Life course socioeconomic position and care dependency in later life: a longitudinal multicohort study from 17 countries

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Summary

Background Care dependency, inability to perform basic daily tasks without assistance due to functional impairment, increases substantially with accelerated population ageing and becomes a pressing public health concern worldwide. Socioeconomic disadvantage has been shown to be associated with elevated risks of care dependency, but how risks are modified by changes in socioeconomic position remains unclear. From a life course perspective, we investigated the association between socioeconomic mobility across the lifespan and care dependency in later life.

Methods In this longitudinal multicohort study, we pooled data collected between 2000 and 2019 from six prospective cohort studies across 17 countries from the Program on Global Ageing, Health, and Policy. Socioeconomic status (SES) at three different life stages was assessed based on parental education in childhood, participants' education in early adulthood, and non-housing wealth in middle-late adulthood. Care dependency was measured using activities of daily living (ADLs) and instrumental activities of daily living (IADLs) following WHO recommendations. Ordinal logistic mixed-effect models were applied to investigate associations between socioeconomic inequalities and their mobility across the life course with later-life care dependency. Furthermore, to investigate contributors to inequalities in care dependency, we applied the difference method to estimate the proportion of these inequalities explained by potential risk factors, and quantified the health and economic benefits of targeted interventions using population attributable fractions.

Findings A total of 103,282 individuals were involved in this study, with an average baseline age of 63.29 (SD 10.70) years and a mean follow-up of 8.75 (SD 0.02) years. Low SES at any stage of life was associated with elevated probability, increased severity, and accelerated deterioration of care dependency in later life, with women being particularly vulnerable. For the probability of IADL dependency, socioeconomic differences by parental education persisted and were greatest at ages 75–80 years (18.10%, 95% CI 14.25%–21.95% for women; 10.23%, 5.82%–14.64% for men). Considering the severity of dependency, differences in low ADL dependency reversed in advanced old age, while differences in high ADL dependency widened consistently with age. Differences in high ADL dependency between high and low childhood SES groups increased from 0.66% (0.64%–0.67%) at age 50 to 15.79% (12.19%–19.39%) at age 100. Compared with a stable high SES throughout life, all other SES mobility trajectories were associated with elevated risks of both IADL and ADL dependency. Individuals who experienced a severe SES decline—high in childhood but low in adulthood—showed a more than ten times higher risk (IADL: OR 18.26, 95% CI 12.45–26.79; ADL: 11.95, 8.47–16.88). A lower risk was observed for those who moved from low SES in childhood to high SES in adulthood (IADL: 2.51, 1.00–6.33; ADL: 1.52, 0.62–3.72). Furthermore, out of risk factors ranging from lifestyles, diseases to social connections, lack of social activities was found to be the primary contributor to socioeconomic inequalities in care dependency (explaining up to 66.63%), with corresponding interventions achieving universal health and economic benefits across countries.

Interpretation Changing socioeconomic status over the lifespan was associated with care dependency risk in later life. Promoting equal educational opportunities from an early age to equitably benefit the most socioeconomically disadvantaged could help mitigate care burdens. Encouraging participation in social activities has the potential to reduce socioeconomic differences in care dependency.

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Research in context

Evidence before this study

We conducted a comprehensive literature review in PubMed with no date and language restrictions, using the search terms: ("lifecourse" or "life course" or "life-course" or "whole life" or "childhood" or "adulthood") and ("socioeconomic" or "education" or "wealth" or "income" or "social mobility") and ("care dependency" or "functional dependency" or "functional limitations" or "disability" or "activities of daily living") and ("longitudinal"). Of the 399 publications identified, 16 longitudinal cohort studies indicated an association between socioeconomic disadvantage and higher risk of functional disability or dependency, but most did not account for socioeconomic status (SES) at different life stages and the long-term SES trajectory. Additionally, 12 of the 16 studies were conducted with small samples from only one single country or region, limiting the applicability to geographic areas with different socio-cultural contexts. Furthermore, potential risk factors contributing to socioeconomic inequalities in care dependency, which could be targets for more effective public health policies to reduce these inequalities and promote health equity, have rarely been investigated.

Added value of this study

Based on a large-scale harmonised dataset from six longitudinal cohorts across 17 countries, this study provides valuable insights into the relationship between changing socioeconomic position and care dependency from a life course perspective. Specifically, our findings highlight the long-term transgenerational association of parental education with care dependency of offspring in older age, and provide solid evidence that individuals who experienced upward socioeconomic mobility had lower risks of care dependency, whereas those who had socioeconomic advantages in childhood but later suffered a severe SES decline faced extremely high risks. Furthermore, this study indicates the lifelong vulnerability of socioeconomically disadvantaged women and the critical role of physical inactivity and lack of social activities in contributing to socioeconomic inequalities in care dependency.

Implications of all the available evidence

This study highlights the association of different SES transition patterns throughout life with care dependency in older age, which is valuable for understanding the relationship between life course social determinants and healthy ageing. Along with equal care resource allocation in later life, a life course approach targeting socioeconomic inequalities, such as providing equal educational opportunities early in life, particularly for vulnerable women of low SES, could potentially prevent or delay care dependency. Additionally, promoting physical activity and fostering social connections are both worth exploring as sustainable means to mitigate socioeconomic inequalities in care dependency.

Introduction

Care dependency, arising from substantial impairment in the functional ability to independently perform daily tasks (such as eating, personal hygiene),[1–3] is associated with adverse consequences such as higher healthcare costs, increased mortality risk, and poorer quality of life. With accelerated population ageing,[4] the growingly pervasive care dependency in later life has become a serious public health concern worldwide, posing a major challenge to already stretched health and social care services. More than half of the older population is excluded from access to essential long-term care services,[5] especially those from disadvantaged segments of society who bear a disproportionate burden of care dependency.[6–8] Therefore, the WHO calls for more integrated and inclusive approaches to maintaining functional ability and independent living for all, with the aim of achieving healthy and equitable ageing.[9]

Health variability is rooted in a range of social-environmental factors and their complex interplay throughout the entire lifespan, highlighting the importance of adopting a life course approach in ageing research. The life course approach concentrates on how numerous factors aggregate and synergistically work to shape lifelong health, rather than being restricted to one or a few exposures at certain life stages and static health status.[10] Socioeconomic status (SES) can change along an individual's development throughout the full lifespan,[11] which may mean its links with later-life care dependency vary across different life stages and diverging mobility pathways. However, limited by the availability of longitudinal population-based studies collecting social and functioning data over decades of life, the majority of current literature fails to capture dynamic changes in socioeconomic position and care dependency process over a long period.[12–17] Consequently, a systematic application of the life course approach is warranted to fully understand the social determinants of care dependency, informing the optimal manner and timing of interventions to optimise functioning trajectories in later life. Another concern is that existing studies have mostly focused on one single country[14–16] or a few high-income countries,[12,17] so given limited study populations and differences in outcome measures, the consistency and generalisability of results across countries remains unclear. A robust multicohort

study, providing large samples from multiple countries, is needed to understand socioeconomic inequalities in care dependency within the broader global landscape.

