

Systematic Reviews and Meta-Analysis

Frailty and socioeconomic status: A systematic review

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Abstract

The relationship between frailty and socioeconomic status has been widely explored in the literature. A deeper understanding toward the underlying mechanism is required to further assist policy makers in reducing the inequalities. The objective of this study is to systematically review evidence investigating the direct relationship between frailty and socioeconomic status. The review was conducted following the principles of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Among the included studies, 52.38% explored the pattern of frailty in age and 42.86% explored mediators as the pathway variables. With various measures and methodologies, included studies did not point to the same conclusions. In terms of the pattern of frailty in age, we found evidence for the age as leveller hypothesis, the status maintenance hypothesis and the cumulative advantage hypothesis. The included mediators differed across studies. However, we found that these mediators can be categorised into behaviours, health, social factors, material resources and mental status. These categories indicate the important aspects to consider for policies aiming at reducing the inequalities in frailty. To obtain a full picture of the underlying mechanism, future research should harmonise different measures for frailty and socioeconomic indicators and apply more comprehensive sets of mediators.

Introduction

Frailty is an age-related syndrome characterised by the loss of physiological reserves and is associated with adverse outcomes such as fall, worsening disability, hospitalisation and death.^{1,2} It has been well-established that frailty is more prevalent among people with low socioeconomic status (SES).³ The aspects of SES in this regard include education, occupation, income and wealth.⁴⁻⁶ The literature has confirmed that the progression in frailty could be partially controlled through interventions such as exercises,⁷ physical therapies,⁸ cognitive training⁹ and nutrition supplements.¹⁰ With further understanding toward the relationship between SES and frailty, policy makers can properly set the target

for interventions to reduce the inequalities in health. This exploration is especially needed for ageing societies where the majority of the population is under the risk of frailty.

Two measures for frailty are widely used in the literature: the frailty phenotype¹¹ and the frailty index.¹² These measures are based on different concepts. The concept of frailty phenotype is based on the presentation of five biological syndromes: weight loss, exhaustion, low physical activity, slowness and weakness. Individuals with the presence of one or two syndromes are classified as pre-frail, and individuals with the presentation of three or more syndromes are classified as frail.¹¹ On the other hand, the concept of frailty index is based on the accumulation of age-related deficits. This index is calculated as the ratio of the number of deficits presented to the number of total deficits considered. The resulting index is a value between 0 and 1 with higher values indicating more severe states of frailty.¹²

In addition to showing the prevalence of frailty by SES, some studies further investigate the association between SES and frailty. A strand of studies explores how the association changes with age. Three competing hypotheses describe the typical patterns found in the literature: the age as leveller hypothesis, the status maintenance hypothesis and the cumulative advantage hypothesis.^{13,14} The age as leveller hypothesis posits that the SES differences in health peak at middle or early old age but eventually narrow in older age. This convergence in health may be due to the government support to the elderly or simply the inevitable ageing process regardless of individual SES.¹⁵ In the context of frailty, supporters of the age as leveller hypothesis would expect to observe a converging pattern of the SES-frailty association in age. The status maintenance hypothesis suggests that the SES differences in health made in early or midlife neither increase nor decrease overtime.¹⁴ Hence, its supporter should expect a constant SES difference in frailty across all age. The cumulative advantage hypothesis posits that the SES differences widen across the life course. The idea is that various advantages/disadvantages related to SES accumulate, so that the inequalities in health widen with age.¹⁶ In the context of frailty, supporters of this hypothesis would predict a diverging trend of SES differences in frailty overtime. If disadvantages related to frailty cumulate, policy makers would have to

