam* 42:627–637
- World Health Organization (2021) Social isolation and loneliness among older people: advocacy brief [Internet]. Geneva, Switzerland: <https://www.who.int/publications/i/item/9789240030749>. Accessed 9 Feb 2022
- Holt-Lunstad J, Smith TB, Baker M et al (2015) Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspect Psychol Sci* 10:227–237
- Thege B (2021) Ways out of social isolation for older people in the context of new media: CONNECT-ED—a project to improve social participation, 1st ed. 2021 ed. Springer Fachmedien Wiesbaden, Wiesbaden. Imprint: Springer
- Census and Statistics Department (2018) 2016 Population by-census—thematic report: older persons. Hong Kong SAR Government, Hong Kong
- The Samaritan Befrienders Hong Kong (2021) Annual report 2020. Hong Kong. <https://sbhk.org.hk/wp-content/uploads/2021/10/2020.pdf>
- Valtorta NK, Kanaan M, Gilbody S et al (2016) Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal observational studies. *Heart* 102:1009–1016
- Holt-Lunstad J, Smith TB, Layton JB (2010) Social relationships and mortality risk: a meta-analytic review. *PLoS Med* 7:e1000316
- Cohen CI, Teresi J, Holmes D (1986) Assessment of stress-buffering effects of social networks on psychological symptoms in an inner-city elderly population. *Am J Community Psychol* 14:75
- World Health Organization (2007) Global age-friendly cities: a guide [Internet]. 8 Feb 2007. World Health Organization, Geneva, Switzerland. <https://apps.who.int/iris/bitstream/handle/10665/43755/9/8921?sequence=1>. Accessed 6 May 2021
- World Health Organization (2020) Decade of healthy ageing: baseline report. World Health Organization, Geneva, Switzerland. <https://www.who.int/publications/i/item/9789240017900>
- Lai ETC, Ho HC, Ho SC et al (2022) Socioeconomic status, physical functioning and mortality: results from a cohort study of older adults in Hong Kong. *J Am Med Dir Assoc* 23:858–864
- Perissinotto CM, Cenzer IS, Covinsky KE (2012) Loneliness in older persons: a predictor of functional decline and death. *Arch Intern Med* 172:1078–1084
- Stessman J, Rottenberg Y, Shimshilashvili I et al (2014) Loneliness, health, and longevity. *J Gerontol Ser A* 69:744–750
- Buchman AS, Boyle PA, Wilson RS et al (2010) Loneliness and the rate of motor decline in old age: the rush memory and aging project, a community-based cohort study. *BMC Geriatr* 10:1–8
- Avlund K, Lund R, Holstein BE et al (2004) The impact of structural and functional characteristics of social relations as determinants of functional decline. *J Gerontol B Psychol Sci Soc Sci* 59:S44–S51
- Green AF, Rebok G, Lyketsos CG (2008) Influence of social network characteristics on cognition and functional status with aging. *Int J Geriatr Psychiatry* 23:972–978
- Step toe A, Shankar A, Demakakos P et al (2013) Social isolation, loneliness, and all-cause mortality in older men and women. *Proc Natl Acad Sci* 110:5797–5801
- Oh A, Patel K, Boscardin WJ et al (2019) Social support and patterns of institutionalization among older adults: a longitudinal study. *J Am Geriatr Soc* 67:2622–2627
- Smith RW, Barnes I, Green J et al (2021) Social isolation and risk of heart disease and stroke: analysis of two large UK prospective studies. *Lancet Public Health* 6:e232–e239
- Penninkilampi R, Casey A-N, Singh MF (2018) The association between social engagement, loneliness, and risk of dementia: a systematic review and meta-analysis. *J Alzheimers Dis* 66:1619–1633
- Gallo LC, Matthews KA (2003) Understanding the association between socioeconomic status and physical health: do negative emotions play a role? *Psychol Bull* 129:10
- Gallo LC, de Los Monteros KE, Shivpuri S (2009) Socioeconomic status and health: what is the role of reserve capacity? *Curr Dir Psychol Sci* 18:269–274
- Deaton AS, Paxson CH (1998) Aging and inequality in income and health. *Am Econ Rev* 88:248–253
- Mauvais-Jarvis F, Merz NB, Barnes PJ et al (2020) Sex and gender: modifiers of health, disease, and medicine. *Lancet* 396:565–582
- Guralnik JM, Butterworth S, Patel K et al (2009) Reduced midlife physical functioning among never married and childless men: evidence from the 1946 British Birth Cohort Study. *Aging Clin Exp Res* 21:174–181
- Huxhold O, Engstler H (2019) Social isolation and loneliness in women and men in the second half of life [Soziale Isolation und Einsamkeit bei Frauen und Männern im Verlauf der zweiten Lebenshälfte]. Women and men in the second half of life: aging in social change [Frauen und Männer in der zweiten Lebenshälfte]. Springer, Wiesbaden, Germany, pp 71–89

29. Ho SC, Woo J, Sham A et al (2001) A 3-year follow-up study of social, lifestyle and health predictors of cognitive impairment in a Chinese older cohort. *Int J Epidemiol* 30:1389–1396
30. Sergeant JC, Firth D (2006) Relative index of inequality: definition, estimation, and inference. *Biostatistics* 7:213–224