Based on longitudinal data pooled from six ageing cohort studies across 17 countries, this study aimed to investigate the associations between life course SES and care dependency in later life. SES in childhood, early adulthood, and middle-late adulthood was measured by parental education, participants' own education, and non-housing wealth, respectively. We hypothesised that: (1) life course socioeconomic mobility trajectories are associated with care dependency risk in older age; and (2) some lifestyle, disease, and social connection factors could account for care dependency inequalities associated with life course SES.

Methods

Study design and participants

This longitudinal multicohort study used data from the Program on Global Ageing, Health, and Policy,[18] which harmonises 11 ageing studies across the world to facilitate cross-national comparisons. These studies follow similar protocols and administer surveys every two or three years, providing comparable information on nationally representative samples of middle-aged and older adults. Our analyses were designed to explore the longitudinal associations between life course SES and care dependency. Hence, cohorts without corresponding measures or with only one or two survey waves were excluded. As a result, six longitudinal cohort studies from 17 countries were selected: the China Health and Retirement Longitudinal Study (CHARLS), the Survey of Health, the Ageing and Retirement in Europe (SHARE), the English Longitudinal Study of Ageing (ELSA), the Health and Retirement Study (HRS), the Korean Longitudinal Study of Ageing (KLoSA), and the Mexican Health and Ageing Study (MHAS). In this study, data from a similar time frame were included: 2011–2018 for CHARLS, 2004–2019 for SHARE, 2002–2019 for ELSA, 2000–2019 for HRS, 2006–2018 for KLoSA, 2001–2019 for MHAS, so that follow-up years were comparable between studies (Supplementary Table S1). A total of 103,282 participants who were older than 45 years were included at baseline. Subsequently, individuals with missing responses regarding SES, care dependency, or covariates at all waves were excluded from the analytic sample (Supplementary Fig. S1). In the total sample, the missing response rates were 5.24% for IADL care dependency and 2.07% for ADL care dependency. 1.25% of individuals had at least one missing predictor value in the analysis of the early adulthood SES-care dependency association, 2.75% were missing in the middle-late adulthood SES-care dependency analysis, and 30.36% were missing in the childhood SES-care dependency analysis. The missing predictor values were handled through multiple imputation by chained equations in the sensitivity analysis. We observed at least 7889 events of ADL care dependency and 9139 events of IADL care dependency at baseline among participants in the complete-case dataset. The sample size was sufficient to get an events per candidate predictor parameter (EPP) exceeding the common rule of 10 EPP.

Procedures

Care dependency

Care dependency arises when functional ability has fallen to a point where an individual is no longer able to undertake the basic tasks that are necessary for daily life without assistance.[3] Activities of daily living (ADLs) and instrumental activities of daily living (IADLs) represent key tasks of daily living. ADLs are repetitive daily activities necessary to maintain basic survival, including dressing, bathing, and eating. IADLs encompass activities that facilitate independent living and typically involve more complex interactions with the environment and instruments, such as cooking, shopping, taking medications. Difficulties in ADLs and IADLs, reflecting significant loss of functional ability, are widely validated measures of care dependency.[2,6,19]

Following WHO recommendation and previous studies,[2,3,6,19] care dependency in this study refers to a participant's requirement of assistance due to the inability to perform the ADLs and IADLs on their own. To harmonise six cohort studies, measures of ADL and IADL care dependency were based on the performance of five ADLs and six IADLs, respectively (Supplementary Table S2). Specifically, ADLs include eating, dressing, bathing, getting in/out of bed, and using the toilet. IADLs include managing money, taking medications, preparing hot meals, shopping for groceries, doing housework, and making telephone calls. Participants were asked if they had any difficulties with those items and their responses of "yes" and "no" were coded as 1 and 0, respectively. ADL difficulty scores (ranging from 0 to 5) and IADL difficulty scores (ranging from 0 to 6) were calculated by summing the number of reported difficulties with ADLs and IADLs. A score of more than 0 was defined as ADL or IADL care dependency and 0 as independency. Additionally, ADL and IADL care dependency were categorised respectively into different severity levels based on difficulty scores: low care dependency (one or two), and high care dependency (three or more).

Life course socioeconomic status

SES reflects individuals' access to material, social, and cultural resources within a stratified society, traditionally measured by indicators such as education, occupation and wealth. In this study, three SES markers were used to capture socioeconomic position at three different stages of life (childhood, early adulthood, and middle-late adulthood).

Parental education is a commonly used indicator of early-life socioeconomic circumstances,[14,20,21] reflecting parents' health literacy, economic status, and educational resources. Families with higher parental education are usually able to provide quality early care and education for children.[22] In this study, childhood SES was assessed using the highest level of parental education, categorised into three levels: low (no formal education), middle (primary or less), and high (more than primary).

Education acquired in early adulthood typically remains stable throughout life and is not subject to reverse causality.[11,23,24] Moreover, highly educated individuals tend to develop a larger set of social and psychological resources that shape health.[25] Therefore, early adulthood SES was measured by participants' own educational attainment and was classified into three levels derived from the 1997 International Standard Classification of Education (ISCED-97): low (primary or less), middle (secondary), and high (tertiary).

Non-housing wealth, reflecting the lifetime accumulation of flexible financial resources such as assets, investments, and savings, is a representative metric of resource disparities when studying older populations.[12] Especially for retired older people, non-housing wealth provides financial security and a source of purchasing power during retirement. Given the liquid nature of non-housing wealth and its meanings for healthcare utilisation among older adults,[26] middle-late adulthood SES was proxied by non-housing wealth reported at baseline, which was divided into tertiles within each cohort.

A more detailed methodology for harmonisation of SES indicators is provided in Supplementary Table S3. By further cross-categorising the three life-stage-specific SES markers, each of which was separately classified into three levels (high 0, middle 1, low 2), a total of 27 mobility pathways were identified. This comprehensive indicator enabled us to capture respondents' socioeconomic mobility trajectories from early life, through middle life, to late life, facilitating the examination of how socioeconomic mobility relates to the risk of care dependency. To explore the association of cumulative socioeconomic exposures with care dependency, a variable measuring lifelong cumulative disadvantage (range, 0–6) was constructed by summing childhood, early adulthood, and mid-late adulthood SES measures. A higher score represents a greater disadvantage.

Risk factors

Previously, risk factors, including unhealthy lifestyles, disease outcomes, and social connections, have been proven to be associated with both SES and care dependency.[23,27–30] Therefore, these factors were considered as potential contributory factors that may explain the relationship between SES and care dependency. Unhealthy lifestyles consisted of currently smoking, high alcohol consumption, physical inactivity, and abnormal body-mass index (BMI). Following the WHO's action plans for chronic diseases and mental health,[31,32] disease outcomes included five common chronic conditions (hypertension, diabetes, cancer, chronic lung disease, and heart disease) and depressive symptoms measured by the CESD scale. Social connections included three factors: no children co-reside, infrequent family interaction, and lack of social activities. Detailed information about all risk factors was obtained through structured questionnaires in six ageing studies. All risk factors were harmonised into time-varying dichotomous variables, and more detailed information is in Supplementary Table S4.