Significance for public health

Socioeconomic differences in frailty are important indicators for health inequalities especially for ageing societies. In addition to recognising the differences, a systematic examination for the underlying mechanisms is needed to assist policy makers in reducing the inequalities. In this review, we found a considerable number of studies illustrating either the pattern of frailty in age or the mediators for the relationship between frailty and socioeconomic status. Observations regarding the pattern of frailty in age assist policy makers in determining the time point for the implementations of frailty treatments or compensation for socioeconomic disadvantages. On the other hand, observations for mediators offers a more detailed picture of the underlying mechanism and thus inform policy makers about the potential tools to reduce the inequalities. Therefore, this systematic review is of public health importance with its implication for policy making in reducing health inequalities.

focus more on compensating earlier SES disadvantages or implementing frailty treatments to lower SES people in advance. Another strand of studies looks for mediators to explain the relationship between SES and frailty. The exploration for mediators offers a more detailed picture of the mechanism underneath the SES-frailty association and thus inform policy makers about the potential tools to reduce the inequalities.

The aim of this paper is to review studies investigating the relationship between frailty and SES in addition to showing the SES gradient in frailty. Included studies should further our understanding of the SES-frailty association regardless of the measures, methodologies or population. Thus, we expect to offer implications for policy makers aiming at reducing the inequalities in health especially for ageing societies.

Methods

We followed the PRISMA statement to conduct the systematic review.¹⁷ The primary search was conducted on 5th March 2020. The review protocol was published in advanced on the PROSPERO database (CRD42020165632). All updates were documented.

Data source and search strategy

The databases searched were MEDLINE, Embase, EconLit, Scopus and Web of Science. We looked for journal articles written in English and published between 2000 and 2020. Two sets of search terms were applied: (1) the search terms for frailty and (2) the search terms for SES. The search terms for frailty with Medical Subject Heading (MeSH) were (“frail*” OR “accumulated deficit” OR “cumulative deficit”). The search terms for SES were (“education*” OR “socioeconomic status” OR “social capital” OR “occupation” OR “employ” OR “income” OR “wealth”). An eligible study should contain both sets of search terms in the title, the abstract, or both.

Eligibility criteria

The following inclusion and exclusion criteria were used for the selection process.

Inclusion criteria: Published papers which examine the direct relationship between frailty and SES variables between 2000 and 2020 in peer-reviewed journals in English language only. Papers will include RCTs, quasi-experimental studies, cohort studies, case control studies, case studies, cross sectional studies, longitudinal studies, systematic reviews, quantitative, qualitative and mixed methods studies.

Exclusion criteria: Papers which do not examine the direct relationship between frailty and SES and treat either frailty or SES variables only as moderators or control variables. Editorials, commentaries, discussion or reviews, position papers.

Study selection

We first selected the papers by screening the title and abstract, and then went through full texts. We applied the above inclusion and exclusion criteria to find the studies illustrating on the relationship between frailty and SES. The study selection was conducted independently by two reviewers. One reviewer went through the full sample, and the other reviewer went through 10% of the sample. All disagreements were solved through discussion.

Data extraction and quality assessment

We used a bespoke form to conduct the data extraction. The form required the information of the first author, publication year, location, sample description, study design and methods, study focus and aims, frailty measures, SES measures, other variables, key findings, conclusion and reported limits/future research. Quality assessment was performed under the guidelines of the STROBE statement.¹⁸ No studies were excluded on the basis of the quality assessment.

Results

Selection process

A pilot study was conducted on 9th December 2019. JW applied the search terms on the MEDLINE and found 2,650 items. The two reviewers screened the titles and abstracts independently and reached an agreement rate of 92.76%. Disagreements were resolved by discussion.

The primary search with all five databases (MEDLINE, Embase, EconLit, Scopus and Web of Science) was conducted on 5th March 2020. This comprehensive search resulted in 9,569 studies. After removing the 3,955 duplicates, reviewers kept 5,614 studies in the sample. To exclude the studies which did not focus on the relationship between frailty and SES, JW screened the titles and abstracts of all 5,614 studies in the sample and CH screened the titles and abstracts of 10% of the sample independently. 5,281 studies were excluded after the discussion between the two reviewers. Then, JW examined the full texts of the remaining studies and CH examined 10% of the remaining studies independently. After a discussion, the two reviewers excluded 312 studies, leaving 21 studies for the final review. A flow diagram for the selection process is presented in Figure 1.