31. Mahoney FI (1965) Functional evaluation: the Barthel index. *Md State Med J* 14:61–65
32. Shah S, Vanclay F, Cooper B (1989) Improving the sensitivity of the Barthel Index for stroke rehabilitation. *J Clin Epidemiol* 42:703–709
33. Patel M, Tilling K, Lawrence E et al (2006) Relationships between long-term stroke disability, handicap and health-related quality of life. *Age Ageing* 35:273–279
34. Collin C, Wade D, Davies S et al (1988) The Barthel ADL Index: a reliability study. *Int Disabil Stud* 10:61–63
35. VanderWeele TJ, Shpitser I (2011) A new criterion for confounder selection. *Biometrics* 67:1406–1413
36. Pearl J (2012) The mediation formula: A guide to the assessment of causal pathways in nonlinear models. John Wiley & Sons Ltd, Chichester, United Kingdom
37. Steen J, Loeys T, Moerkerke B et al (2017) Medflex: an R package for flexible mediation analysis using natural effect models. *J Stat Softw* 76:1–46
38. Vansteelandt S, Bekaert M, Lange T (2012) Imputation strategies for the estimation of natural direct and indirect effects. *Epidemiol Methods* 1:131–158
39. Lai ET, Schlüter DK, Lange T et al (2020) Understanding pathways to inequalities in child mental health: a counterfactual mediation analysis in two national birth cohorts in the UK and Denmark. *BMJ Open* 10:e040056
40. Ridgeway G, McCaffrey DF, Morral AR et al (2022) Toolkit for weighting and analysis of nonequivalent groups: a tutorial for the R TWANG package. RAND Corporation, Santa Monica
41. Pinquart M, Sorensen S (2001) Influences on loneliness in older adults: a meta-analysis. *Basic Appl Soc Psychol* 23:245–266
42. Van Groenou MIB, Van Tilburg T (2003) Network size and support in old age: differentials by socio-economic status in childhood and adulthood. *Ageing Soc* 23:625–645
43. Weyers S, Dragano N, Möbus S et al (2008) Low socio-economic position is associated with poor social networks and social support: results from the Heinz Nixdorf Recall Study. *Int J Equity Health* 7:1–7
44. Algren MH, Ekholm O, Nielsen L et al (2020) Social isolation, loneliness, socioeconomic status, and health-risk behaviour in deprived neighbourhoods in Denmark: a cross-sectional study. *SSM Popul Health* 10:100546
45. Iliffe S, Kharicha K, Harari D et al (2007) Health risk appraisal in older people 2: the implications for clinicians and commissioners of social isolation risk in older people. *Br J Gen Pract* 57:277–282
46. Wong A, Chau AK, Fang Y et al (2017) Illuminating the psychological experience of elderly loneliness from a societal perspective: a qualitative study of alienation between older people and society. *Int J Environ Res Public Health* 14:824
47. Lee S-Y, Chou K-L (2016) Trends in elderly poverty in Hong Kong: a decomposition analysis. *Soc Indic Res* 129:551–564
48. Flaherty J, Richman J (1989) Gender differences in the perception and utilization of social support: theoretical perspectives and an empirical test. *Soc Sci Med* 28:1221–1228
49. Uphoff EP, Pickett KE, Cabieses B et al (2013) A systematic review of the relationships between social capital and socioeconomic inequalities in health: a contribution to understanding the psychosocial pathway of health inequalities. *Int J Equity Health* 12:1–12
50. Shankar A, McMunn A, Demakakos P et al (2017) Social isolation and loneliness: prospective associations with functional status in older adults. *Health Psychol* 36:179
51. Henriques A, Silva S, Severo M et al (2020) Socioeconomic position and quality of life among older people: the mediating role of social support. *Prev Med* 135:106073
52. Engström K, Mattsson F, Järleborg A et al (2008) Contextual social capital as a risk factor for poor self-rated health: a multi-level analysis. *Soc Sci Med* 66:2268–2280
53. Dahl E, Malmberg-Heimonen I (2010) Social inequality and health: the role of social capital. *Sociol Health Illn* 32:1102–1119
54. Legislative Council Secretariat (2018) Statistical highlights—land supply and utilization in Hong Kong. Hong Kong
55. Fors S, Lennartsson C, Lundberg O (2008) Health inequalities among older adults in Sweden 1991–2002. *Eur J Public Health* 18:138–143
56. CUHK Jockey Club Institute of Ageing (2018) Report on Age-Watch Index for Hong Kong 2016 and Hong Kong elder quality of life index. The Hong Kong Jockey Club, Hong Kong
57. Census and Statistics Department (2020) Hong Kong poverty situation report 2019. HKSAR Government, Hong Kong
58. Caetano SC, Silva CM, Vettore MV (2013) Gender differences in the association of perceived social support and social network with self-rated health status among older adults: a population-based study in Brazil. *BMC Geriatr* 13:1–14
59. Yu R, Tong C, Leung J et al (2020) Socioeconomic inequalities in frailty in Hong Kong, China: a 14-year longitudinal cohort study. *Int J Environ Res Public Health* 17:1301

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.