Covariates

Among the variables available in the harmonised dataset, candidate covariates for model adjustment were selected on the basis of literature review. A directed acyclic graph was constructed based on existing evidence to choose the minimally sufficient adjustment set (MSAS). Age, gender, birth cohort, marital status, and cohort were identified as confounders and thus included in the MSAS. Other candidate covariates were likely to be mediators between SES and care dependency (Supplementary Fig. S2). Age was centred on 60 years (i.e., calculated as age minus 60) to align different baseline ages across cohort studies. Other covariates included gender (man, woman), birth cohort (1928 and before, 1929–1938, 1939–1945, 1946 and after), marital status (married or partnered, single), and cohort (CHARLS, SHARE, ELSA, HRS, KLoSA, MHAS). Further details of the covariates are available in Supplementary Table S3.

Statistical analysis

Descriptive statistics were used to present baseline characteristics of participants in each cohort and the pooled sample. Means and standard deviations (SDs) were calculated for continuous variables, and absolute frequencies and percentages were calculated for categorical variables. Missing values were also summarised. Spearman correlation analysis was conducted to assess the correlation between SES indicators (Supplementary Table S5).

To investigate the relationship between life course SES and care dependency, we used mixed-effect cumulative logit models with care dependency severity levels as ordinal response variables. These models included individual-level random intercept with an unstructured covariance matrix, which are advantageous as they consider the correlation of repeated measures on the same individual across time and permit unbalanced data (i.e., not every individual is observed at all times or at the same time points).[28,33,34] The proportional odds assumption was assessed using the Brant test in the general ordinal logistic model. The linearity assumption

between continuous predictor and outcomes was verified by applying component-residual plots.

First, to examine associations of three life-stage-specific SES markers with IADL and ADL care dependency trajectories individually, we defined six base models to derive the probability of experiencing different severity levels of care dependency every 5 years from age 50 to 100. Base models included SES, age, gender, and their interaction terms, with birth cohort, time-varying marital status, and cohort adjusted as covariates. All candidate predictors were prespecified based on an extensive literature review and the availability of data across six cohorts. SES and its interaction with age were used to assess socioeconomic differences in care dependency and whether these differences changed with age. The multiplicative interaction between gender and SES was tested using a product term to assess whether socioeconomic inequalities varied by gender. The additive interaction was also evaluated using the relative excess risk due to interaction (RERI) between SES (low vs. high) and gender (man vs. woman) in logistic regression models using binary ADL and IADL care dependency as outcomes (Supplementary Table S8). Additionally, we estimated trajectories of care dependency probability with age for six cohorts and compared socioeconomic differences between cohorts. To investigate whether socioeconomic position at each life stage independently affects care dependency, we also constructed a model containing all three SES indicators.

Then, to evaluate how lifelong socioeconomic mobility shapes the risk of care dependency, we estimated odds ratios (ORs) with 95% confidence intervals (CIs) for care dependency in different socioeconomic mobility groups compared to the group stabilised at high SES throughout the life course. Similarly, we examined the association between cumulative socioeconomic disadvantage and care dependency, with the lowest cumulative disadvantage being the reference group.

Furthermore, to assess the potential contribution of risk factors to socioeconomic inequalities in care dependency, we applied the difference method to estimate the proportion of these inequalities explained by potential risk factors. We added each risk factor separately into the six base models and calculated percentage changes in socioeconomic differences (log odds ratios) compared with the base models.[28,30] We also adjusted for the three risk factor groups and then for all risk factors to assess the magnitude of attenuation in socioeconomic differences. Finally, we applied population attributable fractions to quantify the potential benefits of risk factor interventions on reducing the care-dependent population and the economic burden of long-term care (LTC) by country.[35–37] A detailed description of the calculation is provided in Supplementary Methods, Fig. S8, and Tables S13–S15.

Sensitivity analysis

We conducted six sets of sensitivity analyses to assess the robustness of our findings by repeating the main analyses. First, we restricted the baseline age of participants included in the analyses to 60 years or older. Second, we included participants who had no care dependency at baseline wave and participated in more than one interview. Third, based on the interval-of-need method developed by Isaacs and Neville,[38] care dependency was recoded as independency (no difficulty in ADL or IADL items), low care dependency (difficulty in bathing, managing money, taking medications, shopping for groceries, preparing hot meals, making telephone calls, or doing housework, and no difficulty in the items defined in high dependency), and high care dependency (difficulty in dressing, eating, getting in/out of bed, or using the toilet). Fourth, we used total wealth, including housing wealth (the net value of the primary residence), as the indicator of SES in middle-late adulthood. Fifth, data were assumed to be missing at random. To reduce bias resulting from missing data, multiple imputation by chained equation was used to impute missing values for life course SES and covariates. Ten imputed datasets were generated and Rubin's rule was used to pool the estimates from each dataset. To facilitate the comparison of results in sensitivity analyses, we estimated odds ratios of care dependency associated with life course SES and socioeconomic differences in care dependency (high vs. low SES) at ages 65, 75, and 85. Finally, we used continuous ADL and IADL difficulty scores as outcomes and applied linear mixed models to analyse the association between life course SES and these scores.

All statistical analyses were done in Stata version 17.0. Graphs were plotted using R version 4.0.5.

Ethics statement

We used de-identified data from public databases, including CHARLS, SHARE, ELSA, HRS, KLoSA, and MHAS. The ethical approval (Supplementary materials) was granted for the original surveys, and no additional ethical approval was required for the present study. The informed consents were obtained from all participants by the original surveys.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

This study pooled large-scale longitudinal data from six prospective cohort studies done in 17 countries, with a mean follow-up of 8.75 (SD 0.02) years. A total of 103,282 participants included in the analytic sample had an average baseline age of 63.29 (SD 10.70) years, of

whom 46,123 (44.66%) were men and 57,157 (55.34%) were women. At baseline, 14,385 (13.93%) participants had IADL care dependency, and 12,972 (12.56%) participants had ADL care dependency. For life course SES, 19.37%, 58.43%, and 35.94% of participants were of low SES in childhood, early adulthood, and middle-late adulthood, respectively (Table 1).

The associations between SES at three life stages and care dependency are shown in Supplementary Table S6. For SES at each life stage, decreasing levels of SES were associated with increasing risks of care dependency compared to high SES. Individuals with low parental education showed higher risk: OR 2.19 (95% CI 1.92–2.50) for IADL care dependency and 1.90 (1.68–2.15) for ADL care dependency. After adjustment for adulthood SES, the association between parental education and care dependency was attenuated but remained (IADL: 1.47, 1.27–1.71; ADL: 1.18, 1.03–1.36). Similar risk patterns were observed for adulthood SES. Care dependency trajectories are shown in Fig. 1 by SES group. With advancing age, the probability of care dependency continues to increase. Compared with people of high or middle SES, those of low SES consistently faced higher probabilities of care dependency over the lifespan, regardless of being socioeconomically disadvantaged in childhood, early adulthood, or middle-late