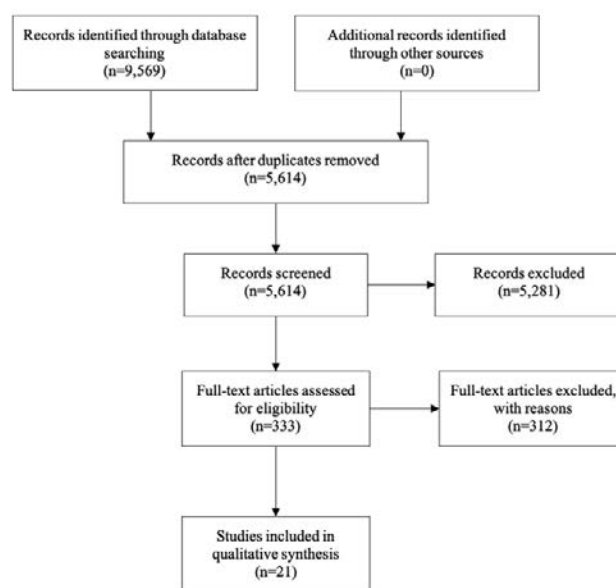


Figure 1. Flow diagram of the study selection process.

Characteristics of selected studies

Table 1 presents the main characteristics of the selected studies. Among the selected 21 studies, 28.57% were cross-sectional studies and 71.43% were longitudinal studies. Most of the studies focused on middle- and old-aged participants, but one study only included the middle-aged participants aged between 45 and 55¹⁹ and two studies included young adults aged over 18²⁰ and 25²¹ respectively.

The selected studies cover a wide range of geographic population. Some of the studies used identical databases: six studies used the Survey of Health, Ageing and retirement in Europe (SHARE) database with one focusing on the participants in Spain²² and the other five investigating participants from different European countries;^{5,14,23-25} two studies used the WHO Study on global AGEing and adult health (SAGE) database with one focusing on India²⁶ and the other one covering the participants from China, Ghana, India, Mexico, the Russian Federation and South Africa;²⁷ two studies used the Longitudinal Aging Study Amsterdam (LASA) database to target on the Netherlands;^{28,29} and two studies used the Health and Retirement Study (HRS) database to investigate on the population in the US.^{30,31} Other selected studies used a variety of databases covering the populations from Australia,²⁰ Canada,²¹ Korea,³² Spain (using the Seniors-ENRICA data),³³ the UK,^{19,34} the Netherlands (with the Older Persons and Informal Caregivers Survey Minimum DataSet),⁶ five Latin American cities (Bridgetown, Sao Paulo, Santiago, Havana and Mexico City),⁴ and Olmsted County in Minnesota, US.³⁵

The measures for frailty differed among the selected studies. Twelve studies applied the concept of frailty phenotype to construct the measures, eight studies applied the concept of frailty index, and one study used both the measures of frailty phenotype and frailty index.³⁰ Among the studies which employed the idea of frailty phenotype, one study transformed the presence of frailty phenotypes into distinct trajectories linking to individual probabilities of death,²⁰ one study examined the “worsening in frailty” defined by the transition from a lower to higher frailty state within two years,²³ and one study combined frailty phenotypes and activities of daily living (ADL) to define the states of being robust, frail or dependent.⁵ Among the studies which employed the idea of frailty index, five studies focused on distinct frailty trajectories rather than the index scores themselves.^{14,24,31,34,35}

Our selected studies covered different aspects of SES. These aspects include education, occupation, income, and wealth. Discussions about the association between frailty and SES primarily revolved around two topics: i) whether the pattern of the association changes in age, and ii) whether particular mediators explain the association. Eleven studies investigated the pattern of the association across different age groups, nine studies explored the mediators for the association, and three studies covered both topics in their explorations. Four studies did not cover these two topics: one focused on the impacts of SES variables at different life courses on frailty but did not infer the pattern of the association with age,⁴ one examined the role of SES on the transition between different states of frailty/disablement,⁵ one explored the role of education-related genes in predicting frailty,³⁰ and one focused on the gender inequalities in frailty in multiple European countries.²⁵

According to the findings, we categorised the studies which covered the pattern of the SES- frailty association in age into the following three groups:

1. *Age as leveller* — Studies which showed the convergence of the SES-frailty association in age.
2. *Status maintenance* — Studies which showed no significant changes in the SES-frailty association in age.
3. *Cumulative advantage* — Studies which showed the diver-

gence of the SES-frailty association in age.

The pattern of the association may vary for different SES variables. Among the nine studies covering the pattern of the education-frailty association in age, four supported the age as leveller hypothesis,^{6,20,26,35} three supported the status maintenance hypothesis,^{14,28,29} one supported the cumulative advantage hypothesis,²¹ and one did not conclude on the pattern.³¹ Two studies explored the pattern of the association between frailty and occupation, and both of them supported the age as leveller hypothesis.^{14,20} Among the seven studies which investigated the pattern of the association between frailty and income, three supported the age as leveller hypothesis,^{14,20,26} one supported the status maintenance hypothesis,²⁸ two supported the cumulative advantage hypothesis,^{21,24} and one did not conclude on the pattern.³¹ Among the four studies which investigated the pattern of the association between frailty and wealth, two supported the age as leveller hypothesis,^{26,34} one supported the status maintenance hypothesis,¹⁴ and one supported the cumulative advantage hypothesis.²⁴

A variety of mediators were explored among the selected studies. These mediators can be categorised into four groups:

1. *Behavioural mediators* — Health-related behaviours such as smoking, drinking, diet, physical activity, and sedentariness.
2. *Health mediators* — Biomedical or physiological factors such as the presence of chronic diseases, multimorbidity, obesity, different biomarkers and medications.
3. *Social mediators* — Social factors such as marital status, network size, and social isolation.
4. *Material mediators* — Material resources such as household income, financial problems, neighbourhood problems and access to healthcare services.
5. *Mental mediators* — Mental or psychological factors such as cognitive function, depressive symptoms and memory impairment.

Among the nine studies which explored the mediators of the SES-frailty relationship, five studies included behavioural mediators,^{19,23,24,29,33} eight studies included health mediators,^{6,19,22-24,27,29,33} three studies included social mediators,^{23,24,29} three studies included material mediators,^{24,29,32} and four studies included mental mediators.^{23,24,29,33}

We followed the STROBE statement to conduct the quality assessment. We found that all studies fit most of the criteria required by STROBE. Nevertheless, eight items were not completely met by all the studies. The lack of these items did not affect the quality of the studies. We summarised the results of the quality assessments regarding those eight items in Table 2.

Discussion

In this section, we provide detailed discussions of the relationships between frailty and different SES variables.

Education and frailty

Seventeen studies contained the discussion about the association between frailty and education. 52.94% of these studies covered the discussion of the pattern of the association in age, 41.18% covered the exploration of the mediators, 11.76% covered the discussion of both topics, and 17.65% did not cover either of the topics.

Among the studies covering the discussion of the pattern of the association, four supported the age as leveller hypothesis,^{6,20,26,35} three supported the status maintenance hypothesis^{14,28,29} and one supported the cumulative advantage hypothesis.²¹ One study dis-

Table 1. Summary of the main characteristics of the included studies.