	CHARLS (n = 17,106)	SHARE (n = 30,126)	ELSA (n = 11,916)	HRS (n = 19,369)	KLoSA (n = 10,254)	MHAS (n = 14,511)	Total (n = 103,282)
Location	China	Europe	UK	USA	Korea	Mexico	..
Length of follow-up, years	5.87 (0.02)	7.63 (0.03)	9.02 (0.06)	11.18 (0.05)	8.81 (0.04)	10.96 (0.06)	8.75 (0.02)
Baseline age, years	59.11 (9.77)	64.04 (10.37)	64.48 (10.57)	67.43 (10.52)	61.71 (11.12)	61.23 (10.05)	63.29 (10.70)
Missing data for age	175 (1.02)	3 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	178 (0.17)
Gender							
Man	8345 (48.78)	13,487 (44.77)	5304 (44.51)	8076 (41.70)	4463 (43.52)	6448 (44.44)	46,123 (44.66)
Woman	8759 (51.20)	16,639 (55.23)	6612 (55.49)	11,293 (58.30)	5791 (56.48)	8063 (55.56)	57,157 (55.34)
Missing data for gender	2 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.00)
Childhood SES							
Low	9676 (56.56)	2936 (9.75)	45 (0.38)	296 (1.53)	1933 (18.85)	5122 (35.30)	20,008 (19.37)
Middle	5645 (33.00)	3968 (13.17)	4044 (33.94)	5363 (27.69)	6800 (66.32)	5534 (38.14)	31,354 (30.36)
High	1339 (7.83)	5263 (17.47)	1666 (13.98)	10,260 (52.97)	1244 (12.13)	961 (6.62)	20,733 (20.07)
Missing data for childhood SES	446 (2.61)	17,959 (59.61)	6161 (51.70)	3450 (17.81)	277 (2.70)	2894 (19.94)	31,187 (30.20)
Early adulthood SES							
Low	14,999 (87.68)	15,541 (51.59)	4987 (41.85)	5329 (27.51)	6402 (62.43)	13,085 (90.17)	60,343 (58.43)
Middle	1746 (10.21)	8945 (29.69)	4543 (38.13)	10,611 (54.78)	2863 (27.92)	323 (2.23)	29,031 (28.11)
High	345 (2.02)	5640 (18.72)	1355 (11.37)	3429 (17.70)	986 (9.62)	1084 (7.47)	12,839 (12.43)
Missing data for early adulthood SES	16 (0.09)	0 (0.00)	1031 (8.65)	0 (0.00)	3 (0.03)	19 (0.13)	1069 (1.04)
Middle-late adulthood SES							
Low	5031 (29.41)	10,006 (33.21)	3862 (32.41)	6437 (33.23)	6292 (61.36)	5491 (37.84)	37,119 (35.94)
Middle	4999 (29.22)	10,052 (33.37)	3924 (32.93)	6447 (33.29)	841 (8.20)	4199 (28.94)	30,462 (29.49)
High	4734 (27.67)	10,068 (33.42)	3923 (32.92)	6485 (33.48)	3053 (29.77)	4766 (32.84)	33,029 (31.98)
Missing data for middle-late adulthood SES	2342 (13.69)	0 (0.00)	207 (1.74)	0 (0.00)	68 (0.66)	55 (0.38)	2672 (2.59)
IADL care dependency							
Independency	13,221 (77.29)	26,131 (86.74)	9477 (79.53)	14,125 (72.93)	8956 (87.34)	11,573 (79.75)	83,483 (80.83)
Low care dependency	2375 (13.88)	2745 (9.11)	1742 (14.62)	1478 (7.63)	810 (7.90)	716 (4.93)	9866 (9.55)
High care dependency	1260 (7.37)	1091 (3.62)	514 (4.31)	914 (4.72)	487 (4.75)	253 (1.74)	4519 (4.38)
Missing data for IADL care dependency	250 (1.46)	159 (0.53)	183 (1.54)	2852 (14.72)	1 (0.01)	1969 (13.57)	5414 (5.24)
ADL care dependency							
Independency	14,125 (82.57)	27,009 (89.65)	9376 (78.68)	15,993 (82.57)	9776 (95.34)	11,894 (81.97)	88,173 (85.37)
Low care dependency	1811 (10.59)	2234 (7.42)	1776 (14.90)	2286 (11.80)	230 (2.24)	959 (6.61)	9296 (9.00)
High care dependency	816 (4.77)	724 (2.40)	581 (4.88)	954 (4.93)	248 (2.42)	353 (2.43)	3676 (3.56)
Missing data for ADL care dependency	354 (2.07)	159 (0.53)	183 (1.54)	136 (0.70)	0 (0.00)	1305 (8.99)	2137 (2.07)

CHARLS = the China Health and Retirement Longitudinal Study. SHARE = the Survey of Health, Ageing and Retirement in Europe. ELSA = the English Longitudinal Study of Ageing. HRS = the Health and Retirement Study. KLoSA = the Korean Longitudinal Study of Ageing. MHAS = the Mexican Health and Ageing Study. Countries in SHARE involved in analyses include Austria, Belgium, Denmark, France, Germany, Greece, Israel, Italy, Netherlands, Spain, Sweden, and Switzerland. SES = Socioeconomic Status. IADL = Instrumental Activities of Daily Living. ADL = Activities of Daily Living. Data are mean (SD) or n (%). The majority of respondents in Korea reported zero non-housing wealth.

Table 1: **Baseline sample characteristics of each cohort (N = 103,282 in total).**