Title	Location	Study design	Participants measure	Frailty	SES measure	Pattern in age	Exploration for mediators
Avarado <i>et al.</i> , 2008 ⁴	5 large Latin American Cities	Cross-sectional logistic regression	age 60+	Frailty phenotype	Family's economic situation Education Occupation Perception of income	N/A	N/A
Arrighi <i>et al.</i> , 2017 ⁵	10 European countries	Longitudinal probit regression	age 50+	Frailty phenotype	Income Wealth self-rated material deprivation	N/A	N/A
Brunner <i>et al.</i> , 2018 ¹⁹	UK	Longitudinal logistic regression	age 45-55	Frailty phenotype	Occupation (employment grade)	N/A	Cardiovascular disease, depression, smoking, alcohol consumption, fruit and vegetable consumption, physical inactivity
Chamberlain <i>et al.</i> , 2016 ³⁵	Olmsted County, Minnesota	Longitudinal logistic regression	age 60-89	Frailty index	Education	Age as leveller	N/A
Chaudhary and Chowdhary, 2019 ²⁶	India	Cross-sectional logistic regression	age 50+	Frailty phenotype	Education Income Wealth	Age as leveller	N/A
Etman <i>et al.</i> , 2015 ²³	11 European countries	Longitudinal logistic regression	age 55+	Frailty phenotype	Education	N/A	Drinking, depression, memory function, chronic diseases, social participation
Fransé <i>et al.</i> , 2017 ⁶	The Netherlands	Cross-sectional logistic regression	age 55+	Frailty index	Education neighbourhood SES	Age as leveller	Morbidities
Gardiner <i>et al.</i> , 2016 ²⁰	Australia	Longitudinal logistic regression	age 18+	Frailty phenotype	Education Occupation Income (difficulty in managing income)	Age as leveller	N/A
Hajizadeh <i>et al.</i> , 2016 ²¹	Canada	Longitudinal GLM	age 25+	Frailty index	Education (rank) Income (rank)	Cumulative advantage	N/A
Hoogendijk <i>et al.</i> , 2014 ²³	The Netherlands	Longitudinal logistic regression	age 55+	Frailty phenotype	Education (rank)	Status maintenance	Material resources biomedical factors behavioural factors social factors mental factors
Hoogendijk <i>et al.</i> , 2018a ²⁸	The Netherlands	Longitudinal logistic regression	age 65+	Frailty phenotype	Education Income	Status maintenance	N/A
Hoogendijk <i>et al.</i> , 2018b ²⁷	6 low-middle income countries	Cross-sectional logistic regression	age 50+	Frailty phenotype	Education Wealth	N/A	Chronic diseases
Huibregtse <i>et al.</i> , 2019 ³⁰	US	Longitudinal logistic regression	mid-to-late	Frailty index Frailty Phenotype	Education	N/A	N/A
Kim <i>et al.</i> , 2017 ³²	Korea	Cross-sectional linear regression	age 65-85	Frailty Phenotype	Education	N/A	Income
Marshall <i>et al.</i> , 2015 ³⁴	UK	Longitudinal growth curve model	age 50-70	Frailty index	Wealth	Age as leveller	N/A
Rodriguez Lopez <i>et al.</i> , 2014 ²²	Spain	Cross-sectional logistic regression	age 50+	Frailty Phenotype	Education	N/A	Obesity
Soler-Vila <i>et al.</i> , 2016 ³³	Spain	Longitudinal logistic regression	age 60+	Frailty Phenotype	Education Occupation (manual and non-manual)	N/A	Smoking, drinking, sedentariness, obesity, morbidities, the number of medications, depression
Stolz <i>et al.</i> , 2017a ²⁴	10 European countries	Longitudinal growth curve model	age 65+	Frailty index	Poverty (co-occurrence of low income and low wealth)	Cumulative advantage	Behavioural factors Education Material resources Psychosocial factors
Stolz <i>et al.</i> , 2017b ¹⁴	10 European countries	Longitudinal growth curve model	age 50+	Frailty index	Education Occupation (occupational class) Income Wealth	Age as leveller (income) & status maintenance (education, occupation and wealth)	N/A
Uccheddu <i>et al.</i> , 2019 ²⁵	9 European countries	Longitudinal linear hybrid model	age 50+	Frailty index	Education Income Wealth	N/A	N/A
Yang and Lee, 2010 ³¹	US	Longitudinal growth curve model	age 49+	Frailty index	Education Income	Cannot determine	N/A

cussed the association but did not conclude on the pattern as the authors found that the patterns were different between birth cohorts.³¹ The selected studies which supported the status maintenance and cumulative advantage hypotheses were all longitudinal studies. These studies suggested that the impacts of education persist or even accumulate through life, echoing some longitudinal observations regarding the educational differences in physical health.¹⁶ Among the four studies which supported the age as leveller hypothesis, two were cross-sectional studies and two were longitudinal studies. The two cross-sectional studies used different measures for frailty: Chaudhary and Chowdhary used frailty phenotype²⁶ and Franse *et al.* used a frailty index.⁶ They both showed a converging pattern of the education-frailty association in age with their results from logistic regressions. This converging pattern implies a weaker effect of education on health in old age. However, they did not indicate if the convergence was robust because it was not the focus of their studies. The two longitudinal studies which supported the age as leveller hypothesis were Gardiner *et al.* and Chamberlain *et al.*^{20,35} Both studies employed logistic regression with frailty phenotype being the outcome variable to identify distinct frailty trajectories. The results of Gardiner *et al.* did not indicate a significant relationship between education and frailty.²⁰ However, they argued that the impact of education on frailty was embedded in the late-life SES, the ability to manage on income. Chamberlain *et al.* tested the associations between frailty and education for different age groups.³⁵ Their results showed that, with the adjustment in the baseline frailty, the association between frailty and education was significant for the younger age groups but not for the oldest old group (age 80-89). As in Brown *et al.*,¹⁵ both Gardiner *et al.* and Chamberlain *et al.* implied that the longitudinal impact of education diminished with advancing age and thus supported the age as leveller hypothesis.^{20,35} Among the studies which investigated mediators, three covered behavioural mediators,^{23,29,33} six covered health mediators,^{6,22,23,27,29,33} two covered social mediators,^{23,29} two covered material mediators,^{29,32} and three covered mental mediators.^{23,29,33} The mediating effect of smoking was examined by all three studies that covered behavioural mediators. One study found that the mediating effect of smoking alone was non-substantial³³ and the other two studies indicated that smoking did not qualify as a mediator.^{23,29} Among the studies which covered health mediators, four studies confirmed that the mediating role of chronic diseases/morbidities,^{6,23,29,33} nevertheless, one study rejected its mediating effect.²⁷ This difference might be due to the fact that this study focused on middle-low income countries whilst the other four studies investigated high

income countries. In contrast to the case of high- income countries, people in lower SES groups were less likely to have chronic diseases in middle-low income countries. Whilst exploring different measures for social mediators, the two studies that covered this area both found a limited contribution of social mediators.^{23,29} The three studies exploring the mediating effect of mental health mediators all included measures for depression. They confirmed the mediating role of depression in the education- frailty association.^{23,29,33} The two studies containing material mediators both used the variable of income and found that the mediating effect of income was strong: Kim *et al.* suggested a full mediation of income to the educational differences in frailty,³² and Hoogendijk *et al.* found a 43% reduction of the education-frailty association also from income.²⁹

Occupation and frailty

Five studies discussed about the association between frailty and occupation. Forty percent of these studies illustrated on the pattern of the association in age, forty percent explored the mediators for the association, none covered the discussion of both topics, and twenty percent did not cover either of the topics.

Two studies discussed the pattern of the occupation-frailty association in age: supported the age as leveller hypothesis²⁰ and Stolz *et al.* supported the status maintenance hypothesis.¹⁴ Both studies were longitudinal studies which looked for distinct frailty trajectories. Gardiner *et al.* measured frailty with frailty phenotype and classified individual occupation based on the type of work (professional, sales/administration, trade/manual, other, never worked).²⁰ Although they did not find any significant relationship between occupation and frailty, they argued that the impact of occupation was embedded in the late-life SES, the ability of manage on income.