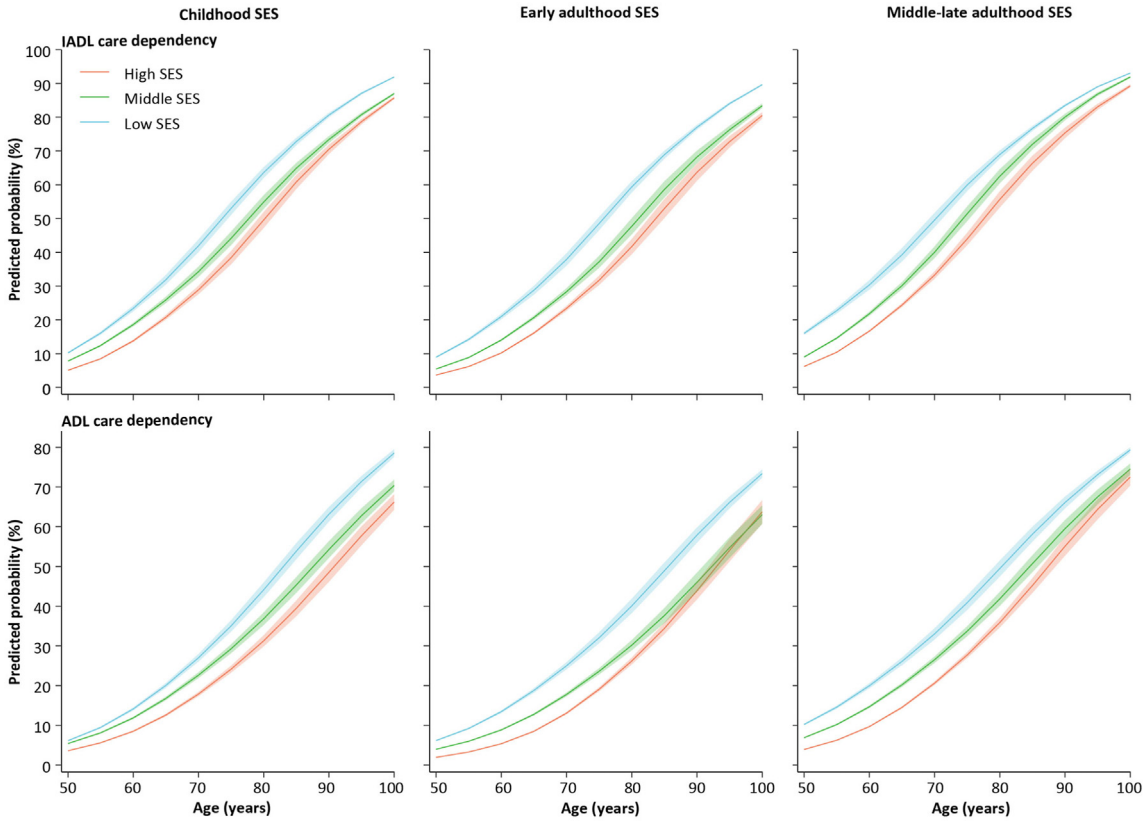

***Fig. 1:* Care dependency trajectories by SES group at different life stages.** The panels show the predicted probability of IADL and ADL care dependency plotted by age for people with different SES at three life stages. The solid line represents the predicted probability and the shaded area represents the 95% confidence interval (CI). Predicted probabilities are based on models adjusted for gender, age, and their interaction with SES, birth cohort, marital status, and cohort and plotted for reference categories for all covariates. The probability of care dependency is calculated as 1 minus the probability of independency. SES = Socioeconomic Status. IADL = Instrumental Activities of Daily Living. ADL = Activities of Daily Living.

adulthood. In addition, among groups by SES and gender, women with low SES had the highest probability of care dependency throughout the life course (Supplementary Fig. S3).

Differences in care dependency probabilities associated with life course socioeconomic inequalities are illustrated in Fig. 2 by gender, showing a pattern of first widening and then narrowing. For women, differences in the probability of IADL care dependency between high and low childhood SES groups increased from 6.70% (95% CI 6.31%–7.09%) at age 50 to 18.10% (95% CI 14.25%–21.95%) at age 75, followed by a decrease. Similarly, differences between middle and low childhood SES groups increased from 5.52% (95% CI 4.67%–6.37%) at age 55 to 11.94% (95% CI 8.07%–15.81%) at age 75, before declining to 7.56% (95% CI 6.88%–8.25%) at age 95. Notably, differences in care dependency associated with childhood SES and early adulthood SES were greater for women than for men. The largest gender gap was observed in the difference in IADL care dependency linked to childhood SES at age 75, which was approximately twice as large for women as for men. Across different cohort studies, the scale of care dependency differences in relation to life course SES was apparent but varied (Supplementary Fig. S5). The widest gap was observed in the cohort representing China, while the smallest differences were in KLoSA.

Moreover, for different severity levels of care dependency, the trajectories and socioeconomic differences were heterogeneous (Supplementary Figs. S6 and S7). The probability of low IADL care dependency increased until reaching about 30% at ages 80–85 and then declined, whereas the probability of high IADL care dependency rose persistently with advancing age, reaching as high as 70%. Similar developmental patterns were observed for trajectories of ADL care dependency. For low care dependency, socioeconomic differences reversed in advanced old age. Notably, for high care dependency, the risk in the low SES group was consistently higher and its differences with the high

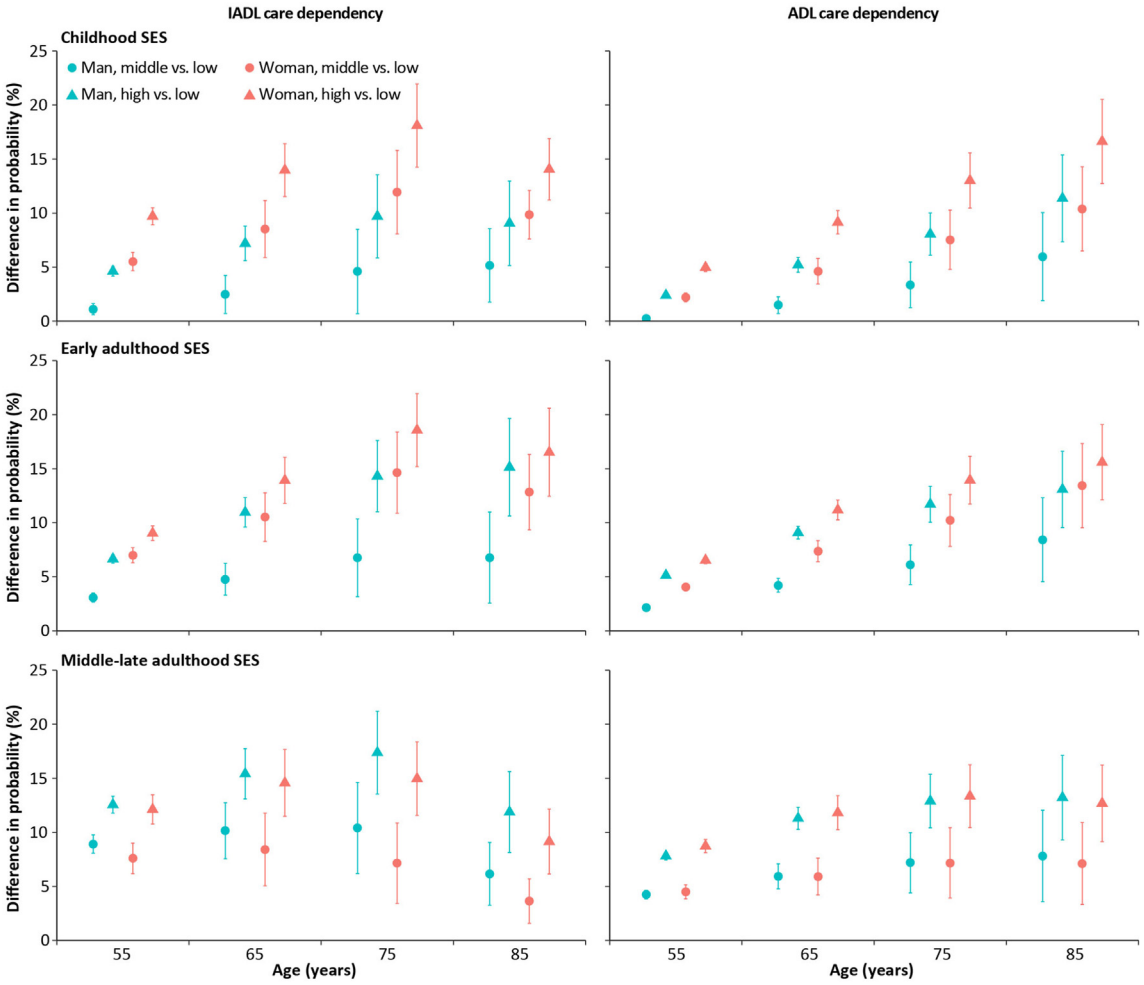

***Fig. 2:* Socioeconomic differences in the probability of care dependency by gender.** Data points are estimated socioeconomic differences in the probability of care dependency at ages 55, 65, 75, and 85, with whiskers showing 95% confidence intervals (CIs). A positive value indicates that people with low SES have a greater probability of care dependency than those with high or middle SES. SES = Socioeconomic Status. IADL = Instrumental Activities of Daily Living. ADL = Activities of Daily Living.