This statement indicated that the direct impact of occupation on frailty did not persist in old age. On the other hand, Stolz *et al.* measured frailty with frailty index and categorised individual occupation into three classes (salaried, intermediate and working class) following the European Socio-economic Classification.¹⁴ As they found the interaction term between age and occupation non-significant, Stolz *et al.* concluded that the pattern of the occupation-frailty association did not change in age.¹⁴

Only two studies explored for the mediators of the occupation-frailty association.^{19,33} Both studies explored the behavioural, health and mental mediators with longitudinal logistic regressions and measures of the frailty phenotype. However, their measures for occupation were different: Brunner *et al.* classified occupation

Table 2. Quality assessment.

	Yes	No
Describe all statistical methods, including those used to control for confounding	11 (52.38%)	10 (47.62%)
Describe any methods used to examine subgroups and interactions	20 (95.24%)	1 (4.76%)
Explain how missing data were addressed	11 (52.38%)	10 (47.62%)
Consider use of a flow diagram (for missing variables)	14 (66.67%)	7 (33.33%)
Indicate number of participants with missing data for each variable of interest	4 (19.05%)	17 (80.95%)
Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7 (33.33%)	14 (66.67%)
Discuss limitations of the study, taking into account sources of potential bias or imprecision.	19 (95.24%)	2 (9.52%)
Discuss both direction and magnitude of any potential bias		
Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20 (95.24%)	1 (4.76%)

with the Civil Service employment grade,¹⁹ and Soler-Vila *et al.* distinguished individual occupation between manual and non-manual jobs.³³ Brunner *et al.* confirmed the mediating effect of smoking,¹⁹ but Soler-Vila *et al.* showed that the mediating role of smoking alone was not considerable in explaining the association.³³ On the other hand, the mediating role of obesity was found considerable by both studies.

Income and frailty

Ten studies discussed about the association between frailty and income. Seventy percent of these studies explored the pattern of the association in age, ten percent explored only the mediators for the association, ten percent covered the discussion of both topics, and thirty percent did not cover either of the topics. It should be noted that income itself was often viewed as the mediator for the association between frailty and other SES variables.^{29,32}

Among the studies covering the pattern of the association in age, three supported the age as leveller hypothesis,^{14,20,26} one supported the status maintenance hypothesis²⁸ and two supported the cumulative advantage hypothesis.^{21,24} Although Yang and Lee observed a converging pattern in their full sample, they did not conclude on the pattern because the patterns were different across different birth cohorts.³¹ All studies covering the pattern were longitudinal, except for one supporter of the age as leveller hypothesis, Chaudhary and Chowdhary.²⁶ Chaudhary and Chowdhary used the frailty phenotype to measure frailty.²⁶ Although they did not test the pattern of the association, their income gradients presented in the graph showed the convergence in age. The two other supporters of the age as leveller hypothesis were Gardiner *et al.*²⁰ and Stolz *et al.*¹⁴ Gardiner *et al.* did not directly test the pattern for income.²⁰ They found that the impacts of early adulthood and midlife SES diminished whereas the impact of the late-life SES (the ability to manage on income) persisted. This observation was in line with the notion of the age as leveller hypothesis.¹³ On the other hand, Stolz *et al.* examined the interaction term between age and income and found a converging pattern with advancing age.¹⁴ Hajizadeh *et al.* and Hoogendijk *et al.* also used the interaction term to determine the pattern but reached different conclusions: Hajizadeh *et al.*²¹ found an increasing pattern in frailty measured by frailty index, but Hoogendijk *et al.*²⁸ found no significant pattern in frailty measured by frailty phenotype. The study covering the discussion of the pattern was Stolz *et al.*, who supported the cumulative advantage hypothesis.²⁴ This study was different because its SES was not merely income but poverty, defined as the co-occurrence of low income and low wealth. Moreover, this study was also the only one which investigated the mediators among the ten studies covering the association between frailty and income. Their exploration covered behavioural mediators (smoking, drinking and physical activities), material mediators (financial problems, quality of accommodation, living condition and neighbourhood problem), social and mental mediators (social isolation). They found that the impacts of social and mental mediators were more important than material mediators on the poverty-frailty association. Moreover, they found that behavioural factors were less important in explaining the association.