SES group persisted and even widened, reaching a maximum of 16.74% (95% CI 13.75%–19.73%) for high IADL care dependency and 15.79% (95% CI 12.19%–19.39%) for high ADL care dependency.

Diverse pathways of lifelong SES mobility were illustrated in Fig. 3, with up to 80.57% of participants undergoing a change in SES, while only 19.43% maintained a stable SES throughout their lives. Of those who experienced SES mobility, 71.08% underwent SES changes between two successive life stages that were limited to neighbouring strata, while only 28.92% faced a sharp decline or leap that skipped strata. In the transition from childhood to adulthood, 2.39% of participants experienced the most downward mobility, i.e., sliding from the top into the bottom. Besides, only 0.29% experienced the most upward mobility, i.e., moving from the bottom to the top. Fig. 4 presents the relationship between socioeconomic mobility over the lifespan and care dependency risk in later life. Generally, compared with the reference group that stayed in high SES throughout life, individuals who experienced other socioeconomic mobility pathways had higher risks of care dependency. In particular, the most downwardly mobile group showed the highest risks: 18.26 (12.45–26.79) for IADL care dependency and 11.95 (8.47–16.88) for ADL care dependency. Meanwhile, the magnitude of risk elevation for care dependency was much lower for individuals who moved from low SES in childhood to high SES in adulthood (IADL: 2.51, 1.00–6.33; ADL: 1.52, 0.62–3.72) than for those who experienced persistent adverse conditions (IADL: 14.76, 11.07–19.68; ADL: 9.15, 7.09–11.82). Additionally, SES mobility trajectories with middle or high adulthood SES tended to show a relatively small increase in the risk of

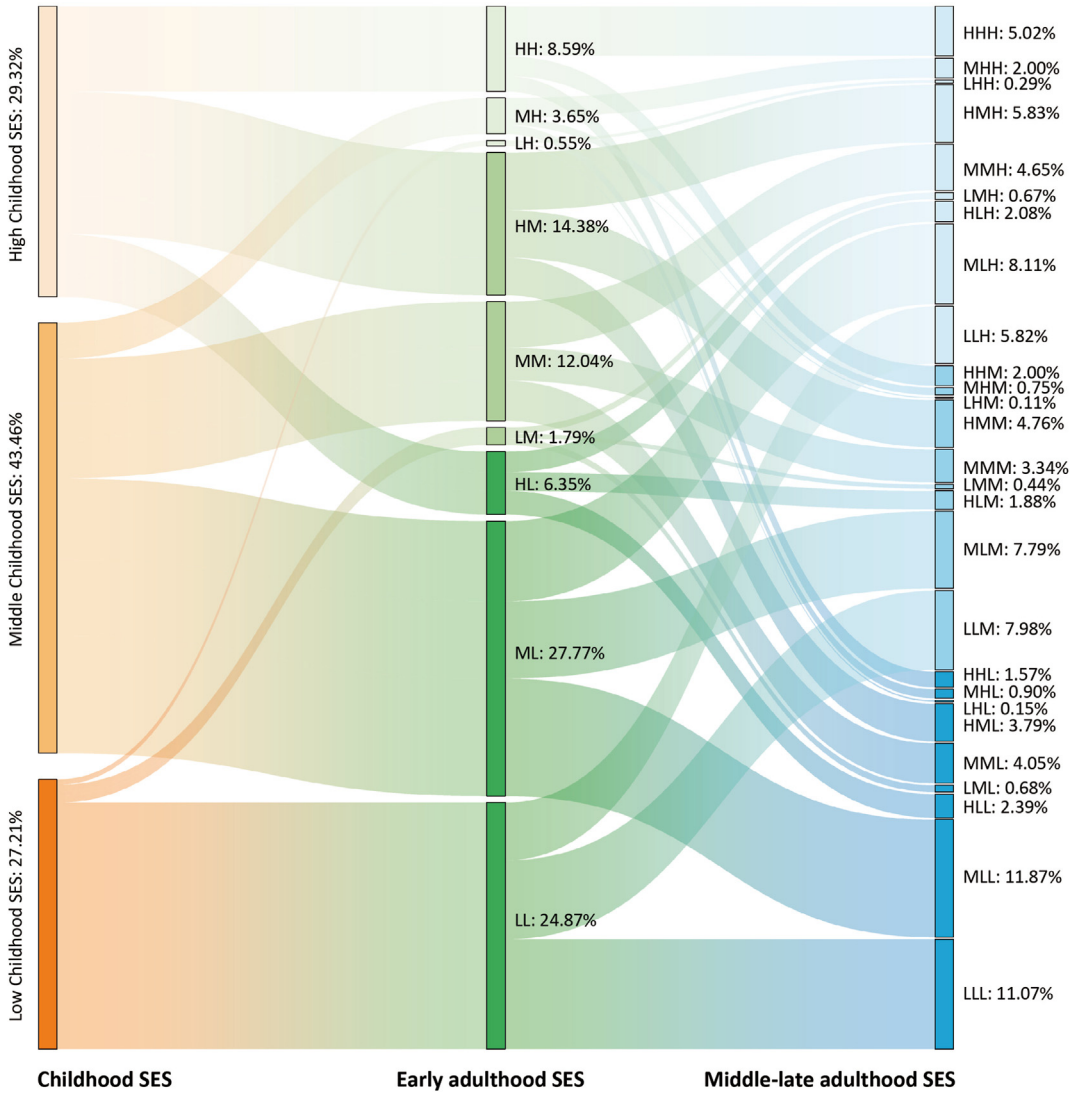

Fig. 3: **Life course socioeconomic mobility pathways using measurements of SES at three life stages.** H = high. M = middle. L = low. HHH refers to the group that experiences a socioeconomic transition from high childhood SES to high early adulthood SES to high middle-late adulthood SES. SES = Socioeconomic Status.

care dependency. When considering care dependency risk by cumulative socioeconomic exposures, a steep, non-linear gradient was observed, with increased risk for higher cumulative disadvantage (Supplementary Table S9). Compared to individuals with the lowest cumulative disadvantage score, those with a score of 1 showed a slightly lower increased risk (IADL: 1.11, 0.76–1.62; ADL: 1.17, 0.84–1.65), while those with persistently low SES throughout their lives (i.e., score of 6) exhibited a disproportionately higher risk of care dependency (IADL: 15.00, 11.24–20.01; ADL: 9.20, 7.13–11.88).

The potential contributions of risk factors to socioeconomic inequalities in care dependency are shown in Supplementary Table S11. The distribution of risk factors by life course SES is also shown in Supplementary Table S12. After adjustment for all risk factors, there was an attenuation of 71.89% in the childhood SES-IADL care dependency association and 53.19% in the middle-late adulthood SES-ADL care dependency association. Among all risk factors, physical inactivity, depressive symptoms, and lack of social activities were the three primary contributors to socioeconomic differences in care dependency, resulting in the greatest attenuations of 32.10%, 43.65%, and 66.63%, respectively. Moreover, compared to the other two primary factors, lack of social activities accounted for a comparable or even more pronounced attenuation of the life course

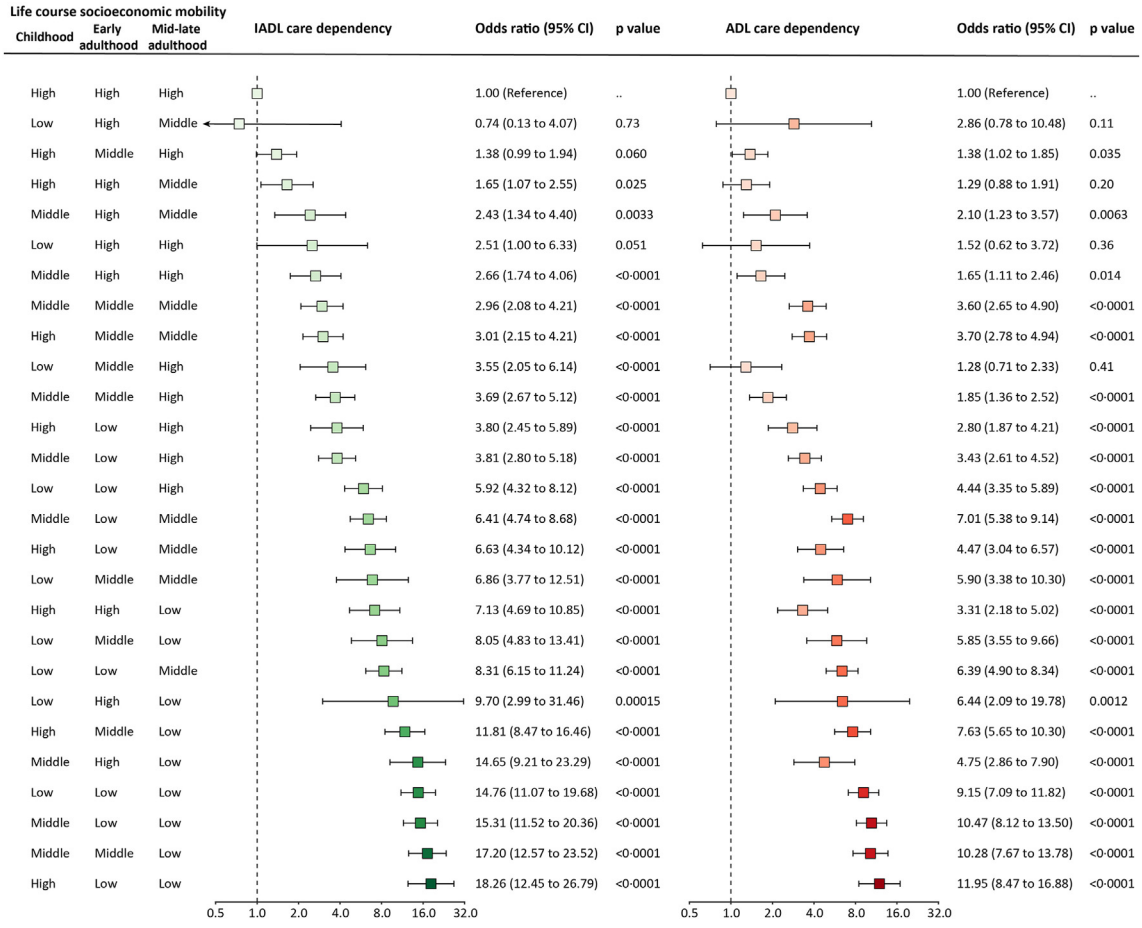

***Fig. 4:* Association between life course socioeconomic mobility and the risk of care dependency.** Life course socioeconomic mobility refers to socioeconomic transition from childhood to early adulthood to mid-late adulthood. For each outcome, the group that experiences a transition from high childhood SES to high early adulthood SES to high middle-late adulthood SES was used as reference category. SES = Socioeconomic Status. IADL = Instrumental Activities of Daily Living. ADL = Activities of Daily Living.

SES-care dependency associations. Interventions targeting these modifiable risk factors could reduce the overall burden of care dependency, bringing significant economic benefits (Supplementary Fig. S9). For countries in our study, physical inactivity and lack of social activities together accounted for more than 19.02% of care dependency burden in the population aged 65 and over. Simultaneously eliminating the two risk factors could reduce total LTC expenditures by $163.44 billion in the EUR-12 countries (11 European countries& Israel in SHARE) and LTC expenditure per person aged 65 years and older by $2481 in the UK.

The results of sensitivity analyses are provided in Supplementary Fig. S10 and Tables S16–S26. Neither excluding participants aged 59 or below at baseline wave, nor including only those who had no care dependency at baseline and participated in at least two surveys, nor using multiple imputation datasets substantially affected the results. Socioeconomic differences in care dependency and their development with age were consistent with the main analyses (Supplementary Tables S16–S19). The sensitivity analysis using total wealth as the SES indicator for middle-late adulthood also showed similar results to those of main analyses based on non-housing wealth (Supplementary Table S20). In addition, the results of the analyses using the interval-of-need method developed by Isaacs and Neville to measure care dependency were broadly similar to the main findings (Supplementary Table S21). The results from linear mixed models using ADL and IADL difficulty scores as continuous outcomes also support conclusions consistent with the main analysis (Supplementary Fig. S10 and Table S22). Besides, although there were slight variations between sensitivity analyses in the extent to which socioeconomic inequalities were attenuated by adjusting for risk factors, the general results remained similar, demonstrating the robustness of our findings (Supplementary Tables S23–S26).

Discussion

Based on large-scale harmonised data from six ageing cohorts in 17 countries, this study revealed that low parental education in childhood had a long-lasting association with the onset and exacerbation of care dependency in later life. Compared with individuals maintaining a stable high SES throughout life, those experiencing a severe socioeconomic decline in adulthood—namely, having highly educated parents but low levels of self-education and wealth—had a more than tenfold increase in the risk of care dependency. Notably, upward socioeconomic mobility throughout the lifespan was associated with a much smaller increase in this risk. Promoting social activities was identified as a potentially effective approach that could reduce care dependency inequalities.

Consistent with prior research,[12–14,16] our study confirmed the substantial inverse relationship between SES and care dependency risk. Additionally, we extended previous work by considering the timing of socioeconomic exposures, demonstrating that disadvantages at each life stage were associated with elevated care dependency risk in later life. Particularly, the independent relationship between childhood SES and care dependency provides support for the "long arm of childhood",[39] highlighting the transgenerational importance of parental education in childhood for the functional ability of offspring in older age. Low parental education typically implies the unavailability of high-quality nurturing care during childhood, a critical period for body and brain development to reach optimal functioning levels.[40–42] This deficiency might hinder neurocognitive development[22,43] and the adoption of healthy lifestyles,[44,45] potentially leading to cognitive impairment and physical dysfunction in later life.