Wealth and frailty

Seven studies contained discussion about the association between frailty and wealth. Of these 57.14% illustrated the pattern of the association in age, 28.57% explored the mediators for the association, 14.29% covered the discussion of both topics, and 28.57% did not cover either of the topics.

Among the studies covering the discussion of the pattern in age, two supported the age as leveller hypothesis,^{26,34} one support-

ed the status maintenance hypothesis¹⁴ and one supported the cumulative advantage hypothesis.²⁴ One study which supported the age as leveller hypothesis was cross-sectional,²⁶ all the other studies were longitudinal. It should be noted that, although Stolz *et al.* was categorised as the supporter of the cumulative advantage hypothesis, they only found little increase in the association by age.²⁴ Therefore, one could argue that this study supported both the status maintenance hypothesis and the cumulative hypothesis. In line with Brown *et al.* and Kim and Durden,^{15,16} the three longitudinal studies all used growth curve model. Moreover, their measures for frailty were all based on the concept of frailty index the measure for frailty. However, they determined the pattern in age differently. As in Kim and Durden,¹⁶ and Stolz *et al.*^{14,24} examined the interaction terms between age and predictors and found little to no effect on frailty trajectories and thus supported the status maintenance and cumulative advantage hypothesis. On the other hand, Marshall *et al.* did not include the interaction term but directly compared the patterns in different age cohorts.³⁴ They found that the extent of the differences by wealth was the smallest at the oldest ages and thus provided evidence for the age as leveller hypothesis.

Two studies investigated the mediators for the association between wealth and frailty: one study covered the discussion of chronic diseases in middle-low income countries²⁷ and the other one covered the exploration for behavioural, material, social and mental mediators in ten European countries.²⁴ Chronic diseases were found non-significant in explaining the wealth-frailty association in middle-low income countries.²⁷ However, this observation may be due to the fact that the prevalence of chronic diseases were higher for the rich than the poor in middle-low income countries. Stolz *et al.*²⁴ examined the mediators for poverty, defined by the co-occurrence of low income and low wealth, and found that social and mental factors such as social isolation, well-being and perceived control were essential in explaining the association.

Conclusions

This systematic review provides the evidence for the relationship between frailty and socioeconomic status. This investigation is needed for policy makers who aim at reducing the inequalities in health especially in an ageing society. Within the review, we found a considerable number of studies illustrating either the pattern in age or the mediators for the relationship. In the investigation of the frailty pattern in age, we found that almost half of the studies supported the age as leveller hypothesis. However, there were also a considerable number of studies supporting the status maintenance or the cumulative advantage hypothesis. The included mediators were different across studies, but they can be generally categorised into behavioural mediators, health mediators, social mediators, material mediators and mental mediators. We found that 55.56% of the included studies covered the exploration for behavioural mediators, 88.89% for health mediators, 33.33% for social mediators, 33.33% for material mediators and 44.44% for mental mediators. These findings inform the important intervention for policies aimed at reducing the inequalities. To capture the full picture of the underlying mechanism for the relationship between frailty and SES, future research should strive to harmonise different measures for frailty and SES indicators and consider a more comprehensive set of mediators.

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Key words: Frailty; socioeconomic status; ageing.

Contributions: JW and CH designed the project and reviewed the included papers; JW wrote the protocol, extracted and analysed the data, and drafted the paper; CH provided the guidance, interpreted results and revised the paper.

Conflict of interest: The authors declare no conflict of interest.

Acknowledgments: We would like to thank Carolina Coelho and Rebeca Whear for their suggestions on our review protocol.

Received for publication: 19 November 2020.

Accepted for publication: 8 April 2021.

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Journal of Public Health Research 2021;10:2036

doi:10.4081/jphr.2021.2036

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