Furthermore, our findings indicated that while all SES mobility trajectories were associated with higher care dependency risks compared to maintaining an advantaged status throughout life, individuals who experienced upward SES mobility had a much smaller risk elevation than those who underwent severe socioeconomic decline. These findings support the social mobility model, suggesting that the direction of transition in and out of different social classes modify later health risk. Upward social mobility may be beneficial in preventing care dependency by enhancing feelings of control and life satisfaction, which contribute to better physiological well-being.[46] In contrast, downward mobility may lead to psychological distress, harmful coping behaviours, and reduced access to health-protective resources such as supportive neighbourhood facilities.[47–49] Neurobiological research has also shown that social status loss potently induces depressive states by affecting brain neuronal circuits,[50] further highlighting the potential impact of social mobility on endogenous systems and its ultimate health consequences. Notably, our analysis of cumulative SES demonstrated a dose-response relationship between life course cumulative socioeconomic disadvantage and care dependency risk. The social mobility model partially incorporates the accumulation hypothesis, as downward mobility increases lifetime exposure to low SES and vice versa. Meanwhile, SES indicators representing different dimensions are intertwined chronologically, implying that education and wealth may cumulatively influence functional ability in older age through different underlying pathways. Additionally, unmeasured confounders are unavoidable.[51] For example, other forms of childhood socioeconomic indicators, such as parental income or occupational prestige, could affect elderly health. Neighbourhood characteristics, genetic factors, and childhood cognitive abilities may also be possible confounders that impact care dependency in later life.

Recognising the complex intersectionality between gender and social determinants, our findings further unveiled the significant care challenges faced by women. Women consistently suffered from an elevated probability and increased severity of care dependency compared to men in the same socioeconomic stratum. Notably, women of low SES deserve particular attention for their highest likelihood of care dependency throughout lifetime across all subpopulations. The lifelong vulnerability of women may stem from biology and sociocultural factors. Biological factors make women more susceptible to major disabling disorders like stroke and Alzheimer's disease.[52] Meanwhile, sociocultural factors, such as social norms, unequal power status, and poor prioritisation of women's health, result in fewer psychological and social resources to cope with illness and functional disability,[53–55] further exacerbating their care needs. Societal expectations of women historically assign them more household and informal caregiving responsibilities, while they themselves remain the most vulnerable group. This dual burden highlights the urgent necessity for tailored strategies to address care needs of women, with underprivileged women being a top priority.

Building upon the understanding of socioeconomic inequalities in care dependency, identifying and prioritising underlying modifiable factors is imperative for developing effective health equity strategies that accommodate the life experiences and health challenges of all. This study revealed the quantitative contributions of extensive factors, ranging from individual behaviours to social networks, with social activity and physical activity emerging as primary contributors. Our findings offer an innovative eco-social perspective, suggesting that strategies grounded in individual, community, and societal levels have the potential to be effective in mitigating care dependency inequalities. Specifically, encouraging physical and social activity through universal access to public sports facilities,[56] social service development,[8,57] and deliberate urban design[58,59] could be beneficial. Notably, a relatively small proportion of care

dependency inequalities associated with middle-late adulthood SES were explained compared to earlier life stages. One possible explanation is that the behavioural and psychological factors we currently focus on are largely shaped by early-life circumstances and are less closely linked to middle-late adulthood SES,[60] highlighting the importance of early interventions. Despite the apparent inequalities in care dependency, interventions targeting primary contributors were estimated to promise considerable health and economic benefits, which is particularly encouraging in the context of limited care resources. Meanwhile, the scale of care dependency inequalities and the benefits of interventions vary across cohort studies, possibly reflecting the role of different health systems, economic structures, and social protection policies across countries. This highlights the importance of policymakers tailoring interventions to their specific national contexts to effectively mitigate care dependency inequalities and maximise public health benefits.

The application of a life course approach to large-scale longitudinal data from 17 countries enabled a comprehensive assessment of how the timing and fluctuation of socioeconomic exposures are associated with later-life care dependency and its underlying contributors. Our findings enhance the understanding of social determinants of care dependency and inform prevention strategies in terms of both upstream and downstream solutions. Despite these strengths, our study had several limitations. First, self-reported SES inevitably implies some degree of recall bias. Individuals' health status may distort the recall accuracy of childhood socioeconomic circumstances. Nevertheless, some studies support the reliability of older adults' recall of simple socio-demographic information.[61] Second, the exclusion of participants with missing data may lead to selection bias. Nevertheless, the sufficiently large sample size ensured statistical power, and sensitivity analyses with multiple imputation demonstrated robustness. Third, all cohorts utilised similar protocols and standardised assessment instruments, but contextual, social and cultural differences may introduce response biases, for which we controlled by adjusting for cohort. Further exploration of statistical harmonisation to account for these differences would be valuable in promoting cross-national comparisons. Fourth, harmonising data entailed a loss of granularity, limiting analyses of detailed categories like years of schooling. Nonetheless, this process favours standardising variables across multiple cohorts, facilitating the interpretation of results at a global level and avoiding potential misclassification bias arising from assigning subjects to overly detailed categories. Fifth, no sample weights were used in our analysis due to the multi-cohort design and inconsistent methods of weight construction across studies, which may slightly bias estimates but does not in principle change the main conclusions. Sixth, unmeasured residual confounding may influence our results and causal inference cannot be made because of the observational nature of this study. Seventh, the estimation of PAF under the ideal scenario of complete exposure elimination may not meet all underlying assumptions, including no unmeasured confounding and other risk factors unaffected by exposure removal. Lastly, given differences in health systems, welfare policies, and economic structures across countries, future analyses should explore in depth the role of country-level factors in explaining care dependency inequalities to inform targeted policies.

In conclusion, our study provides a strong rationale for adopting a life course approach in strategic planning to reduce care dependency for healthy ageing. Moving up the socioeconomic ladder was associated with a lower risk of care dependency in later life, whereas falling from the top to the bottom of the ladder was linked to a disproportionately high risk. These findings suggest that care dependency prevention should take into account not only later life but all phases of the life course. Along with strengthening and expanding care services in older age, providing equal educational opportunities from early life for socioeconomic disadvantaged populations, especially for lifelong vulnerable women of low SES, could be one policy option to mitigate care burdens. Additionally, tailored policies for addressing care dependency inequalities could focus on encouraging participation in physical and social activities for all, which would be essential to achieve equal ageing.

Contributors

Y.Z. conceived the idea for the study and managed the project to the manuscript as corresponding author. Y.Z., C.L., and T.P. designed the study. T.P. and C.L. collected the data, did the statistical analyses, and wrote the statistical analysis plan. T.P. and C.L. contributed equally to the manuscript as joint first authors and wrote the manuscript. Y.Z. reviewed and edited the manuscript. All authors had full access to and verified the data in the study and were responsible for the decision to submit the manuscript.

Data sharing statement

Data analysed in this study are available upon request and application to the corresponding data management organisation. The China Health and Retirement Longitudinal Study (CHARLS) can be accessed via the National School of Development, Peking University: https://charls.charlsdata.com/pages/data/111/en.html. The Survey of Health, Ageing and Retirement in Europe (SHARE) can be accessed via the SHARE Research Data Centre: https://share-eric.eu/data/data-access. The English Longitudinal Study of Ageing (ELSA) can be accessed via the UK Data Service: https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=200011#!/access-data. The Health and Retirement Study (HRS) can be accessed via the RAND Centre for the Study of Ageing: https://hrsdata.isr.umich.edu/data-products/rand. The Korean Longitudinal Study of Ageing (KLoSA) can be accessed via the Korea Employment Information Service (KEIS): https://survey.keis.or.kr/eng/klosa/klosa01.jsp. The Mexican Health and Ageing Study (MHAS) can be accessed via the study website: https://www.mhasweb.org/DataProducts/Home.aspx.

Declaration of interests

The authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2024.102994.

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